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THE VALUE OF VERSATILE ALLEY CROPPING IN THE SOUTHEAST US: A MONTE CARLO SIMULATION

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ABSTRACT

Alley cropping offers a potential alternative to traditional land management practices. However, its implementation in the United States is extremely limited and general awareness and knowledge of alley cropping is lacking. While alley cropping does have a few barriers to entry, the cost of maintaining hedgerow products and foregone returns from primary crops particularly, its offer the potential for positive returns on investment once the hedgerow product, typically timber, is harvested. Thus we determined the need to create an economic model to assess the relative potential of alley cropping with respect to traditional land management practices under certain conditions. Through use of a stochastic Monte Carlo approach, we ran simulations comparing the results of an alley cropping system and a single crop system in the Southeast region of the United States. Preliminary results show that, under certain constraints, alley cropping may be profitable, but we believe this result is sensitive to assumptions about the interactions between system components. Through analysis of the results of these simulations we can determine in which situations alley cropping should be preferred over a single crop system. In the future, we will improve the model to account for more complex interactions and adjust input parameters as we find better data. We will evaluate how alley cropping affects farm risk and how policy programs may affect its profitability.

Keywords: Agroforestry; profitability; stochastic financial model; risk

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1 INTRODUCTION

Alley cropping is a land management methodology wherein land owners/managers use hedgerows of one or more crops to separate wider alleys of other crops. The most common format for alley cropping, and the one assumed within the model presented here, uses a single primary crop grown in the alleys and a different crop, generally a timber product, grown as the hedgerow product.

Alley cropping has not been widely practiced or studied in the United States. Several US studies have investigated yields and responses to interspecific competition within alley cropping systems (Gillespie et al., 2000; Lee & Jose, 2003; Miller & Pallardy, 2001; Zamora, Jose, & Nair, 2007; Zamora et al., 2008). We know of only one empirical study on the economic returns in an alley cropping system in the southeast US: Cubbage et al. (2012). That study found that early-year alley cropping returns on a frequently flooded agricultural site in North Carolina were poor, while tree survival and growth were relatively good by comparison. While this study provides a good starting point and important "ground-truthing" for economic analysis, (1) it only covers the first few years of the system rotation, and (2) does not control for mono-crop agricultural yields on a similar site.

The basic two crop alley cropping model with one primary crop grown in the alleys and a timber product grown in the hedgerows is the simplest model, one of the reasons for its use in this study. Most economic models assume that decision-makers seek profit maximization. Therefore, if there is a crop available which is significantly more profitable than any other crop available, then profits are greatest when this crop is grown whenever possible.

This leads to the obvious conclusion that annual returns on the land are reduced due to the hedgerow products. If, however, these products prove more profitable in the long run than the primary crops grown in the alleys, then alley cropping may be more profitable than a single crop system, hence the necessity of this study. Such could be the case on marginal agricultural land. It should also be mentioned that even if timber products are more profitable in the long run than are other crops, farmers and particularly rent-paying land managers need certain levels of annual income, thus strict timber farming could be financially impractical. Alternatively, alley cropping might be a transitional land management from open land to forest, allowing annual income in the interim. Therefore, for those dependent upon the land for annual incomes yet also with the luxury of being able to invest in the land, alley cropping, if more profitable than a single crop system, can potentially be a practical alternative land management methodology for this segment of the population.

While timber prices are a crucial factor in this model, simple verification of the relationship between timber prices and crop prices does not directly imply the relative profitability of switching to or from and alley cropping model. There are a myriad of other factors which contribute to such an analysis.

Factors such as soil exhaustion and crop rotation will force any model to choose at least a second primary crop on certain years, even in cases in which there is a clear and unique crop which should always be preferred from a pure financial standpoint. Also, while crop rotation can reduce income on certain years, sunlight and soil competition factors can reduce income each year once the hedgerow products reach a certain level of maturity. As the timber products grow they produce more shade which reduces crop exposure to the sun and decrease levels of photosynthesis and thus crop growth. But these timber products also grow more expansive root systems which inevitably compete with the root systems of the alley crops for nutrients in the soil. Therefore any modelling work in the area of alley cropping must address these issues before the analysis of the relative prices and returns of various hedgerow and alley crops can produce the relative profitability of alley cropping.

2 DATA

Before a model could be developed, much data as well as a few constraints were necessary for developing the model. These constraints were temporal and geographical; the model was designed to only last until the timber products were harvested before repeating itself, and the geographical conditions assumed in the model, e.g. soil types and climates, were indicative of the southeastern United States.

Data for historic annual crop returns were downloaded from NASS (2013). These were used to estimate long-run averages, standard deviations, and mean-reversion rates. Historic crop returns were inflated to 2013 dollars using the Consumer Price Index (CPI) (BLS, 2013).

The data collected all came from this same geographical region, specifically coming from four states: Virginia, North Carolina, Louisiana, and Missouri. These data included nominal prices of all crops and timber products, real prices, returns per acre, costs per acre, real costs per acre, and the average change in real price over time. While data was available for many of these factors for as much as the past fifty years in some cases, the previous fifteen years were used in finding the averages which were used in the model.

3 METHODOLOGY

The model itself was a Monte Carlo simulation which ran 10,000 cycles, using a stochastic, mean-reverting random walk. It found the long run continuous average of the relative gains or losses of alley cropping when compared to a single crop format.

The model began with a series of arrays of price and return information which were updated after each year within cycles and reset to their original values at the beginning of each new cycle. These arrays were then subjected to a randomly generated function which determined the additional annual change to the long run rate of change in real price, real cost, and returns due to random market shocks such as inclement weather, etc. Random number generation, as included within the model, had the additional benefit of providing a means of mean reversion in the long run since the randomly generated numbers came from a specific interval, i.e. (0, 1). Once the new data on prices, costs, and returns for that year were found, the model then found the maximum net gain from growing each of the crops and selected that crop which provided this maximal profit level.

Once the most profitable crop for that year, along with its price, cost, and returns data, was chosen, the model then made any necessary adjustments for crop rotation. Since crop rotation is a legitimate concern, being a commonplace practice due to its long run benefits, a crop rotation feature was included to mimic realistic choices within the model. If the same crop had been selected by the model for a third consecutive year, it was discarded during the third year and the model then found the second most profitable crop that year before continuing.

Once a definite choice in crop had been made by the model, profits per acre were stored to represent the profits from a single cropping system while this total was multiplied by a factor of 5/6th to represent the profits from alley cropping in that same year; the 5/6th is representative of the proportion of land dedicated to alleys within the alley cropping model and can be altered is desired, though it should be noted that a 5:1 ratio of alleys to hedgerows in terms of land area is fairly typical of an alley cropping model. Once the profits in the alley cropping model were determined, the cost of maintaining the hedgerows was subtracted from the previous profit line, thus giving the ultimate profit margin per acre within the alley cropping model.

As the model progressed, a competition function was implemented which discounted the returns on the alley crops due to the aforementioned soil and sunlight competition factors which will inevitable stunt the growth and development of the alley crops positioned closest to the hedgerows. This competition function was a basic polynomial which used the age of the tree as the sole variable and used the resistance to shade as a coefficient, thereby impacting those crops which are most heavily dependent upon sunlight most severely and impacting all crops greater as the timber products continued to grow.

This process was then repeated over the course of 32 years to allow for the maturity of the timber products. This timeframe, which slightly lower than that typically assumed by roughly two years, was assumed because trees in these hedgerows are not competing for sunlight to anywhere near the same extent as trees in a forested land area, and thus have the potential to grow slightly faster than trees in forested land areas.

In the 32nd year of the cycle, the model then harvests the timber products and, rather than subtracting the cost of maintaining the timber products, adds to the profits from the alley crop the total gains for the timber harvest. Once the cycle is complete, the model finds the average gains or losses over the total thirty two years of alley cropping with respect to a single crop system. This per acre margin is then stored until the next cycle is completed, when a continuous average is recalculated for all of the completed cycles. After the ten thousandth cycle the model outputs the average long run gains or losses in profits due to alley cropping.

After this initial simulation was completed, other simulations were ran including one in which the trees were grown in a disjoint land area with a full 35 year cycle, one mimicking the initial model in which the competition function was magnified to provide, ideally, an upper and a lower bound to the net profit margin of alley copping compared to a single crop system, and a repetition of the original model with the cycles lengthened to 35 years implying no decrease in the time to maturity of the timber products.

4 PRELIMINARY RESULTS

The results presented here are preliminary. Further refinements of the model will be undertaken to generate more accurate results and will be reported at a later date.

With no competition function and the trees kept disjoint with the crops, there was an overall increase in profits due to alley cropping of $90.01 per acre. This simply shows that, in the long run, forestry is more profitable than growing other, more traditional crops, and that crop diversification can lead to a positive investment when conditions permit.

With a modest competition function, i.e. the initial model, the profit margin was reduced to $47.48 per acre thereby showing that alley cropping can still be more profitable in the long run than traditional single crop systems, even after the negative factors associated with alley cropping are incorporated into the model.

With the severe competition function the profit margin due to alley cropping dropped to ($83.60) per acre. This is indicative of the potential for alley cropping to offer less financial compensation in the long run and leads to some interesting conclusions which will be addressed in the following section.

Finally, the original model with cycles lengthened to thirty five years led to a profit margin of ($125) per acre.

5 CONCLUSIONS

We presented preliminary results from a financial model of alley cropping on marginal agricultural land. These results should not be considered definitive, but do suggest need for further research.

The more promising preliminary results from this study suggest that alley cropping indeed has a theoretical potential to be profitable in the long run. However, as demonstrated by the third and fourth simulations particularly, alley cropping in some cases not be a worthwhile investment.

The third simulation in which the competition function is more severe than in the initial model, shows that further understanding of the impact of timber products as hedgerow products on the alley crops is necessary in order for a more constrained model to be designed. The fourth simulation, furthering the weaknesses of this model, shows that the gains in profits due to alley cropping are largely contingent upon the slightly quickened development of the timber products. If alley cropping does indeed offer a reduction in the time to maturity for certain timber products, alley cropping can prove a positive investment in the long run, but if this is not the case and timber products require a full-term growth cycle, then alley cropping loses its long run financial gains with respect to non-integrated land management methodologies.

An important result was that alley cropping under any conditions never quite performed as well as having a disjoint timber stand, thus a more practical land management methodology may very well be to invest in timber products on a portion of the land which is kept disjoint from the land designated for annual crops.

Our model leaves much work to do. It is obvious to us that more needs to be done to model better the stochastic process that agricultural and timber returns, as well as to account for more complex interactions. We will adjust input parameters as we find better data. Finally, we will evaluate how alley cropping affects farm risk and how policy programs may affect its profitability.

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SOCIOECONOMIC PREDICTORS OF FAMILY FOREST OWNER USE OF FEDERAL INCOME TAX PROVISIONS

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ABSTRACT

Family forest owners control a majority of the South's forest land and nearly half of its growing stock. These owners are a diverse group with widely varied objectives for ownership and management. Many family forest owners manage their holdings for timber production objectives and thus, are concerned with issues such as reforestation incentives and tax treatment of timber revenues. Their actual knowledge of the tax aspects of timber management varies, with some owners unaware of the federal income tax provisions that apply to timber. This paper uses econometric techniques to establish socioeconomic predictors of family forest owner use of federal income tax provisions. Data collected from a mail survey conducted in 2001 to family forest owners in South Carolina is analyzed to show which socioeconomic factors (e.g., size of forest holding, ownership objective, education, age, income) impact whether or not a family forest owner is aware of specific income tax provisions, and more importantly, if the owner is aware of the provisions, which factors impact use of the provisions. A two-step sample selection methodology revealed that membership in a landowner organization and size of forest holding positively influences landowner awareness of the seven tax provisions, while ownership objective and level of education exhibit varying degrees of influence. Overall, the findings suggest that size of forest holding is the key determinant that influences landowner use of the provisions.

Keywords: Family forest owners, taxation, management

1 INTRODUCTION

Family forest owners control approximately 62 percent (264 million acres or 107 million hectares) of our nation's private forest land (Butler 2008). This group of families, individuals, trusts, estates, family partnerships, and other unincorporated groups of individuals has been and still are crucial to maintaining sustainable forests in the United States and crucial to the nation's timber supply (Best 2002). Family forest owners are a diverse group of individuals who hold and manage forestland for a multitude of reasons. Many of these reasons for owning (e.g. Aesthetics, privacy or home, family legacy) do not provide an annual revenue stream to the landowner. When landowners manage their holdings for income producing objectives such as timber production, hunting leases and the like they must pay federal income tax on any revenue derived from their holdings.

The federal income tax has a profound effect on the profitability of managing forestland. Land expectation value, the value of forestland in permanent timber production is significantly affected by the tax rate applied to timber income (Guertin and Rideout 1987, Haney et al. 2001). Especially for low productivity sites, the economic feasibility of forest management practices quickly dissipates if the tax rate is increased. On the contrary, a landowner's use of tax provisions that apply to timber (e.g. the amortization of reforestation expenses) can dramatically improve their returns (Royer and Moulton 1987). Unfortunately, landowner knowledge of the tax provisions that apply to timber, as well as other tax aspects germane to forest management varies greatly (Thrift et al. 1997). Moreover, despite the vast body of family forest literature, few researchers have examined whether family forest owners are aware of or use the incentives and other beneficial income tax provisions found in the Internal Revenue Code (IRC). As beneficial as tax provisions can be to ensure sustainable forest management in the future, efforts must be made to bridge the chasm that exists in the literature. In addition to contributing to the literature, our study establishes socioeconomic predictors of family forest owner use of seven different tax incentives: long-term capital gains treatment of timber income (LTCG), annual deduction of management expenses (ADME), depreciation and the section 179 provision (DS179), deduction for casualty losses and other involuntary conversions (CLIC), the reforestation tax credit (RTC), amortization of reforestation expenses (ARE), and the ability to exclude qualifying reforestation cost-share payments from gross income (ECSP). Logistic regression techniques coupled with a two-stage selection process will be used to develop models that examine which socioeconomic factors are associated with landowner awareness and landowner use of the seven tax incentives. In the first stage, the landowner awareness model will be developed. Then conditional on landowner awareness, a model will be developed in the second stage to determine which factors affected the use of each of the provisions.

1.1 Federal Income tax provisions

Since the early in the twentieth century governmental agencies have established a range of tax provisions in the Internal Revenue Code to encourage sustainable forest management and land conservation. Four of the seven tax provisions examined in this study are available to taxpayers in general.

Treatment of qualifying income as a long-term capital gain

The first of the four tax provisions available to taxpayers in general is long-term capital gain treatment of income from the sale or disposal of a qualifying asset that the owner has held for more than twelve months. Timber sold outright, in a lump-sum sale, qualifies for capital gain treatment if the owner held it as an investment (a section 1221 sale) or if the owner can demonstrate that they held if primarily for use in their business rather than for sale to customers (a section 1231 sale). Owners who hold their forest as part of a trade or business can only ensure capital gain treatment of timber income by disposing of the timber under the provisions of section 631 of the Internal Revenue Code, either pay-as-cut with an economic interest retained (a section 631 (b) disposal) or by cutting the timber themselves and selling logs, pulpwood, or other products (a section 631(a) transaction; Haney et al. 2001). Long-term capital gains are taxed at lower rates than ordinary income. In 2001, when the data was collected for this study, the four upper level ordinary income tax rates ranged from 28 percent to 39.6 percent, the corresponding capital gains tax rate was 20 percent. The bottom ordinary income tax rate of 15 percent had a corresponding capital gains tax of only 10 percent. Obviously, the result of income qualifying as capital gains rather than as ordinary income equates to substantial tax savings. The IRC also requires that timber be held for at least one year and disposed of in one three ways: the landowner must sell the timber in a lump-sum sale, under a pay-as-cut contract in which the owner retains an economic interest in the timber, or cut and sell the timber himself. Finally, capital losses can be used to directly offset any capital income whereas with ordinary income there is a $3,000 limit to offset losses (Haney et al. 2000). Since 2001, passage of the American Jobs Creation Act (AJCA) of 2004 enabled lump sum sales to qualify under Code Section 631 (b), disposal with an economic interest retained. This means that timber gains and losses are netted against other gains and losses from the disposal of business assets (Hoover 2005).

Annual Deduction of Management Expenses

The second provision available to taxpayers in general is the ability to deduct certain management costs from gross income. These costs include the day-to-day activities that are required to manage timber property such as hiring salaried labor, consulting forester fees, and travel expenses that can be directly related to income potential for the property. These types of expenses are considered "operating costs" (Haney et al. 2000). Other expenses, termed "carrying charges," include property taxes, insurance premiums, and interest payments, all of which may also be deducted from gross income. The property does not have to be producing income in order to qualify for this deduction; the deduction is based upon intent to produce future income.

Depreciation and the section 179 deduction

The third provision available to taxpayers in general is the bonus depreciation and Section 179 deduction which allows for up to $24,000 per year in qualified expenditures to be deducted from gross income. Qualifying expenditures include equipment purchases, roads, fences and other such items used in the production of timber. The taxpayer must use the property as a trade or business to qualify and the deduction must be taken the year the equipment is placed into service. For every dollar over $200,000 of qualifying property, the deduction is reduced by a dollar. Of course, equipment, buildings, and other non-permanent assets may be depreciated over their determinable useful life as they are "used up." Timberland owners may depreciate equipment as long as the land is held as either an investment or as an active trade or business. Section 179 allows the qualifying costs, in effect, to be expensed in the current year, rather than be depreciated over a useful life. Since the time of this initial survey, the deductible amount has been increased to $25,000 per year in qualified expenditures per the allowance schedule authorized by the Small Business Job Protection Act of 1996.

Deductions for casualty losses or other involuntary conversions

The fourth tax provision available to taxpayers in general is the deduction for casualty losses or other involuntary conversions. For family forest landowners this provision covers timber losses caused by beetle attacks, ice storms, theft, and condemnation. These are termed involuntary conversions and to qualify the timberland must be held as an investment or as an active trade or business. Normal losses from diseases or natural mortality do not typically qualify for this deduction. Southern pine beetle attacks do qualify for this deduction. However, since they are deemed a sudden and unexpected loss, the amount of the loss that may be deducted is limited to the basis invested in the land.

Reforestation Tax Credit and Amortization of reforestation expenses provisions

The first tax provision in the IRC is the ten-percent reforestation tax credit available to anyone who reforests his or her property. It allows for a ten-percent tax credit on up to $10,000 of reforestation expenditures annually. This equates to a potential $1,000 tax credit each year reforestation expenditures are incurred. Recapture rules apply to the tax credit if the trees are not held for at least 5 years. The second forestry specific provision, seven-year amortization, is tied in with the reforestation tax credit. The qualifying landowner is allowed to amortize (deduct) up to $10,000 of reforestation expenditures per year. Any amount amortized must be reduced by 50 percent of the reforestation tax credit taken. This means that if a $1,000 tax credit were taken, only $9,500 would qualify for amortization. The schedule for amortization is one-fourteenth the first year, followed by one-seventh the next six years, followed by one-fourteenth in the eighth and final year. The trees must be held at least ten years before they may be cut. If this ten-year period is not met, the tax savings from amortization are subject to recapture. Since the time of the initial survey (2001), passage of the AJCA 2004 amended the reforestation amortization section of the laws to allow family forest owners to deduct up to $10,000 per qualified timber property per year of qualified reforestation expenses, while eliminating the reforestation tax credit (Hoover 2005). AJCA 2004 also allowed landowners to amortize any amount in excess of $10,000 over 84 months. Since the data for this study were collected prior to the passage of AJCA 2004, we will examine the awareness and use of both the ARE and RTC provisions.

Ability to exclude qualifying reforestation cost-share payments from gross income

The third forestry specific tax provision concerns government cost-share payments. Qualifying government cost-share payments may be excluded from gross income. Nine federal cost-share programs are available to timberland owners, as well as a multitude of state cost-share programs that qualify for this incentive. Examples are the Forestry Incentive Program and the Agricultural Conservation Program. Two conditions must be met in order for the cost-share payments to qualify for exclusion form gross income: (1) the money must be used to conserve the soil and water, to protect the environment, to improve the forest, or to provide habitat for wildlife and (2) the amount of money cannot substantially increase the value of the property (Haney et al. 2000).

1.2 Effects of Tax Provisions on Family Forest Owners – Literature

Family forest owners' knowledge of federal and state provisions has not always been high. An early survey of small woodland owners in Southwest Arkansas found that none of the respondents mentioned the capital-gains treatment of timber income when asked about taxation (Perry and Guttenberg 1959). Other early family forest surveys never even addressed landowner awareness and use of forestry cost-sharing programs such as the Agricultural Conservation Program (Hutchison and McCauley 1961). The authors even inquired about the influence taxes have on a landowner's plans for using their woodlands. However, they failed to ask whether or not landowners were aware of the tax provisions available to them. In another study, Quinney (1962) inquires about the impact of property taxes on landowner's decisions, but fails to inquire about the awareness of tax provisions available to forest landowners. His study of small private forest landowners in Michigan's Upper Peninsula found that property taxes did not appear to be a major factor affecting the decisions of the majority of those surveyed.

One of the earliest studies that inquired about a landowner's awareness and use of forestry tax provisions was conducted by Schallau (1962). Schallau examined the private forest landownership in the urban fringe area of Michigan. In addition to noting that property taxes had little bearing on the way those surveyed manage their woodlots, In his study, he cites that only 3 percent of those surveyed had taken advantage of the capital gains provision of the Internal Revenue Code. He notes an additional 9 percent were aware of the provision, but never used it because they had not harvested timber products. Those that were aware and had not taken advantage of the provision either believed they would not have derived any benefit from it or felt the red tape involved was not worth the savings they would have incurred. When the provisions were explained to those surveyed, one-third expressed some interest, while 55 percent remained indifferent. Of those who had utilized the provision did not feel that it influenced the way they managed their woodlands. Contrary to his 1962 study, Schallau does little to inquire about the awareness and use of forestry tax provision in a 1964 study of forest owners and timber management in Michigan. Schallau (1964) does inquire about provisions specific to forest landowners in Michigan at the time of the study, The Woodlot Yield Tax Law and the Commercial Forest Reserve Act, both of which were designed to shift the incidence of tax on forest property from periods when no income was being derived to those periods when harvest cuts were made. But no attempt was made to ask about forestry tax provisions found in the Internal Revenue Code.

Farrell's (1964) study of small woodland owners in the Missouri Ozarks is another example where only state specific tax provisions are mentioned. His examination of small woodland owners includes a question on whether or not taxes affect their forest management decisions, but fails to ask about any of the forestry tax provisions. The only tax provisions mentioned are those afforded to landowners by the Missouri Conservation Commission Forest Crop Law. Stoltenberg and Gottsacker (1967) surveyed a random sample of forest owners in six Iowa counties were asked whether or not they were aware of a property tax advantage under the Iowa Forest Preserve Law, but no mentioning of the federal tax provisions is found in their study.

Koss and Scott (1978) profiled nonindustrial forest landowners of western Washington State. Their sample included a majority of landowners enrolled in Washington State's Forest Tax Law-a tax provision specific to the state that made forestry more financially attractive. Nearly half desired more tax incentives to make it more profitable for landowners to manage their lands. Fecso et al. (1982) examined the management practices and reforestation decisions of southern pineland owners who had harvested timber. Their study is one of the first surveys to ask respondents about tax provisions offered under the Internal Revenue Code. Their findings indicate that tax credits and additional deductions for reforestation were likely to have an effect on approximately seven-tenths of the harvested acres in the South. At the time of their study tax credits and deductions for forestry investments had only been in effect less than a year.

Respondents rated improving capital gains treatment for timber income as having a high or moderate possible effect.

In 1987, Royer conducted a study in North Carolina between 1981-1984 evaluating the use of cost-share payments, the ten-percent tax credit, seven-year amortization or the combination of all three by family forest landowners that had sold timber (Royer 1987). His study found that of the landowners that actively reforested, 80 percent used cost-share money, 60 percent utilized the reforestation tax credit, and 55 percent used both incentives. In another study, Royer and Moulton (1987) found that of farmers who had made a final harvest of their timber and then reforested, 71 percent had used the cost-sharing and/ or the reforestation tax incentives. Overall, their study reported that 48 percent of those conducting reforestation had received cost-share payments and 58 percent had used the reforestation incentives. Bliss and Martin (1990) determined that cost-sharing by family forest landowners was beneficial, because they required a Registered Forester to manage their timberland. The authors also cited the fact that although many of the landowners would have done the work without the cost-share payments, the payments allowed them to do more.

Dee (2001; also see Greene et al. 2004) conducted a study of South Carolina NIPF landowners to determine the reasons for use and nonuse of forestry tax incentives and identify the characteristics of those landowners that do utilize tax incentives in their forestry operations. Their study showed that 78% of the landowners surveyed were aware that timber sale income could qualify as long-term capital gain, of those aware 85% had made use of it. A like percentage of respondents were also aware of the annual deduction of management expenses, with an 85% use rate among those aware. Only 50% of those surveyed in their study were aware of the depreciation and section 179 deduction for income-producing property. Of those aware, only 67% had actually used it. Just 54% of their samples were aware of the reforestation tax credit. However, 78% of those aware utilized it. Like the reforestation tax credit, a little over half (56%) of those surveyed were aware of the amortization of reforestation expenses provision, with 80% of those aware using it. Greene et al. (2004) reported that survey respondents were least aware (42%) of the provision allowing NIPF landowners to exclude qualifying reforestation cost-sharing payments from gross income. Of those aware of the provision 70% had used it. Many of the responses from landowners not utilizing the provisions indicated that approximately one-quarter to one-third felt that the benefit was not worth the time and effort needed.

2 METHODS

Data for this study were drawn from a 2001 South Carolina family forest owners survey conducted by Greene et al. (2004). Initial efforts were made to follow the total design method (Dillman 1978). However, budgetary and time constraints prohibited the survey from completely following the survey methodology outlined by Dillman (1978). Greene et al. (2004) obtained a list of family forest owners in South Carolina from a large national forestry organization. A total of 1,350 questionnaires were mailed to South Carolina family forest landowners in late January 2001. The overall response rate Four hundred and ninety eight surveys were returned, of which 472 contained usable forms, yielding a response rate of 35 percent. Those that were deemed unusable were either left entirely blank or were considered incomplete. The questionnaire consisted of 58 questions, seven about knowledge and use of each of the seven tax provisions, and nine about demographic characteristics. The response variable for knowledge and use of each of the seven tax provisions takes the value 1 if a landowner was aware or had used one of the tax provisions and 0 otherwise (Table 1).

Table 1. Summary of Dependent Variables.

Variable	Description
LTCG_Aware	Dummy= 1 if the landowner was aware of the program; 0 otherwise
LTCG_Use	Dummy=1 if the landowner used the program; 0 otherwise
ADME_Aware	Dummy= 1 if the landowner was aware of the program; 0 otherwise
ADME_Use	Dummy=1 if the landowner used the program;0 otherwise
DS179_Aware	Dummy= 1 if the landowner was aware of the program; 0 otherwise
DS179_Use	Dummy=1 if the landowner used the program; 0 otherwise
CLIC_Aware	Dummy= 1 if the landowner was aware of the program; 0 otherwise
CLIC_Use	Dummy=1 if the landowner used the program; 0 otherwise
RTC_Aware	Dummy= 1 if the landowner was aware of the program; 0 otherwise
RTC_Use	Dummy=1 if the landowner used the program; 0 otherwise
ARE_Aware	Dummy= 1 if the landowner was aware of the program; 0 otherwise
ARE_Use	Dummy=1 if the landowner used the program; 0 otherwise
ECSP_Aware	Dummy= 1 if the landowner was aware of the program;0 otherwise
ECSP_Use	Dummy=1 if the landowner used the program;0 otherwise

The independent variables for this analysis were derived from nine demographic questions initially used to analyze the differences between the respondents in Greene et al. (2004). The nine demographic questions focused on the landowner's reasons for owning timberland, education level, household income level, and occupation. Also included in the demographic questions were queries about how many acres of forestland and total acres of land the landowner owned as well as the landowner's membership in a forest organization and use of a written management plan. A summary of the independent variables used in the analysis can be found in Table 2.

Table 2. Summary of Independent variables.

2.1

Variable	Definition
TA	Total Acre owned by the landowner
FA	Total forested acreage owned by the landowner
PF	Percent of forested acreage owned by the landowner
PRO	Value=1 if landowner holds for investment purposes; 0 otherwise
BTO	Value=1 if landowner belongs to a landowner organization; 0 otherwise
MP	Value=1 if landowner has written forest management plan; 0 otherwise
LOE	Value= 1 if landowner has a college education; 0 otherwise
OCC	Value=1 if landowner is blue collar worker;0 otherwise
	Value=1 if landowner is white collar worker;0 otherwise
	Value=1 if landowner is farmer; 0 otherwise
	Value=1 if landowner is homemaker; 0 otherwise
	Value=1 if landowner is retired; 0 otherwise
	Value=1 if landowner works in a field that is not mentioned; 0 otherwise
	Value=1 if landowner is blue collar worker;0 otherwise
AGE	Value= 1 if landowner is <30 years old;0 otherwise
	Value= 1 if landowner is 30-49 years old;0 otherwise
	Value= 1 if landowner is 50-65 years old;0 otherwise
HIL	Value= 1 if landowner is >65 years old;0 otherwise
	Value= 1 if landowner's household income level is <$30,000; 0 otherwise
	Value= 1 if landowner's household income level is $30,000-$85,000; 0 otherwise
	Value= 1 if landowner's household income level is >$85,000; 0 otherwise

Logistic Regression Analysis

Seven separate empirical models, described below, were developed to examine awareness for seven of federal income tax provisions. The response variable represents awareness in one of the seven tax provisions: long-term capital gains treatment of timber income (LTCG_Aware), annual deduction of management expenses (ADME_Aware), depreciation and the section 179 deduction (DS179_Aware), casualty loss and involuntary conversions (CLIC_Aware), reforestation tax credit (RTC_Aware), and exclusion of qualifying cost-share payments (ECSP_Aware). The response variable takes the value 1 if a landowner is aware of a particular tax provision and 0 otherwise. The empirical models also include a number of independent variables described in table 2, measuring land characteristics, ownership characteristics, and demographics. For instance, if we use LTCG_Aware as the response variable, independent variables will include BTO and LOE in order to examine whether a landowner's participation in a landowner organization and whether or not they have a college education is associated with knowledge of the long-term capital gain treatment provision. Due to the binary format of the dependent variables we used binary logistic regression to analyze the data. In binary logistic regression, probabilities are assigned to each of the two possible outcomes. For a binary response variable Y and a vector of independent variables X, the specific form of the function used for the logistic regression model used in this study is:

$$\pi|x_i = \frac{e^{\beta_0+\beta_1 x_1+\cdots\beta_i x_i}}{1+e^{\beta_0+\beta_1 x_1+\cdots\beta_i x_i}}$$

where

$\pi|x_i$ = Probability of the dependent variable= 1.

e= the base of the natural logarithms

β_0= the constant of the equation and,

β_i= the coefficient associated with the independent variable x_i.

The logit transformation is often used for the relationship function (Hosmer et al. 2013).The transformation is defined as:

$$g(\pi(x))=\ln\left[\frac{\pi(x)}{1-\pi(x)}\right]$$

Which results in = $g(\pi(x)) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots \ \beta_i x_i$

The result of this transformation is that the logit $g(\pi(x))$, is linear in its parameters; similar to traditional linear regression. An important difference between traditional linear regression and logistic regression models concerns the conditional distribution of the outcome variable. In the linear regression model the relationship function is

$U_y\,|x_i = \beta_0+\beta_1 x_1+\beta_2 x_2 \ldots \ \beta_i x_i$ and

y= $U_y\,|x_i + \varepsilon$

where

ε is the error term and expresses an observation's deviation from the conditional mean. The most common assumption is that ε follows a normal distribution with mean zero and a variance that is constant across levels of the independent variables (Hosmer et al. 2013).

However, this is not the case with dichotomous outcome variables. The error term in this case can only assume two values: 0 or 1. In this scenario, the value of the outcome variable given x is expressed as:

$$y = \pi|x_i + \varepsilon$$

ε in this case may only assume one of two possible values. When y=1 then

$\varepsilon = 1 - \pi|x_i$ with probability $\pi|x_i$, and if y=0 then $\varepsilon = -\pi|x_i$ with probability $1-\pi|x_i$

Thus ε has a distribution with mean zero and variance equal to $\pi|x_i[1 - \pi|x_i\ ]$. That is, the conditional distribution of the outcome variable follows a binomial distribution with probability given by the conditional mean, $\pi|x_i$.

In this study, the statistical software package JMP was used to perform the logistic regression analyses (SAS 2012). The analysis followed a two-step sample selection model to examine which socioeconomic factors were associated with landowner **awareness** of the tax provision. Then conditional on landowner awareness, a model was developed to determine which what factors affected their **use** of the provisions. Two-stage analyses have been widely used in the literature to analyze cost-share programs, hunting lease markets, and other forestry-related issues (Starbuck et al. 2004; Ovaskainen et al. 2006; Zhang et al. 2006; Hussain et al. 2007; Sun et al. 2009). In this study, a two-step sample selection model is employed to examine the determinants of landowner awareness and use of tax provisions. It is assumed that use of tax provisions are contingent upon whether these landowners are aware of the provisions. In the selection stage, landowner awareness of a specific tax provision is modeled as a function of variables, comprised of landowner characteristics. In the outcome stage, landowner use of the provisions is specified as a function of similar explanatory variables. Conceptually the model is expressed as follows:

Selection equation: $Z_i = g\ (x_i)$

Outcome equation: $Y_i = f\ (Z_i)$

Where Z is a binary variable that indicates whether landowner i is aware of an individual tax provision (i.e., LTCG, ADME, DS179, CLIC, RTC, ARE, ECSP); Z_i equals one if the landowner is aware of the program, and zero otherwise. Y is a binary variable that indicates whether landowner i has used the tax provision, and 0 otherwise. The variables of awareness (Z_i) and use (Y_i) are related but may be influenced by different explanatory variables, or by the same set of socioeconomic factors to a different degree. Therefore, Z_i may be different from Y_i. Both the selection and outcome logistic regressions were reported for each tax provisions.

Since much of the research over the last few decades has found many of these independent variables to be highly correlated, initial screening using contingency tables was conducted to detect any potential multicollinearity that may distort the analysis. Multicollinearity occurs when linear or near linear dependencies exists between the explanatory variables. This can adversely affect the results of the regression analysis. Traditionally, with least squares estimation in standard multiple regressions, decomposition of the correlation matrix of explanatory variables has been used as a diagnostic tool to determine the distortion multicollinearity has on parameter estimation and prediction. Although researchers have been unjustifiably utilizing these least square multicollinearity diagnostics for models comprised of dichotomous data, the normality assumptions of least squares linear regression does not hold with these data (Marx and Smith 1990). Examination of the contingency tables for the explanatory variables resulted in the use of the forested acres (FA) variable as a proxy for total acreage (TA) owned; and landowner organization (BTO) as a proxy for use of a management plan (MP). The FA variable was also used as a proxy for household income level and age. Since the initial study from which the data were derived was not designed around an econometric analysis, the occupation category of variables was omitted from the analysis because no logical grouping of this category could be made upon inspection of the contingency tables for possible multicollinearity and balanced data issues.

3 RESULTS AND DISCUSSION

3.1 Descriptive Statistics -Dependent Variables

The descriptive statistics for the dependent variables used in this study are presented in Table 3. Landowner awareness and use of each provision was measured by a binary variable so its mean also revealed the percentage. Awareness of the provisions varied widely, with respondents being most aware of the capital gains treatment of timber sale revenue (LTCG) and the annual deduction of forest management costs (ADME) incentives (Table 3). While a substantial percentage (>75%) of the respondents were aware of these two provisions, just over half were aware of the reforestation tax credit (RTC), seven year amortization of reforestation expenses (ARE) , section 179 depreciation (DS179), and casualty losses and involuntary conversions (CLIC) provisions (Table 3) . Only 41 percent of respondents indicated they were aware of the exclusion of qualifying cost-share (ECSP) incentive (Table 3). For those not aware of the tax provisions, many reported that their accountants most likely had at least some knowledge of the existence of the provisions (Dee 2001).

Table 3. Awareness and Use of the Forestry Tax Incentives (Dee 2001).

	Knowledge of Incentive		Use of Incentive	
	Frequency	Percentage	Frequency	Percentage
Forestry Tax Incentive				
Capital Gains Treatment	360/465	77	304/360	84
Management Cost	359/465	77	304/359	85
Timber Losses	273/465	59	61/273	22
Depreciation/Deductions	233/465	50	153/233	66
Tax Credit	251/465	54	195/251	78
Seven-year Amortization	256/465	55	203/256	79
Cost-Share Payments	191/465	41	135/191	71

Utilization of the first six provisions ranged from two-thirds to 85 percent (Table 3). Only 22 percent indicated they had taken advantage of CLIC, but given this incentive is subject to opportunity, the low percentage is understandable. Overall, respondents' awareness of the tax incentives is relatively high, as well as use (Table 3). The savings derived from classifying timber income as a capital gain can lead to significant tax savings. Moreover, for landowners that actively manage their forestland, being able to deduct these management costs on an annual basis leads to substantial tax savings each year.

The RTC and ARE incentives are closely tied in terms of landowner awareness as well as in their actual use. Over 50 percent of the respondents were aware of these two incentives, with nearly 80 percent of those aware indicating that they had used the provisions (Table 3).

The respondents knew least about ECSP, which allows owners to exclude qualifying cost-share payments from gross income. Despite low awareness (41percent), 71 percent of those who knew about it had in fact used the tax provision in the past (Table 3). The second least known tax incentive available to NIPF landowners dealt with deductions and depreciation, DS179 (Table 3). Only 50 percent of the respondents claimed having knowledge about these provisions. Of those aware, only 66 percent had used them, making them the second least used tax incentive available (Table 3).

Although awareness of CLIC, which deals with timber losses resulting from theft, condemnation or disease was the third most widely known about (59 percent), only 22 percent reported using this provision in the past. Since this provision is subject to actual timber losses the low usage percentage is in part due to landowner's lack of timber losses to claim (Table 3).

Overall landowner's awareness of the forestry income tax incentives appears to be relatively high with the exception of the cost-share and depreciation/deduction incentives. Landowners knowledgeable about the incentives tend to use the tax provisions, except for the timber loss provision (CLIC). Despite this, a substantial number of NIPF landowners lack awareness of key incentives and others choose not to utilize them.

3.2 Model Results

The results for the econometric models are presented in tables 4 and 5.

Table 4. Summary of Awareness Models for the Seven Tax Incentives.

Independent	Prob> Chisq						
Variable	LTCG	ADME	CLIC	DS179	RTC	ARE	ECSP
Constant	0.0286	0.9156	0.0057*	<.0001*	0.0056*	0.0008*	<.0001*
BTO	<.0001*	<.0001*	<.0001*	0.0001*	<.0001*	<.0001*	<.0001*
FA	0.001*	<.0001*	0.0002*	0.0006*	0.0026*	0.017*	0.0393*
PRO	0.0092*	0.0376*	0.8308	0.1981	0.8811	0.0402*	0.3571
LOE	0.0439*	0.0314*	0.0007*	0.037*	0.0586	0.0003*	0.7638
PF	0.8998	0.0781	0.0815	0.004*	0.0918	0.0342*	0.0074*

*Significant at the α=0.05 level.

A summary of the significant (α=0.05) variables of the awareness models revealed that the variables representing landowners membership in a landowner organization (BTO) and size of forest holding (FA) were consistent at predicting respondents' awareness for all seven of the tax incentives examined in this study (Table 4). Based on our initial screening tests, this also implies that landowners with a professionally prepared management plan would be aware of these incentives. Prudence would advise one from asserting the dependence of one of these demographics on the other. Rather, we can surmise that landowners who are actively involved in a landowner organization or possess a professionally prepared forest management plan tend to be more abreast about issues germane to holding forestland than other groups of owners.

The historically significant variable, size of forest holding (FA) was also a good predictor of landowners' awareness of the tax incentives. Past research has found that size of forest holding is a key characteristic that is highly correlated to forest management on family forests. Even the current family forest literature continues to show size of forest holding to be strongly correlated with many variables related to forest management, especially forest owners' technical knowledge and attitudes towards timber harvesting. This supports the fact that the BTO variable has a substantial influence on landowners' awareness of the provisions. Size of forest holding has also been considered to be a good proxy for landowners' level of education, another one of the variables that was a significant (α=0.05) predictor of landowner awareness in this analysis.

The variable capturing landowners who held their forest land for investment purposes had little influence on the awareness for the casualty loss, depreciation and deductions, reforestation tax credit, and exclusion of qualifying cost-share payments provisions. Theory would suggest that an individual who is in the business of maximizing profits would explore all possible avenues to reduce costs; however, this appears to not be the case. One explanation for this inconsistency is that profit maximizers only expend their energy exploring cost minimizing avenues when needed. The lack of influence PRO has on the awareness of the casualty loss provision would support this claim. It truly is a case specific provision. The same reasoning would apply to the exclusion of qualified cost-share payments incentive. Landowners not engaged in cost-share programs have little incentive to explore avenues which minimizes their tax liabilities from participation. Likewise can be said for the provision that allows for the deduction and depreciation of applicable equipment or property improvements, those engaged in land ownership for investment reasons may find that holding equipment or adding qualified improvements to erode their overall returns. The fact that PRO positively influenced the awareness of ARE but not RTC is a little surprising. Since these two provisions are closely linked one would surmise that knowledge of one would be highly correlated to the awareness of the other. Moreover, PRO has significant influence on the LTCG provision, which is also associated with timber harvesting activities. This suggests that information regarding the seven year amortization and long-term capital gains treatment of timber provisions is more readily available.

Table 5. Summary of the Use Models for the Seven Tax Incentives.

	Prob> Chisq						
Independent Variable	LTCG	ADME	CLIC	DS179	RTC	ARE	ECSP
Constant	0.001	0.0004*	0.0503	0.014*	0.8952	0.4648	0.5207
BTO	0.6856	0.5255	0.1521	0.1341	0.5111	0.1921	0.7165
FA	0.0019*	0.1288	0.0017*	0.0285*	0.0136*	0.0603**	0.31
PRO	0.8895	0.0722	0.7811	0.3364	0.0754	0.1765	0.171
LOE	0.9146	0.8648	0.202	0.4147	0.396	0.8688	0.8182
PF	0.25585	0.1958	0.2198	0.0322*	0.2791	0.2592	0.447

*Significant at the α=0.05 level.
**Significant per the effect likelihood ratio test.

Examining a summary of the use models in this analysis reveals that the size of forest holding (FA) variable was the only significant (α=0.05) one at predicting landowners' use of the provisions (Table 5.34). To some extent this not surprising because the first stage selection model significantly reduced the sample size for the second stage, which was used to generate the use models (Table 5.1). This also confirms the findings of Dee (2001) and Greene et al. (2004), that very few of the socioeconomic predictors examined are useful at estimating landowner use of the provisions.

Our findings suggest that, with a few exceptions, specific landowner demographics can be attributed to a landowner's awareness of the federal income tax provisions examined in this study. These predictors can possibly be used in the future to target specific landowner groups in an effort to better educate them about the tax provisions. The use of the incentives however, does not seem to depend on any particular factor examined, except for the size of forest holding.

4 CONCLUSIONS

Family forest owners hold their land for a variety of reasons; many of which do not produce income. For the objectives that involve generation of income, the owners are subject to the federal income tax. This study examined how the size of forest holding and other landowner characteristics influences family forest owner knowledge and use of federal tax provisions germane to timber management under the 2001 Internal Revenue Code. The seven tax provisions examined in this study were long-term capital gains treatment of timber income, annual deduction of management expenses, depreciation and the section 179 provision, deduction for casualty losses and other involuntary conversions, the reforestation tax credit, amortization of reforestation expenses, and the ability to exclude qualifying reforestation cost-share payments from gross income are offered to family forest landowners in an attempt to encourage sustainable forestry practices through monetary incentives. Respondents were South Carolina family forest landowners who indicated awareness and use of these 2001 tax provisions; some of these provisions have since changed, but the influence of various type of tax incentives is just as relevant today, even for changed provisions. When compared with the general population of family forest owners (Butler, 2008), these respondents appear to be more representative of family forest owners with financially-oriented objectives. So some caution should be used in interpreting these results relative to a more general population of family forest owners.

A two-step sample selection model was employed to analyze their use behavior conditional on their awareness of these tax provisions. The survey revealed that awareness and use of the seven tax provisions varied widely among respondents. The two-stage sample selection model produced several interesting results. From the first stage of selection and binary logistic model, landowner awareness of all seven tax provisions was positively related to size of forest holding and membership in a forest landowner organization. This implies that family forest landowners that both had larger holdings and belonged to some sort of forest landowner organization were most likely to be aware of the seven tax provisions. Having a college education and holding land for investment purposes exhibited varying degrees of influence on landowner awareness of individual provisions. Landowners with these characteristics have also been more apt to receive cost-share funding (Daniels et al. 2010); technical assistance (Kilgore and Blinn 2004), and use a professionally prepared forest management plan (Butler 2008).

Landowners who have at least a college education were more aware of five of the seven tax provisions: the long-term capital gains treatment of timber (LTCG), annual deduction of management expenses (ADME), casualty loss and involuntary conversions (CLIC), the section 179 deduction and depreciation (DS179), and the amortization of reforestation expenses (ARE) than those with less formal education. This finding coupled with the fact that membership in a landowner organization also positively influences awareness provides valuable insights on the importance of disseminating information to family forest owners. These results show this is especially true for the RTC and ECSP provisions. While the ARE provision was closely tied to the RTC provision at the time of the initial survey, landowner awareness for the RTC was influenced by landowner organization membership but not level of education. This is just one example that demonstrates how landowner organizations serve as a conduit for distributing the information produced by forest service and state extension service publications, among others. This finding is further supported by the influence membership has on the CLIC and ECSP provisions. Both of these provisions could be considered case-specific in nature, and do not apply to most family forest owners. However, it further demonstrates the previous statement regarding landowner organizations.

In the outcome stage, landowner use of the provisions was modeled conditional on their awareness of the provisions. Surprisingly, size of forest holding was the only variable that influenced landowner use of the provisions in this study. Although this historically significant variable has been shown to influence many of the forest management activities family forest owners engage in, it is rather disturbing in the sense that, presently, parcelization is considered to be one of the major threats to sustainable forest management. Driven by urban development and other pressures that decrease forest tract sizes, parcelization tends to result in a loss of economies of scale which often makes forestry practices economically infeasible. This may also lead to forest fragmentation, an ecological issue. Tax provisions can be leveraged to mitigate economies of scale losses, which may in turn, reduce overall forest fragmentation. However, as noted by Greene et al. (2004), many family forest owners do not utilize the provisions because they believe that, “It doesn’t apply to their situation,” or “The benefit is too small to bother with.” The former of these responses could be potentially valid due to the specificity of some of the provisions (e.g., ECSP and CLIC), or the fact that the landowner has not engaged in forest management activities that warrant the use thereof. For example, respondents that have not harvested timber have no need to utilize the long-term capital gains or amortization of reforestation expenses (the reforestation tax credit was repealed by the American Jobs Creation Act of 2004) provisions, but may utilize the annual deduction of management expenses while preparing for a timber harvest in the future.

The latter of the Greene et al. (2004) statements is problematic because regardless of the effectiveness education has on landowner awareness; further efforts must be made to show the benefits of these provisions. For example, respondents that did not utilize the long-term capital gains provision, but harvested timber could have realized tremendous tax savings. Moreover, landowners that treat timber income as a long-term capital gain at the time of this writing would save even more than those at the time of the initial survey in 2001.In 2001, the long-term capital gains tax rate was capped at 28 percent, while ordinary income tax rates were capped at 39.6 percent. At the time of this writing, the long-term capital gains tax rate is capped at 20 percent, while ordinary income tax rates are still capped at 39.6 percent. This equates to even larger tax savings than that offered under the 2001 Internal Revenue Code.

Taxpayers that utilize the reforestation tax provisions at the time of this writing would also realize larger benefits versus those offered in 2001. In 2001, the reforestation tax credit provided a ten percent tax credit to landowners that spent up to $10,000 for tree planting costs such as site preparation, seeds, seedlings, and labor that could be subtracted from the amount of taxes otherwise owed to the federal government. Moreover, those that utilized the credit could amortize $9,500 of the $10,000 over an 84 month period by utilizing the amortization of reforestation expenses provision. During this same time period, landowners that spent up to $10,000 but did not utilize the ten percent tax credit could amortize the full amount over an 84 month period. Since the initial study, the reforestation tax credit was repealed by the American Jobs Creation Act of 2004 and landowners are now allowed to deduct up to $10,000 per qualified timber property per year and amortize any amount in excess of $10,000 over 84 months.

Models developed in this study examined which socioeconomic factors influence landowner awareness and landowner use of seven federal income tax provisions. The findings confirm that educational efforts, ownership objectives influence landowner awareness of the provisions. However, none of these are good at influencing landowner use of the provisions. With urban development and other social pressures decreasing average parcel size additional efforts must be made to educate landowners on the benefits of the tax provisions offered through the internal revenue code. Tax policy has profound impacts on the profitability of forest management; it also has the potential to be huge player in the conservation of many forested tracts across the United States. Modifications to some the provisions (e.g. long-term capital gains and reforestation tax provisions) since the initial study in 2001has further increased their benefits, which in turn, could increase the amount of forested acres sustainably managed. Since size of forest holding was the most significant variable at predicting use in this study, further research efforts examining the awareness and use of federal tax provisions by family forest owners must be exerted to understand the exact acreage classes in which landowners are more likely to utilize the provisions than not. This one piece of data would enable forestry researchers to develop tools to reach out to those who are not currently using them. If we as society value the many benefits forests produce, it will be imperative to not only disseminate information on tax provisions, but also educate family forest owners on the benefits of them.

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AMERICAN TREE FARM SYSTEM CERTIFICATION STANDARDS: CURRICULUM FOR A CAPSTONE COURSE IN FOREST RESOURCE MANAGEMENT PLANS

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ABSTRACT

Forest resource management planning was primarily focused on timber production until the late twentieth century. The focus then evolved to address multiple-use and sustainable forest management. Today, forest certification plays a major role in ensuring forest sustainability. The concepts of forest sustainability and forest certification are frequently integrated into the upper level forestry courses in a modern university forestry curriculum. Most forestry curricula have a capstone forest resource management plans or planning course. We report on a survey of the forty-five accredited American forestry programs and ten non-accredited forestry programs regionally distributed across the United States, emphasizing the forest resource management planning aspects of the curriculum. We discuss the various types of capstone courses and the frameworks or standards used to develop forest resource management plans. Included is a broad discussion on the use or non-use of forest management plans, types of forested properties, and management plan templates. Clemson University is utilizing its forestry capstone course to integrate forest sustainability requirements of the American Tree Farm System into the forest management planning process. Sustainable forest management, forest certification, and the American Tree Farm System are molded into a capstone forest management plans course. Clemson's forestry students are presented with an opportunity to broaden their background on these important topics, while working with family forest owners on actual Tree Farm properties. This real-world experience greatly enhances their understanding of a complex aspect of modern forest resource management planning.

Keywords: education; management planning; capstone course; forest certification; American Tree Farm System

1 INTRODUCTION

Many university-level forestry and natural resource management curricula culminate with a forest or natural resource management plans and planning course. Usually this is a capstone course, intended to integrate the prior specialized course work into a final project that includes writing a forest management plan. At one time these courses emphasized timber management and planning that was centered on timber production objectives; gradually non-timber objectives (such as wildlife habitat, recreation, water quality, and aesthetics) became important components of the plans and a multiple-use approach became the norm (Straka, 1993; Fisher, 1996).

Some forestry and natural resource management curricula integrate course work (Gilbert et al., 1993; Fox et al., 1996), while other programs tend to stress integration at various points in the curriculum, and often the capstone course is that point (Petersen, 1993). Integration is crucial if the students are to synthesize their prior coursework from fields like forest management, forest biometrics, silviculture, forest economics and valuation, wildlife management, soils, forest protection, and forest harvesting and operations (Brown and Lassoie, 1998). With the forestry capstone course, all this prior course work is incorporated into one forest resource management planning project or exercise.

Various approaches have been used for this capstone course. Prior to the multiple-use approach, forestry schools stressed traditional timber management plans. These were often developed on university forests in a simulated management environment, with an emphasis on the development of practical field skills necessary for working on industrial and USDA Forest Service timberlands. Since many forestry graduates found employment on these types of timberlands, this approach developed marketable graduates. Gradually the USDA Forest Service moved towards multiple-use and timber values lost their predominance; family forest owners were recognized as having considerable interests beyond timber management (Thrift et al., 1997); and industrial timberlands began to be managed in a much more environmentally sensitive manner (Straka, 1993). Employers expected forestry and natural resource management graduates to have a much-broader sustainable forest management perspective (Brown and Lassoie, 1998; Luckai, 2002).

Private forest land accounts for 56% of total forest land in the United States. Family forest owners account for 62% of that private forest land ownership (Butler, 2008). This means many foresters can expect to work directly or indirectly on family forest lands, perhaps as a consulting forester, county forester, or Extension forester. The faculty at forestry schools recognized that a broader focus on these family forest landowners was necessary if forestry students were to be introduced to this group of potential clients (Tombaugh, 1998). There was also a recognized need with family forest owners; only 17% of their forest land was managed under a written management plan (Butler, 2008). Forestry students needed to develop communication skills to talk to these landowners and the ability to develop management plans for their small properties (Egan, 1996). Direct involvement of forest landowners became common in these capstone courses as a means to include complex forest management and real-life interactions with forest owners and their diverse management objectives.

Capstone forestry and natural resource management courses began to give a priority to real world planning experiences with family forest landowners and multiple-use management objectives and new orientations developed as course foundations. They were described in the literature as landowner-oriented approaches (Straka, 1993), landscape level planning approaches (Prokopy, 2009), multidimensional approaches (Egan, 1996), service learning approaches (Prokopy, 2009; Straka, 2005), problem-based learning approaches (Authur and Thompson, 1999; Prokopy, 2009), adaptive management approaches (Sample et al., 1999), learning centered approaches (Thompson et al., 2003), and ecosystem management approaches (Bengston, 1994; Grumbine, 1994).

Over the last two decades the emphasis on forestry program change and the capstone course has evolved towards new paradigms, such as ecosystem management and forest sustainability (Sample et al., 1999). This is an international shift in emphasis and its impact goes well beyond the American forestry schools (Rebugio and Camacho, 2005; Temu and Kiwia, 2008). Even the standard textbooks on forest management developed a strong forest sustainability perspective (Davis et al., 2001). Forestry and natural resource management seemed to be reorienting or evolving towards the ideal of forest sustainability (Jacobson and Robinson, 1990; Rebugio and Camacho, 2003; Sample et al., 1997) and forest certification, especially at the international-level, appeared to be an important part of the evolution (Konijnendijk, 2000; Temu et al. 2006).

2 FOREST CERTIFICATION AND SUSTAINABILITY

A formal, written management plan is necessary for compliance with all forest certification organizations. In today's environment, people are becoming more and more interested in the concept of "going green" and the idea of sustainability relating to forest resources is becoming an increasingly important issue for landowners. Forest certification is one way in which forest owners can ensure that their land will be managed in a sustainable manner and helps to provide a way to show the public this, such as through the use of logos on commodities and signs on the land. Forest certification is defined as a process by which an independent body conducts an inspection by auditors to determine if the landowner is in conformance with a system of standards developed by the specific certification organization. All forest certification entities establish standards that ensure forest resources are managed in a manner which promotes sustainability on environmental, social, and economic goals (Cox, 2010).

Forest sustainability developed as a global issue starting in the 1980s (Kessler et al., 1992; Straka and Layton, 2010; Vogt et al., 2000; Wang, 2004). The first significant global agreement on sustainable forest management, a Statement of Forest Principles, was produced in 1992 at the Rio Conference or Earth Summit, the United Nations Conference on Environment and Development held in Rio de Janeiro (Lindenmayer and Franklin, 2003). The United Nations Forum on Forests was established in 2000 to promote sustainable forest development and in 2007 its General Assembly approved the "Forest Instrument" to serve as a global framework for sustainable forestry. Significantly, one year following the Rio Conference, an International Seminar of Experts on Sustainable Development of Boreal and Temperate Forests was held in Montréal. The criteria and indicators that are used to identify sustainable forest management, called the Montréal Process, developed from that meeting (Montréal Group, 2008).

The basis of the Montréal Process is seven key criteria and seven similar thematic areas. They are considered a foundation of sustainable forest management at the regional or national levels and form a structure for systems that certify forest sustainability. The Montréal Process is generally accepted as an implicit definition of sustainable forest management. The seven thematic areas are (1) extent of forest resources, (2) biological diversity, (3) forest health and vitality, (4) productive functions of forest resources, (5) protective functions of forest resources, (6) social and economic functions, and (7) legal, policy and institutional framework (Montréal Group, 2008).

In the two decades that preceded the Rio Conference the forest sustainability issue developed from environmental groups becoming increasingly alarmed at the massive deforestation of tropical rainforests and the rapid loss of biodiversity. They called for increased "eco-labeling" of wood products, especially those from the tropics. Eco-labeling is a "claim" (tag) attached to a product that indicated its environmental characteristics (Perera and Vlosky, 2006), allowing consumers to identify environmentally-friendly products and to direct their purchasing power to the firms producing those products. Forest certification qualifies as eco-labeling that identifies forest products that originate from sustainably-managed forests. It is an attempt by the market place, rather than government regulation, to ensure forest products are harvested using sustainability criteria (Maser and Smith, 2001).

The United States, Canada, and Europe had substantial environmental regulations that impacted both private and public forests (Fletcher and Hansen, 1999). However, many in the public, especially those in the environmental groups, felt these regulations were not effective. This was an opportunity for environmental groups to develop programs that certifies forest products that meet the forest sustainability requirements. Forest products trade associations quickly followed suit and developed their own certification programs, ensuring their customers that the timber that went into their products was managed correctly. Some of the certification pressure was indirect; the U.S. Green Building Council introduced Leadership in Energy and Environmental Design (LEED) to improve the environmental performance of buildings; LEED recommends the use of certified forest products in buildings (Hansen et al., 2006). Even logging organizations have developed systems to ensure that harvesting systems support sustainability objectives (Rametsteiner and Simula, 2003).

Forest certification schemes take two forms: process-based and performance-based. Process-based systems focus on a systematic approach to management and performance-based systems specify performance standards that must be met. A system can contain elements of both. Environmental groups tend to favor performance-based systems that include specific environmental protection standards (Innes et al., 2005).

There are three major forest certification organizations in the United States: the Forest Stewardship Council (FSC), the Sustainable Forestry Initiative (SFI), and the American Tree Farm System (ATFS). The FSC was established in 1993 and is performance-based (Forest Stewardship Council, 2011). FSC indirectly certifies forests; it accredits other organizations that do the actual on-the-ground certifications (called certification bodies). FSC certification is worldwide and covers nearly 444 million acres of forest in over 81 countries. Its voting members compose three chambers representing commercial interests (like wood products retailers), socially beneficial forest management interests, and environmentally-friendly forest stewardship interests; this means they operate through multiple stakeholder negotiation (Cashore et al., 2004;

Fischer et al., 2005). The SFI was established in 1994 by the American Forest and Paper Association, an industry trade organization (Sustainable Forestry Initiative, 2011). It was organized to promote sustainable forestry standards on forest industry lands and it has since become an independent organization that certifies about half the area of the FSC. Its standards are a hybrid process- and performance-based system, certification is by third parties, and the program is based in North America (Fischer et al. 2005).

In the United States, the ATFS dates back to 1941 (American Tree Farm System, 2011). The program originally had a wood supply orientation, but it has always promoted sustainable forestry and is one of the oldest certifiers. It has always considered multiple resources, such as recreation, wildlife, and water, but its definition of sustainability has changed dramatically over time to better reflect today's standards. ATFS is performance-based and certification is based on a set of standards and guidelines, and it offers a group certification for tracts under the same management. Much of its certified forest land is owned by family forest owners and about 24 million acres are covered by the program. Both ATFS and SFI are recognized by the Program for the Endorsement of Forest Certification schemes (PEFC). PEFC was established in 1999 as an independent non-governmental third-party umbrella organization to recognize local certification schemes. PEFC was established by landowner groups with timber production interest and forest industry; this may explain why FSC is not a member of PEFC (Fischer et al., 2005).

The objectives, standards, and criteria used by the various certification groups tend to be similar (Guynn et al., 2004; Leslie, 2004; McDonald and Lane 2004; Ozinga, 2004). However, there are significant differences in terms of what is allowed on the ground, due to structural differences in the programs (Cashore et al., 2004; Holvoet and Muys, 2004). National laws or standards may also cause rules to vary. These differences seem to originate from the differing focuses of the founding groups; FSC, founded by environmental groups, stresses basic goals like minimizing forest conversion, respect of worker's rights, respect of human rights, especially with regard to indigenous people, limited use of hazardous chemicals, no corruption, and special protection for significant cultural areas (Innes et al. 2005). SFI and ATFS were founded by forest industry friendly groups and tend to have a stronger timber production orientation.

Sustainable forest management and forest certification schemes have gained wide acceptance over the last twenty years (Dickinson, 1999). About 10% of the world's forested area is now under some form of forest certification (Durst et al., 2006). The area under forest certification has grown steadily and the concept has earned strong support not just from environmental groups, but also non-governmental organizations, and even forest industry/timberland investment groups (Floyd, 2002). Environmental groups have been able to gain considerable power, not from government regulation, but rather from the marketplace (Meidinger et al., 2003). Consumers have not yet fully shown the willingness to pay for an added level of certification. These certification systems can be costly; forest management activities and plans must be changed, special inventories might be needed, and tracking systems could be required (Lachapelle et al., 2003). Production costs can increase by as much as 25% (Viana et al., 1996.). Industrial and investment ownerships comprise most of the certified forests. However, a significant portion is in small ownerships or family forests (Rickenbach, 2002) and these owners are likely to be the focus of growth in certification (Washburn et al., 1999).

3 AMERICAN TREE FARM SYSTEM

University forest and natural resource plans and planning courses have long utilized family forest owner approaches (Straka, 1993). This approach offers an opportunity for the student and the landowner to directly interact. Of the North American forest certification schemes, the ATFS is the only one with a strong family forest focus. If forest certification was to be integrated into a forest resource management plans course, the ATFS would provide the best opportunity for interaction between forest owners and the plan preparers (students).

The ATFS forest certification scheme is based on standards of sustainability (American Tree Farm System, 2011). All forest certification schemes have a similar document that outlines standards of sustainability (Fletcher and Hansen, 1999; Meidinger et al., 2003). The ATFS is recognized by PEFC and its standards are organized in the same manner as other forest certification schemes. Thus, these standards form an excellent basis to introduce forestry students to forest certification standards.

There are eight standards of sustainability (Table 1). Each has performance measures to help the forest auditor evaluate and judge compliance; for greater and more specific guidance, each performance measure has indicators (specific element of the management plan that indicates compliance). In addition, each indicator has detailed guidance on how to evaluate and interpret that aspect of the management plan (American Tree Farm System, 2011). Table 1 illustrates the eight standards, but does not address the performance measures and indicators. For example, Standard 2 provides an opportunity to address the performance measures and indicators. Standard 2 is; “Compliance with Laws.” It has one performance measure: “Forest owner must comply with all relevant federal, state, and local, laws, regulations and ordinances.” This performance measure has two indicators: “forest owner must comply with all relevant laws, regulations, and ordinances and will correct conditions that led to adverse regulatory actions, if any” and “forest owner should obtain advice from appropriate professionals, or contractors who are trained in, and familiar with, relevant law, regulations and ordinances.” These standards, performance measures, and indicators are summarized in the Woodlands Management Template that the ATFS provides for foresters that want to implement an ATFS forest resource management plan (Americana Tree Farm System, 2011). Table 2 summarizes the content of a management plan developed from that template.

Table 1. American Tree Farm System Standards of Sustainability for Forest Certification (American Tree Farm System, 2011).

Standard 1. Commitment to Practicing Sustainable Forestry—Forest owner demonstrates commitment to forest vitality by developing and implementing a sustainable forest management plan.

Standard 2. Compliance with Laws—Forest management activities comply with relevant federal, state, and local laws, regulations, and ordinances.

Standard 3. Reforestation and Afforestation—Forest owner completes timely restocking of desired species of trees on harvested sites and non-stocked areas where tree growing is consistent with land use practices and the forest owner's management objectives.

Standard 4. Air, Water, and Soil Protection—Forest management practices maintain or enhance the environment and ecosystems, including air, water, soil, and site quality.

Standard 5. Fish, Wildlife, and Biodiversity—Forest management activities contribute to the conservation of biodiversity.

Standard 6. Forest Aesthetics—Forest management plans and management activities recognize the value of forest aesthetics.

Standard 7. Protect Special Sites—Special sites are managed in ways that recognize their unique historical, archeological, cultural, geological, biological, or ecological characteristics.

Standard 8. Forest Product Harvests and Other Activities—Forest product harvests and other management activities are conducted in accordance with the management plan and consider other forest values.

Table 2. Forest Resource Management Plan Outline Using the ATFS Template (American Tree Farm System, 2011).

1. Owner name, address, telephone number, and e-mail contact information. Owner signature.

2. Plan author name, address, telephone number, e-mail contact information. Author signature.

3. Date(s) that the plan was competed and revised.

4. Property description.

   a. Location (legal description, tax map number, location map, GPS).

   b. Basic tract information (acres owned, acres forested, acres in plan, owner information).

   c. Topography, slope, roads, watershed.

5. Property history.

6. Forest management objectives and goals.

7. Forest natural resources enhancement and protection.

   a. Protect special sites and social considerations (special sites, adjacent stand or ownership concerns, recreation, and access).

   b. Air, water, and soil protection (soil protection, roads, steams, wetlands ponds, lakeshore, effects of natural disasters, and carbon sequestration (optional)).

   c. Fish, wildlife and biodiversity (Fish and wildlife, threatened or endangered species).

   d. Management of forest resources (protection from pests, reforestation and afforestation, prescribed burns (optional), management plan implementation constraints).

   e. Other.

8. Stand level information

a. Description.

b. Current condition.

c. Desired future stand condition.

d. Forest management activities.

9. Management activity schedule and tracking (management activity by scheduled date, stand, cost, and expected cost-share).
10. Signatures and approvals.
11. Appendix, tax, business.

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4 INTEGRATING FOREST CERTIFICATION INTO A CURRICULUM AND CAPSTONE COURSE

In 2012 Clemson University began to integrate the ATFS sustainability and certification standards into its senior-level forest resource management plans course, using current ATFS tools and procedures. This capstone course puts senior forestry undergraduate students into the real-life management planning process by partnering them with family forest owners. A well-developed forest management plan is the basis for certification in the ATFS and family forest owners are unable to be certified without one. Skills learned in the process of forest management plan development help graduating students to prepare for jobs they may receive after college. This is an attempt to create a situation which incorporates all of the students' previous education and professional experience with the complex issues of the real-world that takes them out of the comforts of a traditional classroom setting.

The design of this capstone course was to have interactive real-world situations with landowners and for students to graduate as Certified Tree Farm Inspectors. The objectives of the course were to give graduating seniors an introduction to the forest resource management planning process, to write a natural resource plan based on various management techniques, to review and implement knowledge acquired from previous coursework in management plan development, to provide students with field practice on a family forest owner's property, to provide students with an interactive and participatory forum for management plan development and completion and to provide students with training and certification as ATFS inspectors.

Students were paired in teams and were allowed the option of working with family forest owners that they knew, or were able to select from family forest owners who were interested in partnering with the University in developing management plans on their property. Students were assigned reading material from the ATFS website (http://www.treefarm system.org) including:

"About Us", "Statistics and FAQ", a YouTube video on the "Goals and Programs of the American Forest Foundation", "About Tree Farming", " What is Tree Farming" and the "Management Plan Template" and "Certification" guidelines. The management plan template designed by the ATFS served as the foundation for the entire course. The professor provided lectures on the basic components of a management plan and obstacles that many professionals face when dealing with landowners while writing their management plan. One of the main objectives was to establish a good working relationship with the landowners in order to understand their short-term and long-term objectives for the land. This is also an area in which many of the students find challenging with this class. Historically, this class just focused on creating management plans for private landowners, but that year the students were asked to add the certification component with ATFS serving as an example. Management plans varied greatly between landowners, region, and personal preferences. All management plans shared several key components including management objectives, stand descriptions and recommendations, management schedule of activities, maps and aerial photographs and budget guidelines (Straka, 1993).

The students contacted their landowners and scheduled on-site visits to review the landowner objectives and evaluated what additional measures would need to be taken to develop the management plan. Students then had to make plans for additional visits to the forest tract to accumulate forest inventory data for analysis. The students were provided with the ATFS management template to use for the project and the main topics from the template were highlighted in Table 2. When completed, each team submitted their plan for review. A formal class was held where commonalities and complications were discussed regarding the finalized management plans.

A scheduled time was then allotted for training provided by the ATFS for the students to become Certified Tree Farm Inspectors upon completion of the training course and graduating with a Society of American Foresters (SAF) accredited forestry degree. Students were led through the requirements of the ATFS and what their roles would be as inspectors. Throughout the presentation, the management plans developed by the students were interwoven to provide examples and lead a more interactive and participatory discussion. Qualified ATFS training instructors presented the formal four hour training session and the inspection instructor provided feedback to each of the students. This was the first time ATFS and Clemson University have collaborated to integrate certification and inspection into the classroom environment.

5 OBJECTIVE OF THE STUDY

The objective of this study was to evaluate the forty-five Society of American Foresters (SAF) accredited forest resource management programs and ten non-accredited natural resource management programs to determine if these programs taught forest resource management planning as the capstone course or as a stand-alone course within the required forestry curriculum. A second important aspect of the study was to determine how forest management planning was taught in the courses and if the students were required to write a forest resource management plan. The results of this study would reveal the point in the curriculum where management planning was taught, how management planning courses have changed over time due to changing requirements in forest certification, and the likelihood of the program to adopt the American Tree Farm System's management template for teaching management planning to students.

6 METHODS

The study used standard survey techniques to conduct two individual surveys. The first survey evaluated the curriculum and course descriptions of the SAF accredited forestry programs and selected natural resources programs from the National Association of University Forest Resources Programs (NAUFRP) members list. These natural resource programs included: Alcorn State University, Cornell University, Delaware State University, Abraham-Baldwin Agricultural College and the Universities of Connecticut, Hawaii, Nevada, Rhode Island, Washington and Vermont. All accredited and non-accredited programs evaluated offer a four-year forest resource management degree or a Bachelor of Science degree in natural resources with an emphasis in forestry.

The first survey evaluated program curricula and determined if forest resource management planning was taught as a capstone course or as a stand-alone course at some other point in the curriculum. The capstone course designation was determined by reviewing the course title and description. If the course title or description included the words "capstone" then that it was designated as a capstone course. This goal was accomplished by reading the curriculum outline for each program and determining at what point management planning was taught. After determination of when the course was taught, it was then necessary to read the course description to determine how the course was taught and if the students were required to develop a written management plan as part of that course. The curriculum outlines and course descriptions for each school were found at each program's webpage. Results were recorded for the fifty-five evaluated programs after determining whether management planning was taught as a capstone course or not and if the students were required to write a management plan in the management plans course, no matter if it was a capstone course or a stand-alone course within the curriculum.

A second survey was developed to provide feedback regarding changes that are taking place and planned regarding how and why forest resource management plans are written. This short survey was sent to forestry professors of the forty-five SAF accredited programs who teach the management plans courses at universities throughout the country. The survey questions involved changes or updates that have taken place in management plans courses due to changing requirements and the increased popularity of certification and sustainability programs. The survey also asked if the forestry program would be likely to adopt the American Tree Farm System's standards and management plan template as tools for engaging students in management plan writing. The survey of professors was conducted via email and the results were tabulated as responses were received. Nearly half of the forty-five SAF accredited forestry programs provided data in the second survey.

7 RESULTS AND DISCUSSION

The survey results showed how forest resource management programs integrate management planning into their curricula and provide insights regarding when the planning course was being taught in the curriculum, if it was taught as a capstone course, and what changes have been made to these courses to reflect changes in forest management issues and forest certification.

The first portion of the study determined the point in the curriculum where forest resource management planning was taught. Figure 1 shows the percentage of curricula that specifically have a forest management plans course and those that teach it as a capstone course or stand-alone course. The sample size for this survey was the forty-five accredited forestry programs and the ten other natural resource management programs chosen from the National Association of University Forest Resources Programs (NAUFRP) members list. The highest percentage, forty-seven percent, represents the programs that teach management planning as a stand-alone course within the curriculum. This stand-alone course was found to be taught mostly to junior or senior level students and was frequently titled “Forest Management Planning” or “Forest Resource Decision-Making.” Capstone courses represent the second highest percentage at twenty-nine percent. The programs that offered management planning and plan development as the capstone course required the students to utilize all of the forestry skills they have learned to develop a workable forest resource management plan. The lowest percentage of programs, at twenty-four percent, were those that showed no evidence of teaching management planning or requiring a written resource management plan in any of the forestry courses within the curriculum. These programs may integrate the planning process into other courses, but do not provide information about learning objectives based on management planning in their curriculum outline or course descriptions.

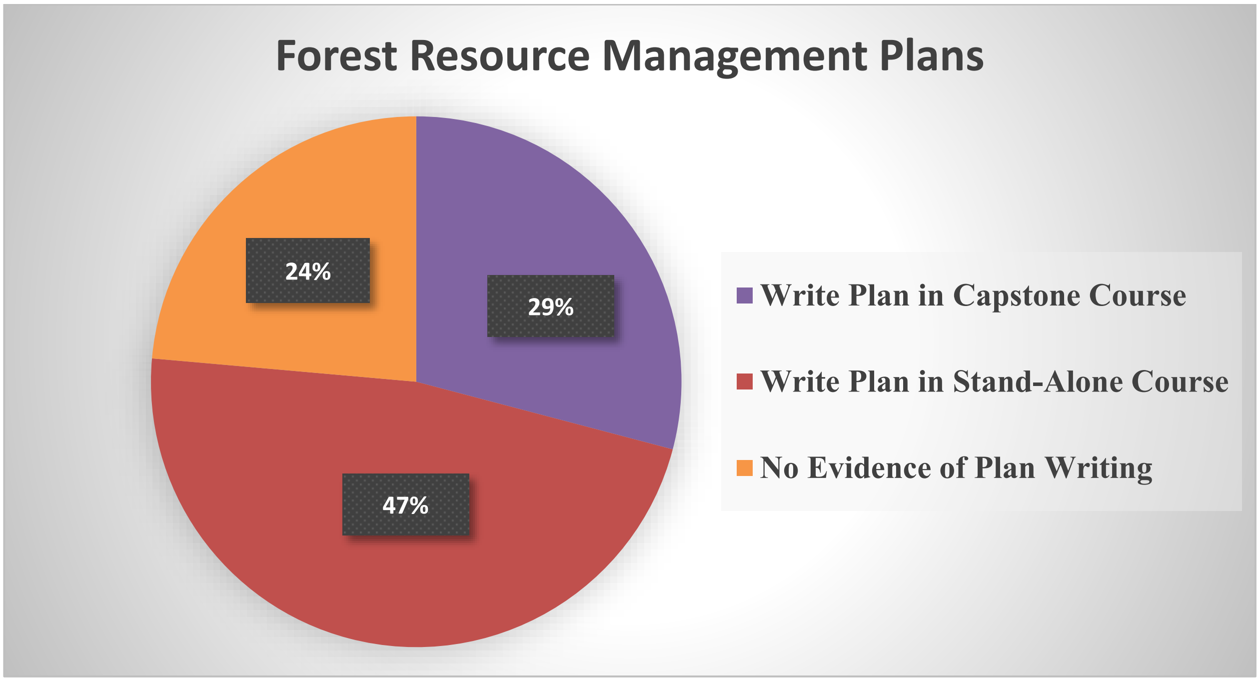

Figure 1: Percentage of surveyed programs that write management plans in a capstone course, a stand-alone course within the curriculum, and ones provide no evidence of plan writing in their curriculum or course descriptions.

The second portion of the study determined if any changes were made or planned in the management planning courses taught by the accredited forestry programs (Figure 2). The questions were asked on a basis of the prior five years when evaluating recent changes or possible upcoming changes to these courses that reflect sustainable forest management issues. Nearly half of the accredited programs responded to this survey (twenty-two respondents). Eight respondents were from the northern region of the United States, nine from the southern region and five were from the western region. The fairly equal regional distribution of the respondents minimized any bias in the survey that may have occurred due to location.

The survey addressed if there had been changes made over the past five years or if there was anticipation of change in the next five years that reflect changing requirements in a management plans course. About sixty-eight percent of the programs have made changes to the planning course that they offer. Out of the programs that said they have not made any changes or updates, over half said they do anticipate change within five years.

The third question on the email survey asked if issues involving sustainable forest management was a major driver for changes/updates to these planning courses. For those that answered that changes/updates have been made or anticipate changes in the future, about two-

Summary of Email Survey Results

n = 22

1. Has the content of your forest resource management planning course been changed and/or updated to reflect changing requirements within the last five years?

15 – Yes

7 - No

2. If not, do you anticipate changes within the next five years?

4 - Yes

3 - No

3. Would it be fair to say sustainable forest management issues were a cause for change or cause for anticipating change? If yes, the major reason, or one of many reasons.

13 – Major reason for change

6 – One of many reasons for change

4. Describing the Tree Farm Management Template and related Power Point slide show, how likely would your program be to adopt at least some of the framework for your management plans course?

5 – Definitely

9 – Likely

4 – Perhaps

4 – Not Likely

Figure 2: Summary results of email survey that was sent to the accredited programs including the four questions concerning changes in management plans courses and the number of responses received for each answer.

thirds stated that issues involving sustainable forest management were a major driver for the changes. The other one-third stated that issues involving sustainable forest management was one of many reasons for changes/updates to their management plans course.

Lastly, the final question was used to evaluate the possibility of adoption of at least some portion of the American Tree Farm System (ATFS) management plan template and related PowerPoint slides to enhance their management plans course. This question was answered using a Likert-type scale with four different response options ranging from "definitely" to "not likely." The results from this question showed that about sixty-four percent of the programs showed considerable interest in adopting a portion of the template and related slides by answering "definitely" or "likely." The other thirty-six percent of programs were not likely to incorporate the ATFS material into the course. Therefore, the majority of the accredited forestry programs would consider adoption of the ATFS management plan template and/or the related slides that were developed for teaching a management plans course.

8 CONCLUSIONS

As forest resource management has changed over time, the processes and techniques of writing a management plan have also changed. The owners of forested lands are no longer large industry-driven companies, but small private land owners who own what we call "family forest lands." Not only has land ownership changed, but the values of those who own the land have also changed. Land owners and managers have started managing land for other reasons such as aesthetics, water quality, wildlife habitat, and recreation, not just for timber and the revenues that can be gained from timber production. The new mindset on becoming sustainable and "green" has also played an important part in the way our forest lands are currently managed.

With the changes in land ownership and the values by which lands are being managed, there must be a change in how a forester is trained through education to encompass all of the aspects that are now relevant to the profession. Sustainable forest management has moved to the forefront of forestry education and this has been proven by this study on how forest resource management plans courses are taught at the university level. This includes what frameworks are being utilized to teach the courses and also how the courses are being updated to keep up with the current issues.

This study on forestry resource management programs and their management planning courses revealed that teaching management plan writing as a capstone course is not necessarily the current norm. The study did reveal that over seventy-five percent of the programs surveyed were teaching management planning at some point in their forestry or natural resources curriculum. Based on the results of the questionnaire, many forestry programs were making changes to how they teach management planning to maintain touch with the rapidly changing sustainability and certification issues. Due to the issues that deal with forest sustainability and certification it may be necessary to adapt by implementing new techniques into the way management planning is taught to students.

As issues arise that may shape the way forest resource management plans are written, the framework from which the plan is developed is very important. The framework is important because it must allow the plan to be written to include all aspects and values of forest resources and fit within the guidelines of certification organizations. One way to ensure all aspects are covered is to adopt a management plan template or framework such as the one the ATFS provides. Clemson University is using the ATFS template to integrate forest sustainability and certification requirements into its management planning capstone course. Using the ATFS template and related PowerPoint slides has proven to be an effective way to teach students management planning and engage them in real-world issues that forest landowners deal with when managing their lands. The forestry programs evaluated have shown a considerable interest in adopting a portion or all of the ATFS framework and teaching tools that Clemson uses, which would help these programs make the necessary changes in their management planning courses. These changes related to forest sustainability and certification are an integral part of a forester's education and training today.

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EVALUATING FACTORS INFLUENCING CARBON DIOXIDE SEQUESTRATION FROM LANU USE, LAND-USE CHANGE, AND FOREST ACTIVITIES IN U.S.

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ABSTRACT

More than 15 years after the Kyoto protocol convention, greenhouse gas (GHG) emissions continue to be a global concern as more research and evidence point to emissions of GHG as the major driver of global warming (e.g., Bonan 2008; Keith et al. 2005; Lashof and Ahuja 1990). Carbon dioxide (CO_2) is the primary GHG compared to other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) due to human activities (e.g., transportation, especially fossil fuel combustion and electricity) (EPA 2014). Additionally, CO_2, which is stored by trees and other plants, has been monitored in the U.S. since 1990. Between 1990 and 2012, CO_2 sequestration increased by about 18% from land use, land-use change, and forestry (EPA 2014), but little is known about the primary economic and demographic factors affecting CO_2 sinks from land use, land-use change, and forestry. Therefore, the objectives of this research are to identify and monitor the amount of global and U.S. CO_2 sinks; identify the factors influencing carbon dioxide (CO_2) sequestration associated with land use, land-use change, and forest activities in U.S.; summarize the major causes of emissions; and assess methods to mitigate carbon dioxide (CO_2) emissions from land use, land-use change, and forest activities.

Keywords: greenhouse gases; carbon dioxide; land use, land-use change, forestry; tobit

1 INTRODUCTION

Greenhouse gases (GHG) are gases that absorb and emit radiation within the range of thermal infrared radiation (IPCC 2007). The major sources of greenhouse contributors are water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Ozone (O_3), chlorofluorocarbon (CFCs), and halons (Baede, Linden, and Verbruggen 2004; Wuebbles 1995).

The existence of GHG effect was first described by Joseph Fourier, Claude Pouillet, John Tyndall, and Svante Arrhennius in 1824, 1827, 1859, and 1896, respectively (Issac and Soden 2000; Tyndall 1873). In December 1997, the GHG emissions were mentioned in the Kyoto Protocol Conference in which proposals were offered to limit the amount of GHG emissions by the partners (UNFCCC 1997). *The United Nations Framework Convention on Climate Change (UNFCCC)* reported that 84 of 192 countries had signed the treaty by March 1999. The United States (U.S.) signed to be a member of the Kyoto Protocol but it did not ratify the agreement. The three major GHG emitters of the world in 2012 were China, the United States, and India, respectively.

The U.S. was the second emitter of annual CO_2 emissions estimates in 2012 (CDIAC), emitting approximately 5.190 billion tonnes (EDGAR 2013). The main sources of GHG emissions in the U.S. are electricity generation (33%), transportation (28%), industrial production (20%), commercial and residential use (11%), and agricultural (8%) (EPA 2012). Carbon dioxide was the primary source of GHG emissions. The inventory of U.S. greenhouse gas emissions and sinks between 1990 and 2011 reported by EPA (2012) included CO_2 (84%), CH_4 (9%), N_2O (5%), and fluorinated gases (2%) (Figure 1).

The primary U.S. GHG released from land use, land-use change, and forestry (LULUCF) was CO_2 (EPA 2014). Approximately 18% of U.S. CO_2 sequestration was associated with LULUCF (EPA 2014, IPCC 2007). That is, CO_2 emissions from land use and land-use change can be reduced by minimizing land disturbance by such methods as no-till agriculture (West and Marland 2002; EPA 2014).

1.1 Carbon dioxide (CO_2)

Carbon dioxide is a chemical compound composed of a single carbon atom covalently bonded to two oxygen atoms. It is a colorless and odorless gas in the Earth's atmosphere. In the seventeenth century, Jan Baptist van Helmont found the ash from burning charcoal and he was the first person to use the term "gas" for this process (Ebbe 2003). Subsequently, carbon dioxide (CO_2) was studied by Joseph Black and Joseph Priestley (Priestley and Hey 1772), and in 1823, Humphry Davy and Michael Faraday reported the production of liquefied CO_2 (Davy 1823). Thilorier (1835) also found that the cooling known as a "snow" of solid could be produced by the rapid evaporation of the liquid.

The carbon cycle refers to the natural circulation of carbon among the atmosphere, oceans, plants, soil, animals, and man-made activities (NRC 2010). The combustion of fossil fuels (coal, natural gas, oil) for energy, transportation, and industry is the primary source of U.S. and global CO_2 emissions. In 2011, 38%, 31%, 14%, 10%, and 6% were from electricity, transportation, industry, residential and commercial building, and other fuel combustion, respectively shown in Figure 2 (EPA 2014).

Since 1990, the management of forests and non-agricultural land in the U.S. stored more CO_2 in plants, trees, and below-ground than was emitted into the atmosphere (EPA 2014). Examples of CO_2 reduction strategies include reducing energy consumption (e.g., using more fuel-efficient vehicles and electrical appliances; turning off lights and electronics) and using renewable energy (e.g., biofuels) (EPA 2014).

2.1 Methane (CH_4)

Methane is the second most prevalent greenhouse gas, accounting for approximately 9% from human activities in the U.S. in 2011. In addition, U.S. methane is emitted from natural gas and petroleum systems (30%), enteric fermentation (23%), landfills (17%), coal mining (11%), manure management (9%), wastewater treatment (3%), and other sources (7%), as reported by the inventory of U.S. greenhouse gas emissions and sinks: 1990-2011. CH_4 in the U.S. decreased by 8% from the exploration and production of natural gas and petroleum productions between 1990 and 2011. The EPA has proposed several ways to reduce CH_4 emission such as upgrading the equipment from the processes of production, storage, and transportation and altering manure and landfill management (EPA 2014).

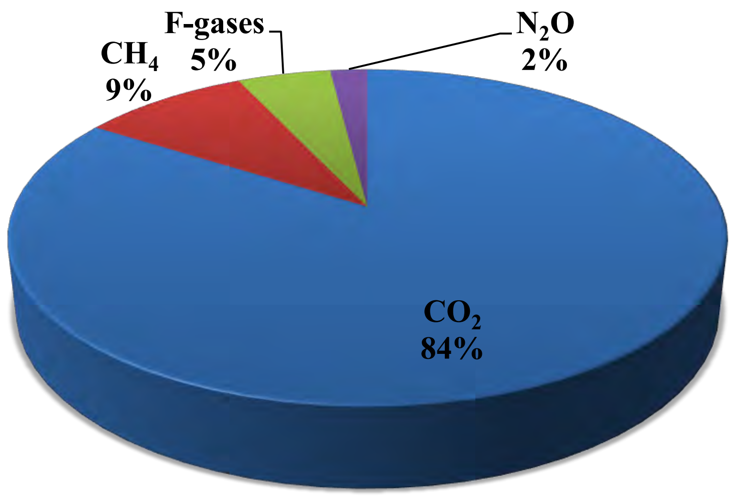

Figure 1: U.S. Greenhouse Gas Emissions by Gas (Source: IPCC 2007)

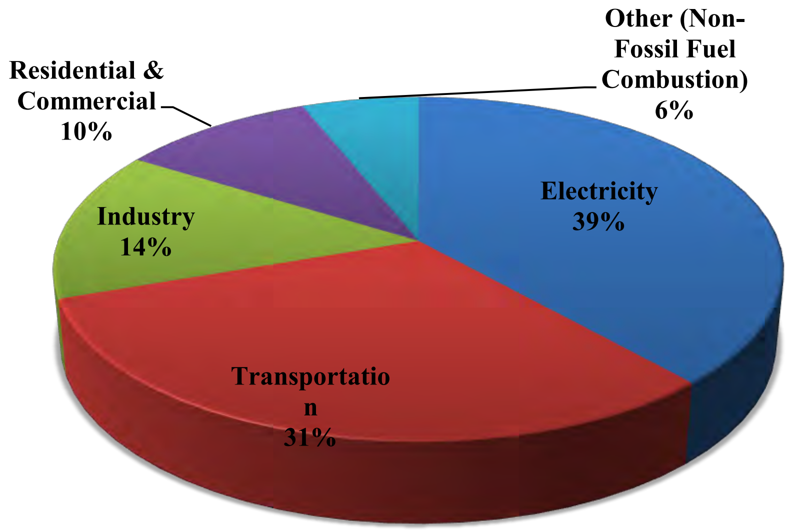

Figure 2: U.S. Greenhouse Gas Emissions by Source (Source: EPA 2014)

1.3 Nitrous Oxide (N_2O)

Nitrous oxide is one of the most important GHG in the U.S., with 40% of N_2O emitted by human activities (e.g., agricultural production, fossil fuel combustion, wastewater management, and industrial processes) (EPA 2010). From 1990 to 2011, N_2O emissions decreased by 4% because of variation of agricultural soils. N_2O emissions can be reduced most readily by decreasing nitrogen-based fertilizer applications, consuming fuel more efficiently, and improving industrial production (EPA 2005; 2014).

1.4 Trends of Carbon Dioxide Emission

Data from the World Bank (2010) indicate that global carbon dioxide emissions increased from 1990 to 2008 as shown in Figure 3, with the main source being fossil fuel combustion. Total carbon dioxide emissions were estimated at 122,259.90 tg CO_2 eq. in 1990 and increased to 203,071.24 tg CO_2 eq. by 2008, an increase of approximately 82,000 tg CO_2 eq.

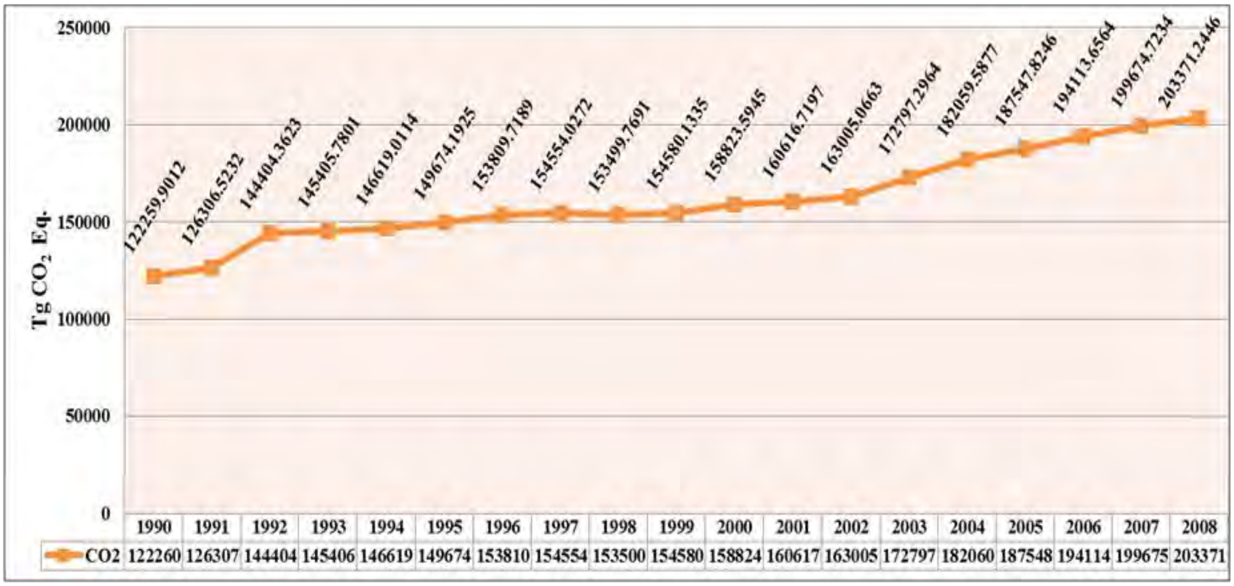

Figure 3: Trends of Global Carbon Dioxide Emissions (Source: The World Bank)

Additionally, Figure 4 presents trends of U.S. CO_2 emissions between 1990 and 2011. In 2007, carbon dioxide emissions totaled 7263 tetra carbon dioxide equivalents - the largest amount recorded - and then dropped by almost 480 tetra carbon dioxide equivalents by 2009. Figure 5 depicts U.S. CO_2 emissions from land use, land-use change, and forest activities (EPA 2014). In 2012, 15.1 % of total U.S. CO_2 emissions came from land use, land-use change, and forest activities such as land converted to cropland and grassland remaining grassland. The net carbon sequestration from forest land remaining forest land, cropland remaining cropland, land converted to grassland, settlements remaining settlements, and landfilled yard trimmings and food scraps increased by approximately 17.7% between 1990 and 2012. The main sources of CO_2 from land use were due to cropland (e.g., liming and fertilization of agricultural soils), wetlands, and peatlands (EPA 2014).

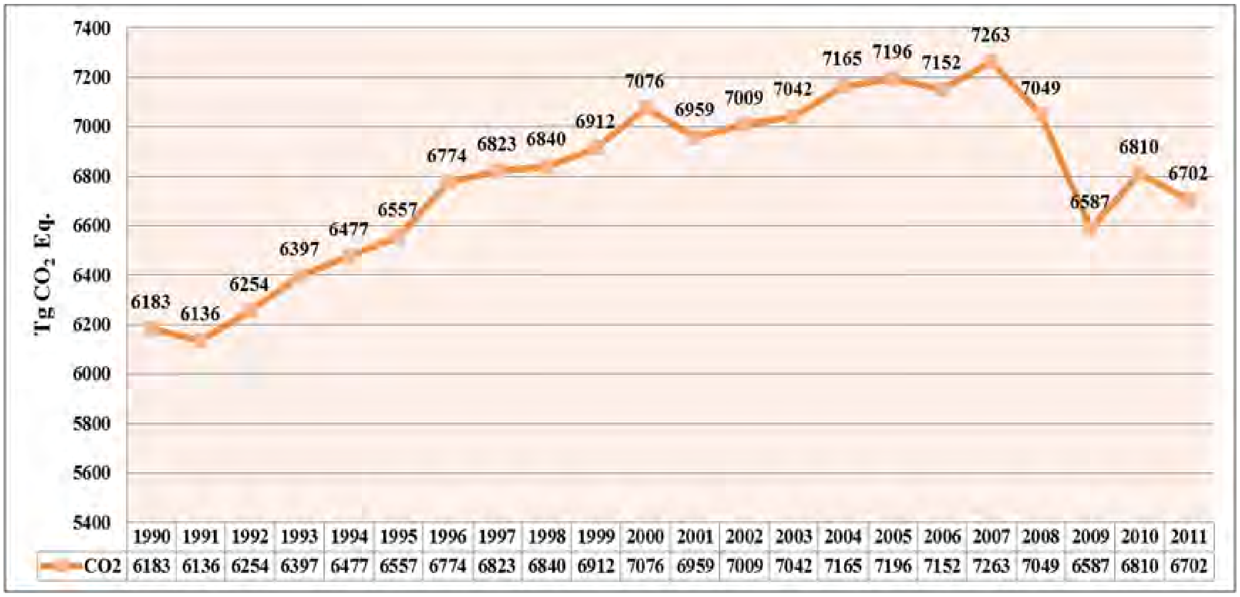

Figure 4: Trends of U.S. Carbon Dioxide Emission by EPA (2014).

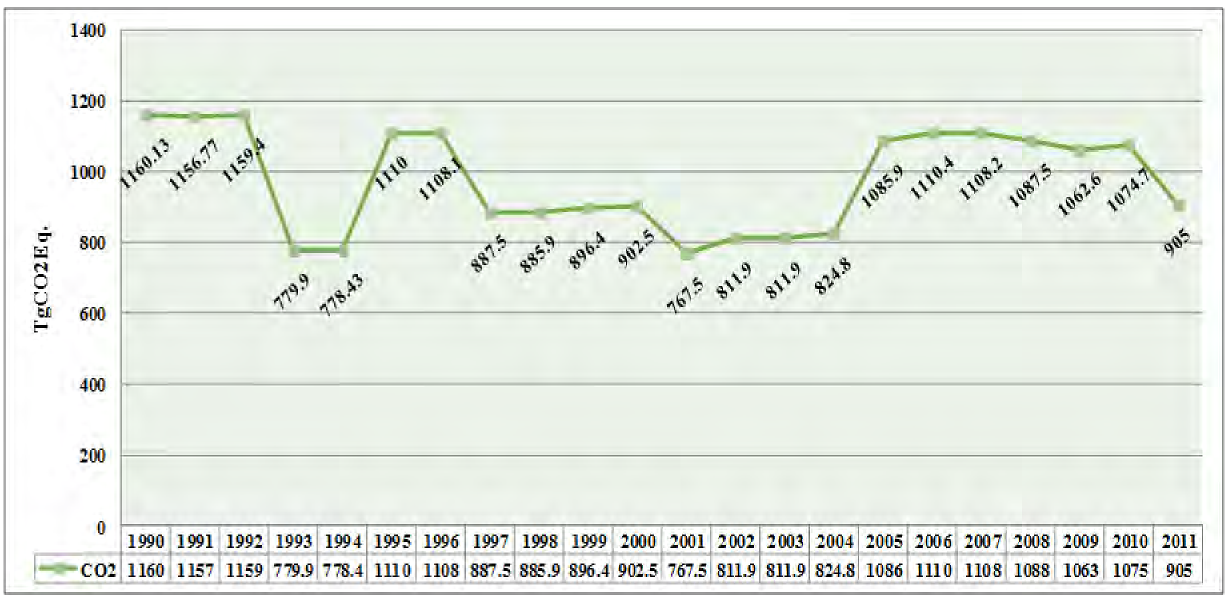

Figure 5: U.S. Carbon Dioxide Emission from Land Use, Land-Use Change, and Forest Activities between 1990 and 2011.

1.5 Research Objectives

The objectives of this research are to identify and monitor the amount of global and U.S. carbon dioxide (CO_2) emissions; identify the factors influencing carbon dioxide (CO_2) emissions from land use, land-use change, and forest activities in the U.S.; summarize the major causes of emissions; and assess methods to mitigate carbon dioxide (CO_2) emissions from land use, land-use change, and forest activities.

2 METHODS

2.1 Data

All data were obtained from The World Bank, National Oceanic & Atmospheric Administration (NOAA), United Nations Food and Agriculture Organization (FAOSTAT), and U.S. Environmental Protection Agency (EPA) for the period of 1990 to 2011. This research uses the amount of carbon dioxide (CO_2) sequestration due to from land use, land-use change, and forestry activities as the dependent variable and factors influencing CO_2 sinks as independent variables.

2.2 Methods and Procedures

A tobit model was specified for the amount of CO_2 from 1990 and 2011 (Greene 2012):

$$\mathrm{CARBON}_i^* = \beta_k' x_i + \varepsilon_i, \varepsilon_i \sim N(0, \sigma^2), \quad (1)$$

where β_k' is a vector of unknown parameters, x_i is a vector of factors that affect CARBON_i^*, ε_i is an error vector, and the distribution of CARBON_i^*, given x_i, is $\mathrm{CARBON}_i^* | x_i \sim N(\beta x_i, \sigma^2)$.

The observed value of CARBON_i is:

$$\mathrm{CARBON}_i = \begin{cases} \mathrm{CARBON}_i^* & \text{if } \mathrm{CARBON}_i^* > 0 \\ 0 & \text{if } \mathrm{CARBON}_i^* \leq 0. \end{cases} \quad (2)$$

If $\mathrm{CARBON}_i > 0$ (uncensored observation), but if $\mathrm{CARBON}_i = 0$ (censored observation). The marginal effect with censoring at zero on the expected value of CARBON_i^* for is:

$$\partial E[\mathrm{CARBON}_i^* | x_i, \mathrm{CARBON}_i > 0] / \partial x_i = \beta_k \Phi\left(\frac{\beta' x_i}{\sigma}\right), \quad (3)$$

where β_k are k = 0,…, m parameters to be estimated using maximum likelihood and Φis the standard normal distribution function.

Maximum-likelihood methods are used to estimate the vector of β that maximize the log-likelihood function for carbon sinks (Greene 2012):

$$\ln L = \sum_{\{i|\mathrm{CARBON}_i > 0\}} \ln\left[\sigma_i^{-1} \phi\left(\frac{\mathrm{CARBON}_i^* - x_i' \beta_k}{\sigma_i}\right)\right] + \sum_{\{i|\mathrm{CARBON}_i = 0\}} \ln\left[1 - \Phi\left(\frac{\mathrm{CARBON}_i^* - x_i' \beta_k}{\sigma_i}\right)\right]. \quad (4)$$

2.3 Empirical Model

The following model was specified to determine the factors influencing carbon sinks between 1990 and 2011:

$$\mathrm{CARBON}_i = \beta_0 + \beta_1 \mathrm{CROPIND}_i + \beta_2 \mathrm{EMPLOY}_i + \beta_3 \mathrm{EDUCAT}_i + \beta_4 \mathrm{INFLAT}_i + \beta_5 \mathrm{LEND}_i + \beta_6 \mathrm{GDPG}_i + \beta_7 \mathrm{POPGR}_i + \beta_8 \mathrm{PRODUCT}_i \quad (5)$$

$$+ \beta_9 \text{TEMPE}_i + \beta_{10} \text{RAIN}_i + \varepsilon_i,$$

where the variable definitions, hypotheses and means are given in Table 1. Table 1 includes the hypothesized signs of the explanatory variables in Equation (5). A positive/negative hypothesized sign indicates that an increase/decrease in the explanatory variable is expected to affect carbon sequestration from land use, land-use change, and forest activities.

2.4 Multicollinearity Diagnostics

Farrar and Glauber (1967) mentioned that interdependency among independent variables is evaluated. Standard errors might be biased and harm the coefficients of estimators, if two or more independent variables are highly correlated, standard errors might be biased and harm the estimated coefficients and inferences (Mansfield and Helms 1982). Variance inflation factors (VIF) are applied to diagnose collinearity among independent variables. The variance inflation factors are calculated by Equation (6) (Afifi and Clark 1984; Fox 1984),

$$\text{VIF} = \frac{1}{1-\text{R}^2}, \tag{6}$$

where R^2 is the coefficient of determination of a regression of an independent variable on all the other independent variables (Nagelkerke 1991). AVIF value greater than 10 indicates that multicollinearity may exist among independent variables (Neter, Wasserman, and Kutner 1985).

Table 1. Definitions and Hypothesized Signs for Dependent and Explanatory Variables Used in Tobit Regressions.

Variable[1]	Definition	Sign
Dependent Variables		
CARBON	Amount of carbon sinked from land use, land-use change, and forest activities (Tg CO_2 eq.)	N/A
Explanatory Variables		
CROPIND	Crop production index shows agricultural production for each year relative to the base period 2004-2006 including all crops except fodder crops	–
EMPLOY	Employees are people who work for a public or private employer and receive remuneration in wages, salary, commission, tips, piece rates, or pay in kind.	–
EDUCAT	School enrollment, tertiary (% gross)	+
INFLAT	The annual percentage change in the cost to the average consumer of acquiring goods and services	–
LEND	The bank rate that usually meets the short and medium-term financing needs of the private sector	–
GDPG	Annual percentage growth rate of GDP at market prices based on constant local currency	–
POPGR	Population growth (annual %) is the exponential rate of growth of midyear population from year t-1 to t	–
PRODUCT	All forest products (tonnes)	–
TEMPE	Average annual temperature in all states (°F)	–
RAIN	Average precipitation (millimeters, mm)	–

[1]All data were collected from 1990 to 2011.
Source: The World Bank, National Oceanic & Atmospheric Administration (NOAA), United States Environmental Protection Agency (EPA) and United Nations Food and Agriculture Organization (FAOSTAT).

2.5 Heteroskedasticity

If heteroskedasticity exists, the maximum likelihood estimators will be inconsistent (Maddala and Nelson 1975; Hurd 1979; Arabmazar and Schmidt 1982a,b; and Brown and Moffitt 1982). Peterson and Waldman (1981) recommended checking for a heteroskedatic tobit model using a Lagrange multiplier (LM) test:

$$\mathrm{LM} = \mathrm{n}\mathrm{R}^2 \tag{7}$$

The null hypothesis of homoscedasticity is $\alpha = 0$. If the LM value of the model exceeds the critical value of LM, the null hypothesis is rejected (Greene 2012).

3 RESULTS & DISCUSSION

3.1 Multicollinearity Diagnostics

Multicollinearity results for carbon sinks are presented in Table 2. Results show a mean VIF value of 3.72 and a maximum VIF among the independent variables of 6.72 for forest products. Therefore, it was determined that collinearity among the independent variables was unlikely to affect the estimated coefficients or affect inferences drawn from test using the standard errors.

Table 2. Multicollinearity Diagnostics

Variables	VIF
CROPIND	4.53
EMPLOY	3.88
EDUCAT	4.04
INFLAT	2.85
LEND	4.13
GDPG	2.16
POPGR	5.46
PRODUCT	6.27
TEMPE	2.38
RAIN	1.47
Mean VIF	3.27

3.2 Lagrange multiplier (LM)

The value of LM test from tobit regression was 1.54. The test failed to reject the null hypothesis ($\alpha = 0$), so no heteroskedasticity existed.

3.3 Tobit Regression

Mean, standard deviation, and minimum and maximum values for all variables are shown in Table 3. Results suggest that crop production index, the percent gross of school enrollment in tertiary, annual inflation, interest rates, and average annual temperature had a significant and positive effect on carbon sequestration, but the annual percentage growth rate of GDP was negatively associated with carbon sinks (Table 4).

When the crop production index increased by one unit, carbon sequestration increased by 6.57 tg CO_2 eq. This may be due to no-tillage operations increasing for the major U.S. crops (corn, cotton, soybean, rice, wheat, sorghum, oats, barley) between 2000 and 2007. Since the 1980s no-till has been encouraged across the U.S.; the Department of Agriculture reported that the rate of no-till farming is increasing by 1.5 percent per year. In addition, the United Nations Environment Program (UNEP 2014) estimated that no-tillage operations have helped the U.S. avoid CO_2 emissions of about 241 million metric tons (883.67 tg CO_2 eq) since the 1970s.

School enrollment at the tertiary level was another factor influencing carbon sequestration. A one percent increase in tertiary school enrollment increased carbon sequestration by 23.84 tg CO_2 eq. More of the population with higher education might allow for a greater understanding of the complex issue of climate change in general, and related to land use, land-use change, and forestry. That is, more educated people might gain more information and be more conscious of forest conservation.

If the annual percentage change in inflation increased 1 percent, the amount of carbon sequestration increased by approximately 51.41 tg CO_2 eq. Carbon sequestration my be positively related to inflation because rising inflation decreases purchasing power for consumers – reducing the demand for all products.

The amount of carbon sequestration approximately increased about 49.33 tg CO_2 eq when the bank rate was increased by one unit. Similar to inflation, rising loan rates signal an increased cost of doing business, thereby reducing borrowing and, subsequently production. Therefore, land use, land-use change, and forestry are not affected by industrial growth.

Annual growth in GDP and the amount of carbon sinks were negatively related. When the annual percentage growth rate of GDP increased by one percent, carbon sinks decreased by 38.74 tg CO_2 eq. GDP reflects economic growth and when the economy grows, more goods and services are produced to support the demand, thereby increasing demand for agricultural and forest products, as well as increasing the demand for land for non-forest uses.

Finally, if the annual average temperature increased by one unit per year, carbon sequestration increased by 62.41 tg CO_2 eq. Friend (2014) noted that if the temperature rises by 4 degrees, CO_2 will be released rapidly back into the atmosphere from oxidation. But in the data of this research the annual temperature did not increase, so this might be a reason why carbon sinks and annual average temperature were in the same direction.

Table 3. Mean, Standard Deviation, Minimum and Maximum Value for All Variables.

Variable[1]	Mean	Std.Dev.	Min	Max
CARBON	984.15	150.28	767.50	1160.13
CROPIND	92.26	9.45	74.20	105.6
EMPLOY	2.50	0.61	1.00	3.00
EDUCAT	78.05	6.46	67.85	93.29
INFLAT	2.75	1.17	-0.40	5.40
LEND	6.72	2.04	3.25	10.01
GDPG	2.43	1.86	−2.80	4.80
POPGR	1.07	0.17	0.80	1.40
PRODUCT	$3.23e^{+08}$	$4.12e^{+07}$	$2.5e^{+08}$	$3.7e^{+08}$
TEMPE	53.11	0.77	51.27	54.32
RAIN	30.53	1.63	27.73	32.97

[1]Variables are defined in Table 1.
[2]Marginal effects.
[3]Standard Errors.
*, **, *** Significant at the 0.1, 0.05 and 0.01 probability levels, respectively.

Table 4. Significant Marginal Effects of the Explanatory Variable from the Tobit Regression for Carbon Dioxide Emissions from Forest Conversion in U.S.

Variable[1]	M. E.[2]	Std.Err.	P-Value
CROPIND	6.57	3.95	0.096*
EMPLOY	81.90	56.90	0.15
EDUCAT	23.84	5.46	0.000***
INFLAT	51.41	25.34	0.042**
LEND	49.33	17.44	0.005***
GDPG	−38.74	13.84	0.005***
POPGR	356.26	0.00	0.842
PRODUCT	$-2.12e^{-07}$	0.00000	0.319
TEMPE	62.41	35.06	0.075*
RAIN	7.10	13.01	0.585

[1] Variables are defined in Table 1.
[2] Marginal effects.
[3] Standard Errors.
*, **, *** Significant at the 0.1, 0.05 and 0.01 probability levels, respectively.

4 CONCLUSIONS

Land use, land-use change, and forest activities are one of the most important sinks for CO_2. Approximately 18% of net CO_2 sequestration was due to land use, land-use change, and forest activities between 1990 and 2012. The reason for the net CO_2 increase might be from maintaining forestland and cropland, land converted to grassland, and landfilled yard trimmings and food scraps (EPA 2014). West and Marland (2002) reported that three sources of CO_2 emissions were the use of machinery for cultivating lands, fertilizer and pesticide production and application, and soil disturbance. Therefore, methods to increase CO_2 sequestration from land use, land-use change, and forest activities include reducing deforestation, crop inputs and soil disturbance.

The results reveal that crop production, higher education, inflation, interest rates, and average annual temperature were factors influencing carbon sequestration. Conversely, the annual percentage growth rate of GDP is negatively related to carbon sequestration. The results provide decision makers with some indication of how economic variable can affect carbon sequestration and net emissions. Moreover, they point to some future research questions related to economic and social factors influencing carbon dioxide emissions, the need to improve forest management, and the importance of NGOs and individuals educating the public about the role of land use, land-use change, and forest activities in carbon dioxide emission levels.

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THE CONCEPTUAL DISCUSSION OF ECONOMICALLY MARGINAL LANDS FOR PLANTING ENERGY CROPS

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ABSTRACT

A major critique of large scale biomass production is competition for land between food and energy crops. A commonly suggested solution is to limit energy crops production to marginal lands. Physical marginality (soil quality, slope and location) is often used when discussing marginal lands. However, as important is the economic marginality. This paper will first identify economically marginal lands by comparing break-even prices for energy crops and food crops and then turn to assess farmers' willingness to plant energy crops on economically marginal lands by using discrete choice model. By combining economical margin with biophysical margin, we can provide a comprehensive map of marginal lands for food crops, and in so doing identify lands targeted for energy crops.

Keywords: Marginal lands, Bioenergy crops, Break-even price

1 INTRODUCTION

Increasing demand for bioenergy has fueled the research for the sustainable bioenergy feedstocks. Led by switchgrass (*Pancium virgatum*), miscanthus (*Miscanthus x giganteus*) and willow (*Salix spp*), energy crops are currently at the center of considerable attentions and researches by taking advantages of fast growing, high yield and creating environmental benefits (Perlack & Stokes, 2011). Nevertheless, a commercial plantation of energy crops will intensify land competition with food crops (Field, Campbell, & Lobell, 2008)and place greater cost burden on farmers (Duffy & Nanhou, 2001; Volk et al., 2006).

A commonly suggested solution to these two problems is to limit the plantations to marginal lands (Bryngelsson & Lindgren, 2013), while the concept of marginal lands is not well addressed. Marginal lands are intuitively regarded as the lands with barren soil. Soil quality of marginal lands such as soil texture, soil drainage, have been deeply examined by the previous studies (Kang et al., 2013). Other biophysical factors, such as land cover, terrain and climate, also appear in different studies to define marginal lands. However, biophysical factors can only partially interpret the word "marginal". The all-sided assessment for the marginal lands should be conducted based on the method presented in figure 1:

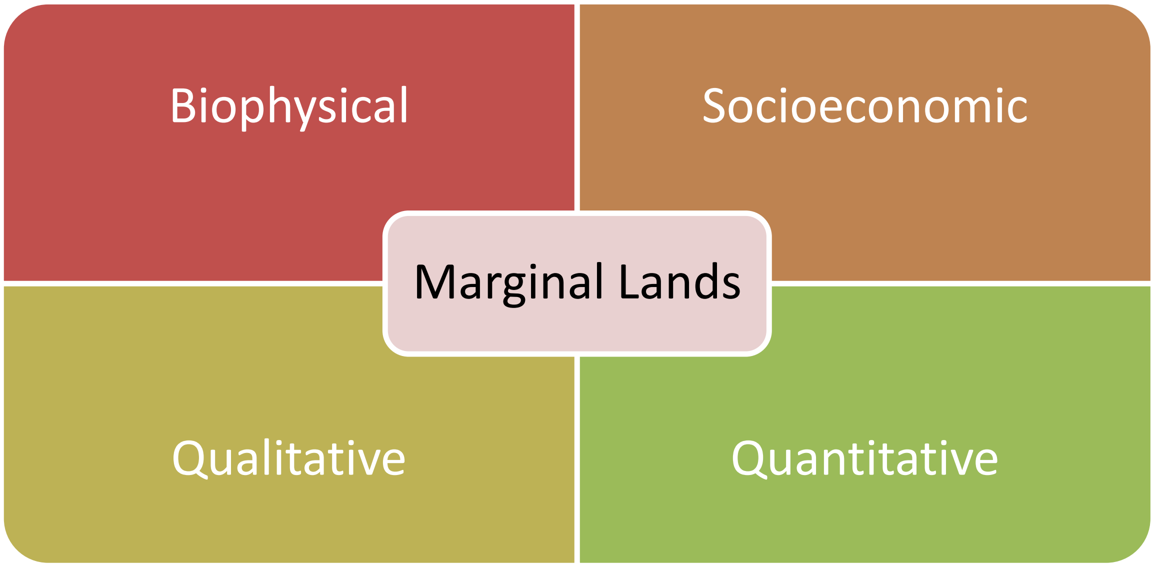

Figure1: Sustainable framework for marginal lands

This figure implies a sustainable and comprehensive view on defining marginal lands. The sustainable assessment for marginal lands will expand the research scope by involving socioeconomic factors, which means it will examine the human role in defining and utilizing marginal lands. Profit, cost, price are the socioeconomic factors contributing to the word "marginal" and, thus, need more attentions. The combined qualitative and quantitative analysis describes the feature of research method for marginal lands. The qualitative analysis aims to do a completed, detailed description. It hints that this analysis usually focus on the small but representative samples that contain rich information. On the other hand, the goal of quantitative analysis is to develop and apply mathematical or statistical models explaining phenomena from large samples. The combination of qualitative and quantitative analysis will present a clear picture of marginal lands with a detailed description and an accurate measurement.

However, most studies just focus on the qualitative and biophysical analysis (Gopalakrishnan, Cristina Negri, Snyder, & Negri, 2006; Tang, Xie, & Geng, 2010) , ignoring the socioeconomic parts. Therefore, this study aims to define the economically marginal lands.

2 LITERATURE REVIEW

The history of defining marginal lands from socioeconomic perspective can be dated back to 1930s, when Peterson and Galbraith (1932) define marginal land as land at the extensive margin of production. That is the land where revenue from optimal production just equals the cost (profit equals to zero). In this paper, two features of marginal lands are highlighted. The first one is the "relative", which means a site as being "marginal" for one crop can result in land being considered profitable for another crop. Thus, specifying minimum two crops (land uses) is prerequisite to examine marginal lands. The other one is "dynamic", which means marginal lands are not necessarily as permanent. Any change in force governing peoples' willingnesses to use land will lead to a transition between "marginal lands" and "normal lands". The old but not out–of-fashioned idea is implemented by Swinton et al. (2011) and Bryngelsson et al.(2013). In Swanton's study, two different land uses are specified at the beginning: biofuel crops vs. food crops. In addition, this paper also theoretically examines price's effect on the transition of marginal lands. Brynegelsson et al. (2013) expand this research scope by examining the effects of other parameters such as cost on the changes of land rent.

3 METHODOLOGY

In this study, "economically marginal lands" are interpreted as lands which are marginal to food crops but not marginal to energy crops. Specifically speaking, it is the lands at the extensive margin of food crops but before the extensive margin of energy crops. Therefore, the key for identifying economically marginal lands is to determine the extensive margins (break-even points) for food crops and energy crops. Estimating the break-even points of these different crops using the following equation(Jain, Khanna, Erickson, & Huang, 2010):

$$P_e[\sum_{t=0}^{T} \frac{Y_t}{(1+d)^t}] = \sum_{t=0}^{T} \frac{C_t}{(1+d)^t}$$

Where T is the life of the crop; C_t is the unit production cost of crop in period t; Y_t is yield in year t and d is the discount rate. Thus, the follow-up research will focus on the estimation of production costs and yields for energy crops and food crops given the incomplete information on prices of energy crops. The yields information will be obtained by running Cycles growth model and the cost information will be obtained from various literatures. The study sites will be across the northeastern region of the United States. The second part of this research will assess the social factors' effects on the transition of marginal lands via a survey in the study sites.The objective of this study is to examine the marginal lands from a socioeconomics perspective and quantitatively identified economically marginal lands by doing profit analysis. It aims to answer two basic questions: what the economically marginal lands are and how many of the economically marginal lands are available. The answers to these questions will land the basis for further analysis on farmer's willingness to supply energy crops from the economically marginal lands.

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FACTORS AFFECTING NONINDUSTRIAL PRIVATE FOREST LANDOWNERS' WILLINGNESS TO DEFER FINAL HARVEST FOR FOREST CARBON SEQUESTRATION IN THE SOUTHERN U.S.

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ABSTRACT

Forested lands in the southern U. S. represent a significant carbon sink and play an important role in climate change mitigation. Increasing rotation length, reducing disturbance and harvest removal, fertilization, and increasing productivity are some of the major strategies prescribed to increase carbon storage. However, the willingness of NIPF landowners, the most dominant ownership group in this region, to manage their forest for carbon sequestration has been less understood. This study aims to identify NIPF landowners' climate change attitudes and the factors affecting their willingness to manage forests for carbon sequestration. A regional mail survey was conducted in Fall 2013 to the randomly selected 5,110 NIPF landowners in the Southern U.S. We found that the landowners held varied attitudes toward climate change. The results demonstrate that parcel numbers, ownership length, climate change attitude, and their household income influence their willingness to manage forest for carbon sequestration. Findings of this study will assist policy makers in designing and implementing more effective climate change mitigation policies in the southern U.S.

Keywords: Climate change; Carbon sequestration; NIPF; Willingness

1 INTRODUCTION

Forests are the most effective natural option for atmospheric carbon reduction and global climate change mitigation. Trees store carbon in various tree components and in harvested wood products for extended periods. Practices such as longer rotation ages, reduced harvest removals, fertilization, and decreases in fire use are some of the major strategies often suggested for increasing forest carbon sequestration. In contrast, major forest disturbances such as wildfire, disease and insect infestations, poor management, and land conversion release stored carbon back to the atmosphere. Forested lands in the southern U.S. represent a significant carbon sink and play an important role in climate change mitigation. In terms of greenhouse gases, forests in this region sequester about 13% of the regional greenhouse gas emissions per year (Smith and Heath 2004). The carbon forest management strategies in this region are considered to be a low cost and high volume carbon sequestration opportunity, having the potential to sequester about 400 million tCO_2e per year in this region (Galik et. al. 2013).

In the southern U.S., however, non-industrial private forest (NIPF) landowners are the dominant ownership group. Given the significant acreage of forest land they own in this region, their choice of forestry practices would be important for significant carbon sequestration in this region. Butler (2008) showed that NIPF landowners pursue varying objectives and forest management strategies.

Joshi and Arano (2009) conducted a survey of NIPF landowners in West Virginia and found that their reasons varied for owning forest land as well as types of forest management activities they employ. Furthermore, Arano and Munn (2006) found that NIPFs often practice less intensive forest management practices than other similar ownership groups. However, NIPF landowners have been found to respond positively to financial incentives aiming to change their forest management practices (Conway et al. 2003; Kline et al. 2000).

Earlier studies analyzing factors affecting NIPF landowner willingness to engage in forest carbon sequestration have evaluated their preference for various carbon trading scenarios in the North Lake States (Miller et. al. 2012; Markowski 2011). Markowski (2011) identified how various socio-economic and forest resource factors affected NIPF landowners in North Lake states to enroll in forest carbon sequestration programs. In the Southern U.S., Soto and Adams (2012) estimated the willingness to accept amount of Florida landowners to enroll in various carbon trading scenarios. Alternatively, in a simulation study, Nepal et al. (2011) found that joint carbon and timber management could be a viable management strategy for Mississippi landowners. None of these studies have analyzed how these factors affecting a NIPF landowner willingness to practice forest carbon sequestration as a joint forest management strategy for timber and carbon sequestration in the southern U.S. The goal of this study is to identify NIPF landowners' climate change attitudes and the factors affecting their willingness to manage forests for carbon sequestration.

2 METHODS

2.1 Sampling

The study included NIPF landowners with forestlands in the Southern U.S. The study included only 11 southern states except Tennessee in the study. The list of NIPF landowners was purchased from List Giant, a private database vendor. Thompson and Hansen (2012) used the same vendor database of NIPF landowners for their forest carbon sequestration study. The number of surveys to send out was determined as described in Dillman (2010) for econometric analysis; and the factors considered were anticipated response rate, population size, desired precision, and other factors. A total of 5,000 NIPF landowners from the selected states were randomly drawn for final survey.

2.2 Data

The study employed a mail survey methodology for data collection. To conduct mail survey, a survey instrument was developed to send out to selected NIPF landowners. The questionnaire included three sections related to their forestland characteristics, environmental preferences, and socio-economic details. The draft questionnaire was shared with experts active in NIPF related researches and revised to include their recommendations. Then, the survey was pretested among NIPF landowners in County Forestry Association (CFA) meetings in Mississippi. The comments received from these tests were used in revising the survey instrument.

The survey instrument was mailed in the Fall of 2013using protocols from Dillman Tailored Design Method (2010). The Dillman method involved sending out a series of letters to the landowners depending on whether their response has been received from earlier mail outs. A total of three mail outs were conducted and the time between successive mailings to the non-responding landowners was approximately 3 weeks. Each mail out included an individually signed cover letter, survey questionnaire and a return envelope.

2.3 Non-response bias

To test for non-response bias, we called 50 randomly selected non-respondents and obtained answers on three key questions from the survey instrument. The questions were related to their forest land (size of largest forested parcel), management behavior (availability of written management plan), and climate change attitude (Human activities are contributing to climate change). A statistical comparison of t-test between responders and non-responders indicated that there is no difference between these two groups in terms of the key questions. This suggests this study does not have non-response bias.

2.4 Statistical analysis

After cleaning the data for missing and invalid responses, a binary logistic model was fit on the measure of NIPF willingness to defer harvest for carbon sequestration. The analysis included landowners with greater than 20 acres of forest. The question to assess their willingness to manage for carbon sequestration was stated on the survey questionnaire as "*Would you be willing to defer final harvest of your timber stand for more forest carbon sequestration if such action were to contribute to climate change mitigation as well as generate additional revenue for you*?" Given the binary nature of the willingness measure i.e. dependent variable, a binary logistic model was fitted between dependent and independent variables. Let explanatory variable X, binary response variable Y, success probability of x denoted by π(x); then, the logit of this probability

$$\text{Logit } \pi(x) = log\left(\frac{\pi(x)}{1-\pi(x)}\right) = \alpha + \beta x$$

Now, the logistic regression formula gives the probability $\pi(x) = \frac{\exp(\alpha+\beta x)}{1+\exp(\alpha+\beta x)}$

Since the coefficients of binary logistic model couldn't be interpreted directly, the marginal effect of the independent variables included in the model was calculated.

2.5 Model and independent variables

Based on earlier studies regarding carbon sequestration (Markowski et al. 2011), various socio-economic, land and forest type, and their attitudinal characteristics could affect a NIPF landowner's decision to manage forests for carbon sequestration. Table 1 lists the variables included in the logistic model, their brief description and the summary statistics.

Table 1: The definition, mean and standard deviation of the independent variables included in the binary logit model (N=475)

Variables	Definition	Mean	Standard Deviation
Acres	Total forest land (acres)	331.4918	747.0957
Parcel number	Number of forest parcels	2.0589	1.7163
Ownership length	Length of ownership (years)	26.8578	25.6874
Management plan	1= have a written forest management plan, 0 = otherwise	0.2757	
Timber goal	1= own for production of timber products, 0= otherwise	0.6147	
Future Harvest plan	1= plan to harvest within 5 years, 0= otherwise	0.3410	
Climate change attitude	1= climate change will substantially affect my forest, 0= otherwise	0.2694	
Age	Age (years)	64.2673	
Gender	1= Male, 0 = Female	0.8421	
Education	1= above bachelor degree, 0= otherwise	0.5684	
Income	Natural log of annual household income in dollars	11.4762	0.7091

3 RESULTS & DISCUSSION

3.1 Response results

After adjusting for bad addresses, undeliverable surveys, and deceased landowner, the adjusted sample size was determined. A total of 735 responses were received, for an adjusted response rate of 15.74 percent which provided sufficient data set for our analyses. A similar response rate was reported in NIPF carbon sequestration study by (Thompson and Hansen 2012).

3.2 Descriptive statistics

The mean and standard deviation of the variables included in the logistic model is presented in Table 1. The average forest land size is 331.49 acres and the average length of ownership is 26.85 years. The majority of respondents are relatively older and mostly male. Few landowners have a forest management plan.

3.3 Climate change attitude

We found that there is varied opinion regarding climate change among NIPF landowners. Out of those respondents who provided an opinion, 38% of the respondents agree or strongly agree that climate change is happening, and 25% disagree or strongly disagree (Figure 1).

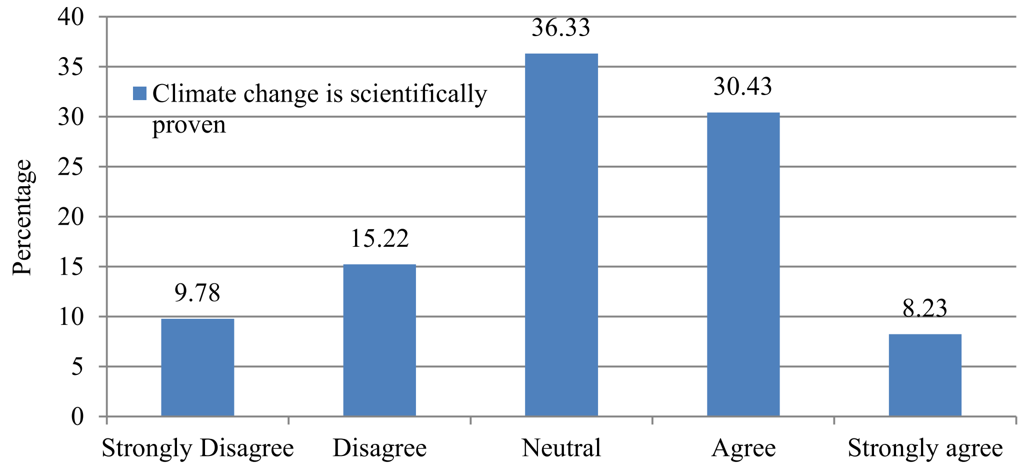

Figure 1: Climate change attitudes of NIPF landowners in the southern U.S.

3.4 Logistic regression results

Table 2 provides parameter estimates and marginal effects of the variables included in the logistic model to identify factors affecting NIPF willingness to defer harvest for carbon sequestration in the southern U.S. The log-likelihood ratio test of the overall model fit was statistically significant at 1% level. In addition, the variables total acres, ownership length, timber production goal, and age were negatively related with their willingness to defer final harvest for carbon sequestration. In contrast, parcel number, management plan, future harvest plan, climate change attitude, gender, education, and income were positively related with their willingness to carbon sequestration.

Table 2: Variables fitted in logistic regression model, their parameter estimates and the marginal effects (N= 475)

Variables	**Estimates**	**Marginal effects**
Acres	-0.00021	-0.00004
Parcel number	0.20577**	0.04520
Ownership length	-0.00727*	-0.00159
Management plan	0.00849	0.00186
Reason of owning land	-0.05066	-0.01112
Future harvest plan	0.06658	0.01462
Climate change attitude	0.80694**	0.17727
Age	-0.00817	-0.00179
Gender	0.11961	0.02627
Education	0.33369	0.07330
Income	0.56034**	0.12309

Constant	-6.30984**
Likelihood ratio	55.56**

**significant at 1%, *significant at 10%

Furthermore, the variables parcel numbers, ownership length, climate change attitude, and household income were statistically significant factors affecting NIPF willingness to defer harvest. The respondent's willingness to defer harvest increased with the increase in parcel number, income, and positive attitude toward climate change. Conversely, the willingness to defer harvest decreased with the increase in the length of ownership. This implies that relatively wealthy landowners owning multiple parcels would be more willing to defer harvest and increase carbon sequestration. In the marginal effect analysis, the variables climate change attitude and income has higher marginal effect than rest of the variables. This means relatively wealthy landowners with positive attitude toward climate change are more likely to manage their forests for carbon sequestration.

4 CONCLUSIONS

NIPF landowner willingness to defer harvest for sequestering forest carbon is useful not only in making better forest management decisions, but also assisting policy makers in designing and implementing more effective policies to mitigate climate change. Therefore, it is important to consider factors affecting willingness to defer harvest for this important ownership group in order to design and implement more effective policies to mitigate climate change in the southern U.S.

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TOWARDS A NEW WOOD-INTENSIVE ECONOMY

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ABSTRACT

Wood is a versatile material and available in many climates. It is primarily used in construction, paper, and increasingly in the biomass industries. Today, there is much debate regarding the efficiency of wood energy, deforestation, and the construction industry.

How can the US transition from a fossil fuel economy to a renewable wood-centric economy? To promote such a transformation, there is a need for a study of this material's implications on a broader economic and environmental level. This paper examines some of the many benefits of a wood-intensive economy with special attention to the construction industry for its possible role as a leader in the future of forest harvesting and conservation.

The investigation concludes with a discussion on a example cross-laminated timber house design that challenges the conventions of traditional wood construction in the US. Design can showcase new wood technology and new construction methods and demonstrate wood's widening application. Demand for wood in the construction industry can be further stimulated with support from a growing informed public and strategic policies. The increased importance of wood in the economy will establish it as a truly viable and renewable global resource and require our commitment to its responsible regulation and sustainable management practices.

Keywords: Wood-intensive; economy; cross-laminated; renewable; construction

1 INTRODUCTION

The construction sector and building operations are responsible for the greatest portion of global greenhouse gas emission, fossil fuel consumption, and waste production. The current fossil fuel economy is increasingly becoming socially and environmentally too costly. Ironically, it is wood—the earliest source of fuel and material for construction—that can lay a new groundwork for a more sustainable society.

This paper examines the possibilities of a wood-intensive economy examining:

- current environmental footprint of the construction related sector;

- wood's properties as a construction material and the benefits related to substitution of high energy embodied materials;
- wood biomass as a source of renewable energy;
- the possibility of expanding forest cover;
- European models of wood-intensive economies and favorable policies;
- existing construction related imports and markets;
- the pitfalls of the current "green" movement;
- design and technological advancement of wood related products;
- and environmental benefits

In studying the broader implications of economic choices and activities, informed decisions can be made to attain greater outcomes. Long-term social and environmental costs can ultimately be equally or more important than the limited myopic vision for immediate financial results.

2 METHODS

This paper begins with an overview of the construction sector and its environmental footprint and the wood industry's potential as a source of biomass fuel. The paper then compares the different wood economies of the US and European wood-centric economies like Austria, and later turns to the American construction sector and its role in the current and future economy of the US. Finally, the paper focuses on historical examples of design innovations and the many potential developments related to wood products currently in progress. Traditional 2x lumber construction is questioned and a cross-laminated timber (CLT) panel case study house is examined.

Research used in the paper is listed in the Literature Cited section. No empirical data was challenged or independently collected for the preparation of this work.

3 RESULTS & DISCUSSION

The construction industry contributes less than 4% to the US GDP, yet it is the greatest consumer and producer of energy, and waste. Approximately half of all non-renewable resources mankind consumes are used in construction, making it one of the least sustainable industries in the world (Figure 1). Moreover, these materials account for approximately 50 percent of all waste generated prior to recycling (Figure 2).

Wood of course is the only self-renewable building material. It is a versatile material and available in many climates. A sustainable increase of wood use in construction can transition the US into a new wood-intensive economy with immediate positive impact on the construction sector and environment. This new economy will favor wood as a climate neutral and socially viable source of renewable energy.

There are many reasons why wood should be the preferred construction material. Wood has both high compression and tensile strength. It has low embodied energy in contrast to steel, brick, or concrete. If high-energy materials can be limited to certain construction types then carbon footprints and greenhouse gas (GHG) emissions can be reduced in the construction sector simply by using such material only where needed. Wood is a lighter material (76500 kg/m^{3}76 compared77against772,000 kg/m^3 for armed77concrete77or777,800 kg/$m^3$77for77steel) so timber structures will require smaller foundations further reducing concrete use in construction. Wood has better thermal and acoustic properties than other construction materials. Steel is 400 times more conductive and concrete 10 times more. This means that additional insulation is required to achieve the same thermal characteristics that wood can achieve by itself. Building operations are responsible for nearly 26% of global GHG emissions and 40% of energy consumption in the US. Improved performance will reduce global energy consumption for heating and cooling buildings. Better insulation and air tightness are the basic components for efficient design and a superior building stock for the country.

Construction wood can be locally or regionally available further reducing transportation related energy consumption and GHG emissions. The application of unusable timber or cut offs and sawdust towards the processing of composite wood products and biomass in the wood production process results in a highly efficient production cycle with little waste (Figure 3). Locally sourced biomass can be efficiently collected from nearby timber industry.

Wood energy is entering a new phase of importance and visibility with climate change and energy security concerns. A concentrated effort focusing on the promotion of wood—through policy changes, government incentives, design, new products and applications—can stimulate demand for wood products and establish the foundation for a wood-energy-industrial evolution. Demand can justify larger forest cover increasing the source of biomass for renewable energy production. Some states have already implemented favorable policies like ‘Fuels for Schools’ to promote renewable advanced wood combustion (AWC). 20% of public school students in Vermont now attend wood-heated schools.

According to a report for the US Forestry Service, “…the annual rate of growth… averaged about 2.8 percent per year since 1996.” Increased use of wood will require additional forest cover in the US to maintain existing growth to harvest ratios. An expanding timberland area has many benefits for the physical environment. Sustainable forests help water conservation, control soil erosion, reduce heat island effects, and even help increase rainfall. Careful selection of tree species can cultivate diverse eco-habitats. New forests require many years to grow and can serve as recreational outdoor areas and promote general wellness for decades before they are harvested.

Even in urban settings, tree cover can be intensified with the goal of off setting fossil fuel combustion (Figure 4). Strategically placed trees can reduce urban heat island effects lowering air conditioning needs of surrounding buildings by almost 30 percent while simultaneously improving air quality, noise reduction, and quality of life in cities. Municipalities that convert existing fossil fuel electric plants to use wood and other biomass can benefit directly from the local biomass supply generated from regular maintenance, and the periodic removal of diseased and storm-damaged trees. Many communities pay to dispose of this wood and lose the potential benefits of its clean combustion. St. Paul Minnesota refurbished a coal-plant and has been generating heat, cooling, and power by cleanly burning about 250,000 tons per year of urban wood waste and organic materials. Wood is easily recycled and biodegradable and with proper management and incentives wood construction and demolition waste can be redirected from landfills to energy generation. It is estimated that there are some 30 million tons of safely combustible urban wood produced in the United States per year.

The US is made up of 751 million acres of timberland covering approximately 1/3 of the country. Unfortunately, it is underutilized in comparison with some EU countries. Austria, for example, is 47% forest cover (Figure 5). Although the sizes of the two countries are drastically different—the US has 111 times more land—Austria still has a high forest to person ratio (approximately 1.13 acres/person and the US 2.39 acres/person). This is even more impressive when considering that Austria has almost three times the population density. It's no surprise then that forestry is Austria's second largest source of foreign currency after tourism. The country's tourism is closely linked to the abundant nature and associated outdoor activities which draw visitors from all over the world as much as its cultural and heritage attractions.

With so many natural resources, Austria is also one of the leading countries in the world for green energy. It produces nearly 70% of its domestic needs from renewable energy. "Biomass fueled 11.2% of Austria's total primary energy supply and 21% of heat production, according to International Energy Agency statistics," reports Delphine Straus in the LA Times. There are more than 1000 advanced wood combustion (AWC) facilities in Austria, nearly all local community–based and more than 100 combine heat and electric power. AWC is an important contributor to energy production in many other countries like Scandinavia, France, and Germany. Daniel Richter writing in *Science Magazine* notes, "…wood-energy economics are generally more favorable in North America… and it is ironic that AWC was initiated in Europe."

A wood-intensive economy is a more sustainable model for the American economy to aspire to. Planting new trees is an alternative to intensified drilling, fracking, or mining. Increased wood substitution, more efficient buildings, and adapting biomass can offset fossil fuel combustion. Additionally, increasing forest cover will sequester more carbon naturally instead of complex capture and storage technology currently proposed that might only result in long-term detrimental effects on the environment. Advanced wood societies favor both the environment and the economy (Figure 6).

It's the economy, stupid!

Currently, the US is one of the world's leading manufacturers and consumers of forest products. It is also one of the greatest importers of wood. In 2012 this amounted to over $12B. That same year, the US was the world's largest steel importer. Portland cement and clinker for concrete is another important import. Most steel and cement related imports are currently necessary because demand is greater than domestic supply. Substitution of these products with wood can reduce unnecessary importation and if demand can be controlled US production levels may even be enough to meet domestic needs.

Weaning off of exotic woods imports will of course be better for the economy as well as the environment. Specifying domestic wood products secures American jobs (forest related manufacturing is difficult to offshore work to low-wage countries) and promoting sustainable forestry practices is a smart investment creating new wood industry jobs that will stay in the country and contribute to recovering some of the 6 million manufacturing jobs lost in the last decade.

Advancement of wood industry and wood energy leadership will position the US as an international leader for new wood applications and products and maintain its position as a major exporter to resource limited countries. A policy that favors wood industry and wood energy can increase domestic employment and energy independence. Improved transportation and infrastructure will result as efficient delivery methods of wood products are needed.

Since wood is a renewable resource prices can be stabilized, unlike steel and cement. A large reserve timberland can control shortages and price hikes. Literally growing supply to meet market demands and without endangering conservation and preservation efforts. Lower demand for steel and concrete can ultimately contribute to reduced material costs improving opportunities especially for first time homebuyers.

The American housing market forms a critical component of the economy. At its peak the US built 2.5M homes in 2005, and more recently in 2013 there were 750,000. According to economist Bill Conorly writing in *Forbes*, he believes the US needs approximately 1.5M new units annually to accommodate population growth, vacation homes, and replacement of demolished homes.

The “Green Home Builders and Remodelers Study” reports that green homes comprised 17% of the overall residential construction market in 2011 and are expected to grow to between 29% and 38% of the market by 2016—from $17 billion to $87-$114 billion—based on the five-year forecast for overall residential construction. The market is clearly reflecting interest in efficient design with concerns for "higher quality" and "increases in energy costs" leading the trend. The study suggests that today’s green homebuyer is not just a green consumer.

The construction industry has been busily catering to this growing market such that so much green-wash marketing sometimes results in misinformation. Notable robotist, Catherine Mohr, shares her personal experience of building a green home in a *TED Talk* and warns of the danger of getting too caught up with sustainability warning that, “…sometimes the things that you least expect… have a bigger effect than any of those other things that you were trying to optimize.” She points out how too much press is often focused on green finish materials when it has little impact on overall construction.

The forest related industries should take note. They would do well advocating the only renewable construction material in the world not as just another green material. Trees may not be as news worthy as a desert full of photovoltaic panels, but wood just may be that least expected thing that has the greatest impact on construction and the environment. Advancements in wood technology have created many new uses and applications for wood. Glue laminated beams, strand board, particleboard, MDF, HDF were introduced in the last century and are now commonly available. Ecor products, Ecovative products, Corelam, wood fiber insulation, cross-laminated timber panels are recent advancements in construction materials that promise greater efficiencies (Figure 7). Combined with new advanced wood combustion systems and mixed fuel furnaces being introduced for biomass conversion wood has the additional cachet as a source of renewable energy. No other construction material can share this claim. Wood’s growing role in the economy will be founded on such new technology developments in both the construction and energy sectors.

Historically, wood has always been a desirable material choice for various applications and at many different scales. Wood has been around for a very long time and there are no signs of any decreasing usefulness. Rather it is proving to be only limited by the imagination.

Design is a vehicle for change and it certainly is no different when it comes to promoting wood's potential. Michael Thonet's patented bent wood techniques resulted in Chair 214 (1859) that has been popular and in production now for over a century. Hans Wegner wood chair designs are still striking today as they were when first introduced in 1950. Designers Charles and Ray Eames experimented with plywood in the early 20th century and are probably the most responsible for making what was then considered a very industrial product acceptable as a finish material.

Today, new designers are pushing the limits of wood even further. Jasper Morrison's minimal and super lightweight Ply Chair reintroduced wood as a fashionable material in modern design. The Ripple table by Benjamin Hubert is a large corrugated plywood table that weighs only 20 pounds. Hermann Kaufmann is one of the leading architects (Austrian of course!) using CLT technology. His Life Cycle Tower One is a recently completed 8-story office building that will surely be the first of many. Vancouver based Michael Green is seeing a good deal of press lately for his wood skyscraper proposals. SOM recently published a study supporting the viability of forty-story wood towers. Shigeru Ban just completed a wood office building in Zurich without any screws or bolts. These are all exciting achievements and showcase the possibilities of wood's many applications.

If necessity is the mother of all invention, then design is the creativity of need. Perhaps no other brand reflects this notion better than Apple. Steve Jobs embraced design to re-invent the PC. From the first McIntosh and candy color iMacs, to the iPhone and iPad, design changed the way the world now lives and works with technology. Apple inspired everyone to "think different".

In the home construction industry, William Levitt arguably accomplished the equivalent introducing a revolutionary delivery method and other new concepts of the modern home. Levittowns became synonymous with the American dream: white picket fences; cars and suburbia. The homes were affordable and quick to build thanks to Levitt's reverse assembly line strategy (moving workers from one house to the next). Levitt built 180,000 new houses in this manner and turned a cottage industry into a major manufacturing process.

Developer Homeworks LP hopes to draw upon some of the same strategies to re-invent home construction using CLT panel technology (Figure 8). Up until the late 20th century, 2x lumber construction made sense. It was economical and easy to assemble, heating was inexpensive, and insulated houses were an exception. Today, as fossil fuel concerns have recaptured the attention and the insecurity of the American public combined with environmental concerns, dimensional lumber may no longer be an efficient solution. The growing complexities of insulation requirements, air tightness, and water and moisture protection techniques are creating a risk mitigation nightmare on job sites. Homeworks LP applies new methods and wood technology to address some of these concerns.

The X-House is a wood-intensive housing solution that is sustainable, efficient, scaleable, and can be replicated in many areas of the US. Panels are CNC milled in factories and assembled on site reducing material waste to a minimum. Approximately 20 panels are needed for the standard 1250sf X-House as opposed to thousands of 2x lumber and sub structural board panels of standard construction. The proposed typology can be assembled and enclosed in less than a week. Panels can be left exposed on the interior reducing labor and material costs for additional finishes. Due to the nature of its assembly and the small number of parts, the house is extremely airtight and well insulated in comparison to traditional construction. The streamlined design and assembly reduces construction time and field errors.

Figure 1: Wood-intensive vs. Fossil fuel-intensive, illustration by author 2014, original Forest photo by JasonBrown2013 2012 and Oil Refinery photo by Pascal Kammer 2011.

Figure 2: Edmonton Waste Management Facility, photo by Green Energy Futures 2013.

Figure 3: Wood Pellets (altered by author), original photo by USDA 2012.

Figure 4: Allé de Bristol, 33000 Bordeaux, France, photo by Googlemaps 2014.

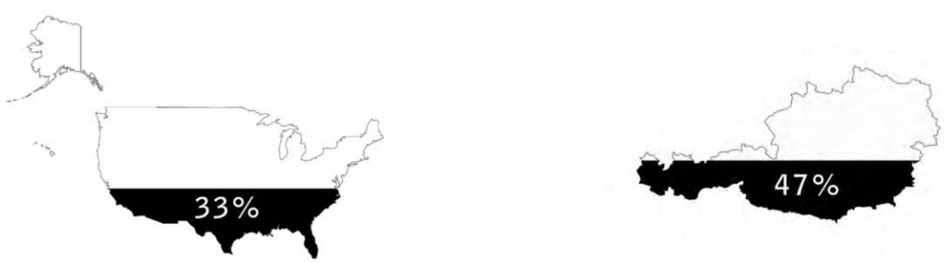

Figure 5: USA vs. AT Forest Cover (not to scale), illustration by author 2014.

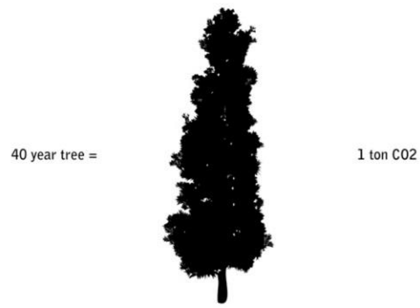

Figure 6: Estimated CO2 Sequestration Capability of a 40 year-old Tree, illustration by author 2014.

Figure 7: Cross-laminated Timber Panel Assembly, photo by Structurlam 2012.

Figure 8: Interior of the Homeworks X-House, ilustration by MOREMAS 2014.

Figure 9: Deforestation, photo by Michael Coghlan 2013.

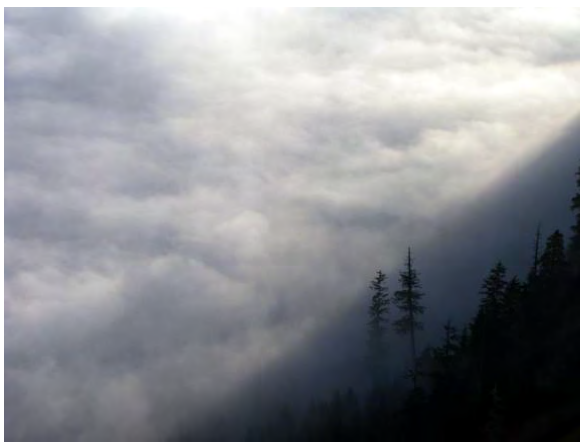

Figure 10: From Above, photo by Dru 2013.

Figure 11: The World Without Us, illustration by Ji Lee originally printed in the NY Times book review "Starting Over" by Jennifer Schuessler, September 2, 2007 reprinted with permission.

4 CONCLUSIONS

As the greatest consumers of material and energy, designers and builders must revaluate their construction method choices and question the business as usual practices that have become commonplace. Design and the construction sector can make greater efforts to bring about change in the way the world builds and lives today. It will be the joint effort between designers, construction industry, forestry sector, the public, and legislation that will really bring about a new culture of wood.

Recently, British Columbia enacted the "Wood First" policy that requires wood to be considered as the primary building material in all new publicly funded buildings, such as schools, libraries or sports complexes. Less steel, masonry, and concrete in smaller buildings, especially in single-family homes, will promote wood use in construction and allocate higher energy embodied materials for larger complex structures.

The increased importance of wood in the economy will establish it as a truly viable and renewable global resource and require our commitment to its responsible regulation and sustainable management practices. The emphasis on wood energy as a byproduct of the manufacturing process will redefine the industry as both a materials provider and as a green energy provider.

There are many advantages for the US to move towards a new wood-intensive economy but the most important may not be only what happens at home, but instead in what might occur in the many countries experiencing deforestation today (Figure 9). In choosing to place higher value on trees—both financial and ecological—the economics of forestation can reshape and alter the way societies interact with nature (Figure 10). A new wood culture will profoundly lower carbon emissions, and perhaps even global wealth inequality. The combination of design, technology, advocacy, and legislation will advance changes toward a greener and more sustainable future (Figure 11).

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CARBON SEQUESTRATION AND FOREST ROTATION AGE: A META-ANALYSIS

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ABSTRACT

Carbon sequestration has been well discussed in the field of forest economics in recent years, and is proven to be able to affect forest landowners' decisions on harvest rotation age. However, the problem how study designs and assumptions can affect the estimated results has not been fully examined so far. This meta-analysis research reviews 38 studies worldwide concerning forest rotation age under the scheme economic benefit brought by carbon sequestration with weighted least square, random and fixed effects panel-data models. The results reveal that higher carbon payments, one-time payment, other non-market forest values and the assumption of stochastic timber price can increase rotation ages. On the other hand, higher discount rates, accounting of product decaying process and the consideration of fossil fuel replacement decrease rotation ages obtained from existing studies. The conclusion of this study will help defining problems and making assumptions for research concerning similar issues in the future, and also help policy makers to control carbon policy designs within expectation.

Keywords: meta-analysis; carbon sequestration; forest management; harvest rotation; Faustmann model

1 INTRODUCTION

Understanding the mechanism of how carbon sequestration can affect forest landowners' decision is becoming an important issue. Carbon dioxide emissions have been attributed as one of the leading reasons for global warming (IPCC 2007). Meanwhile, carbon sequestration by forests has been regarded as an important strategy to diminish the build-up of atmospheric carbon dioxide (Dixon et al. 1993, Sampson and Sedjo 1997, Murray 2000). Since Kyoto Protocol takes account of forest ecosystem sinks as a CO_2 emission reduction, carbon sequestration has become a frequently visited topic in forest economics. In most recent 20 years, it has been commonly incorporated into traditional Faustmann and other rotation estimation models in the discussion of harvesting and regeneration problem. Existing studies have shown that the possible revenue brought by carbon sequestration can impact landowners' decisions on harvesting rotations.

Numerous articles have been conducted to investigate how harvesting rotation ages can be affected by carbon sequestration since early 1990s by combining carbon sequestration with benefits and costs under various carbon policy schemes. Before Kyoto Protocol was issued in

1997, there are not any formal existing system to estimate quantity and value of sequestered carbon. Therefore, all the early articles made relatively simple assumptions when modeling the process. After more policy schemes have been designed and executed with more deeply and widely scientific understanding on carbon cycling process, designs and assumptions of studies on harvesting rotations become diversified. This phenomenon is enhanced when the problem of forest carbon sequestration is comprehensively investigated with other ecological functions of forests, such as conservation and bioenergy production. Although it would be informative to synthesize all the factors into a single model and conduct sensitivity analysis based on each factor, associated problems and assumptions are too diversified to be allowed to complete it. Therefore, it is important to do a review study to obtain a generalized idea on this issue.

So far, no study has reviewed the relationship between forest rotation age and elements considered in existing studies with advanced statistical method. Thus, objective of this article is to review how different designs and assumptions affect existing studies' results and conclusions on harvesting rotations under the consideration of forest carbon sequestration with a meta-regression. Meta-regression is a widely-adopted statistical method to review a group of studies and their explicit impacts on the same issue. It has been employed to examine cost of forest carbon offsets (van Kooten et al. 2004, van Kooten et al. 2009), which can be respected as a closely related problem of this study. Comparisons between the conclusions among the three studies can help examining the forest carbon sequestration from different perspectives.

Review of the interaction between estimated rotations and forest carbon sequestration is important. From the perspective from conducting research, by identifying differences in study designs and assumptions, trend of this issue can be summarized. Moreover, influences of various study designs, assumptions and methods can be examined. Therefore, it can help researchers interested in the same problem making proper assumptions and preview consequences. From the perspective of policy design, by fulfilling the objective of this study, impacts of different carbon policy schemes can be evaluated; the neglected and overestimated factors can be discovered. It is also possible that some policies are designed to be neutral on harvesting rotations but proven to be able to shorten or lengthen them, or vice versa. Thus, this study can also help carbon policy makers avoiding to make policies with unexpected consequences.

The interrelationship between carbon sequestration and harvesting rotations will be discussed in Section 2 in details. Meta-regression, model specification and model selection will be illustrated in Section 3. The process on article search and selection are in Section 4. Empirical results are reported in Section 5. In the concluding section, implications of the results will be discussed.

2 CARBON SEQUESTRATION AND FOREST ROTATION AGE

Since IPCC's creation in 1988 creation, many scientists conducted research on climate change and concluded that it was reasonable to believe that global climate change had been induced by human activity to some degree, especially by house gas (GHG) emission. From then on, studies have been conducted in relation to GHG emission and forest carbon sequestration. Among them, harvesting rotation is an important decision related to both timber production and carbon sequestration. It can not only determine the quantity and quality of the timber that can be harvested, but also determine what kind of wood products can be produced with the timber (Liski et al. 2001). Although studies have extended Faustmann model to account for carbon sequestration, there is not a generally accepted idea on this problem. Conclusions of different studies highly depend on the specific scientific and political designs and assumptions the authors have made.

By using simple carbon accounting system, early studies attributed longer rotation age as an important method to accumulate more carbon in standing forests (van Kooten et al. 1995, Hoen and Solberg 1997). From the perspective of silviculture, it was reasonable because a longer rotation may increase timber volume, and increased the proportion of long-lifetime wood products before saturation period is reached, leading to decreased instant carbon release after harvest. What's more, it also reduced the frequency of site preparation, which could alleviate decomposition of soil and litter and increase carbon stock in standing trees (Baral and Guha 2004).

However, it was argued that reducing timber harvesting for a short period could decrease carbon stored in wood products in the long run (Birdsey et al. 2000). Conversely, studies concluded that a continuing cycle of harvesting combined with efficient utilization of biomass could sequester more carbon than non-harvesting or prolonging rotation beyond maximum mean annual increment (Sampson and Hair 1996). A study focusing on carbon sink also pointed out that successively harvested pine with short rotation had the capacity to sequester more carbon than uncultivated, unharvested forests when applying fertilization and weed control (Johnsen et al. 2001).

Some articles held a neutral or ambiguous point of view toward this issue. As one of the earliest studies that combined carbon life cycle into Faustmann model, Englin and Callaway's (1993) paper estimated carbon sequestration and release's impact on optimal harvesting schedule, and concluded that different carbon prices did not impact optimal rotation ages substantially. Another study pointed out that the relationship between rotation age and carbon sink was difficult to examine (Liski et al. 2001). To summarize, the effect of longer harvesting rotation is complex to estimate, but in general, it is widely accepted "a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fiber or energy from the forest, will generate the largest sustained mitigation benefit" (IPCC 2007).

Models that have been adopted to estimate the relationship has also evolved. In a classic paper, van Kooten, Binkley, and Delcourt (1995) introduced carbon taxes and subsidies into Hartman model, and designed a political method to solve the problem on how to use forests to sequester GHG even before Kyoto Protocol was signed in 1997. Recent studies of forest carbon sequestration mostly focused on existing policy systems with stochastic model. One among them compared two possible carbon credit allocation systems with the real option model, and stated that although both systems could discourage deforestation, only the system compensating landowners for the actual carbon sequestrated could postpone harvest (Guthrie and Kumareswaran 2009). Most recently, Köthke and Dieter incorporated carbon crediting schemes and thinning regimes into the calculation of forestland expectation values and optimal rotations, and stated that the assumption treating harvesting as carbon emission source had a substantial effect on the results (2010).

Estimated rotation ages under the consideration of forest carbon sinks may also vary on inconsistent policy schemes. Some rules in one policy system may be the opposite in another on the problems of before-project baselines, definitions of carbon sink pools, adopted carbon accounting schemes, and decisions on whether or not to distinguish carbon decaying processes in different products. Well-designed forest policies can encourage favored changes in forest management and product manufacture patterns that can stock more carbon or generate less carbon emission (Malmsheimer et al. 2011). On the contrary, flawed carbon policy may invite problems beyond policy makers' expectations. For example, one research has proven that ignorance of existing forests in Kyoto Protocol could accelerate harvesting (Murray 2000). Another study compared four carbon-accounting methods and concluded that two schemes that were more similar to Kyoto Protocol offered little or no incentives to the landowners (Cacho et al. 2003). The inclusion of underground carbon into carbon sink pool is also a debating problem (Johnsen et al. 2001, Liski et al. 2001).

Harvesting rotation estimation can also be influenced by new findings and projects derived from development of science. Bioenergy production may drive rotation ages to the direction of less sequestered carbon (Bjørnstad and Skonhoft 2002). Although not investigated comprehensively with harvesting rotations, wood's replacement of energy-intensive construction material as concrete could help reducing CO2 emission (Gustavsson et al. 2006), which can be a influencing factor to estimated rotations if it is considered in the modeling process.

In summary, numerous studies have been conducted to investigate how harvesting rotations can be influenced by forest carbon sequestration. By reviewing existing studies, it is possible that when the assumptions are varying, the results are closely related the assumptions and do not reveal a real connection between carbon sequestration and harvesting rotations. So far, no study has comprehensively reviewed studies on harvesting rotations under carbon sequestration based on different designs and assumptions. Therefore, a review study with a comprehensive consideration of various perspectives should be completed to fulfill the knowledge gap.

3 METHODS

3.1 Meta-analysis

Meta-analysis was initially designed by Glass in his article on integrating individual studies' findings (Glass 1976). It relies on statistical analysis to report trends or findings (Stanley 2001), which is suitable to be adopted to complete a quantitative review study. The rationale behind this model is that a single study can estimate connection between variables at a specified point; the meta-regression tries to identify general connection between the variables by including a group of studies with the same issue and similar factors (Smith and Kaoru 1990).

Meta-analysis is a widely accepted method to evaluate factors that can influence a specific phenomenon (van Kooten et al. 2004). When a relatively large number of articles are evaluated, meta-analysis can help finding significant relationships between the target variable and some key factors, even under the situation those factors are not reported as significant variables in primary studies (Mann 1994). This method can also help distinguishing how different methods, designs and assumptions of primary studies can impact estimated results from a macro perspective (Stanley 2001), which is suitable to fulfill the objective of this article. Because of the advantages of meta-analysis, it is widely adopted to review and evaluate non-market values, such as benefit transfer (Rosenberger and Stanley 2006, Moeltner et al. 2007), willingness to pay or accept (Cai and Aguilar 2013) and prices of currently-non-existing products (van Kooten et al. 2004, van Kooten et al. 2009).

Three problems are frequently raised when conducting a meta-analysis study: sample heterogeneity, heteroskedasticity and correlation within and between primary studies (Nelson and Kennedy 2009). Heterogeneity occurs when studies in meta-analysis vary in designs, procedures, participants and interventions and may or may not cause the differences in their results, which is a common property of meta-analysis (Higgins and Thompson 2002). Statistically, it refers that the variation of values between studies may be too large to be explained by the standard deviation estimated by the meta-regression (Thompson and Sharp 1999).

Two reasons may lead to heterogeneity: methodology and the facts (Christensen 2003). If method of primary study is uncommon or flawed, the estimated results can't represent the population. The factual reason implies that although primary studies are discussing similar issues, the specific facts included in each study may vary. This reason usually refers to forest economics studies because of the differences in species, sites and geographic environments in primary studies. There are two methods that can help solving heterogeneity. On one hand, observed heterogeneity can be enrolled in explanatory variables during model estimation, typically as binary dummies, which is actually the rationale behind conducting a meta-regression. On the other hand, for the part of heterogeneity that can't be observed or included, estimates of primary study can be modeled as random draws from a distribution. In other words, each primary study is estimating a different population effect size, known as panel-data model (Nelson and Kennedy 2009), which is employed by this article.

Heteroskedasticity can be induced by different sample sizes and estimation procedures of primary studies. This problem is related to heterogeneity but demonstrates statistically as increasing variances with the increasing of dependent variable or other factors. It can be solved by adopting variances in primary studies into estimation, which is impossible to obtain under some circumstances. Sample size of primary study is usually reported and can be used as a proxy of the variances. However, either of adjustments with variances or sample size can be applied to this study because those two factors are not frequently reported in harvesting rotation estimation. Besides that, heteroskedasticity can also be solved by using proper weights in regression or adopting robust standard errors, both of which are employed to deal with heteroskedasticity in this article.

Collected data of meta-analysis may not be independent of one another due to between-study and within study correlations. Between-study correlation is caused by same data sources of primary studies, similar data manipulation processes, or other unobserved common characteristics. Within study correlation is more common in meta-regression because one study usually provide more than one observations. Observations from one primary study are regarded to be correlated with one another when comparing to between-study observations. This problem can be solved by using a single estimate from each primary study, which is not commonly adopted as it may consume the sample size dramatically. Other solutions are based on econometrics, such as adoption of penal-data model.

3.1 Estimation models

Variables are designed and classified based on van Kooten et al.'s article on carbon offset costs and factors included in existing studies concerning about harvesting rotations and carbon sequestration. Dependent variable is the estimated rotation age indicated in primary studies. Explanatory variables include four groups: forest characteristics variables, economic variables, methodology and design variation variables and study quality variables. Heterogeneity brought by different species in different areas is planned to be estimated by forest characteristics variables. Economic variables are designed to enroll consideration of benefit and cost when making harvest decisions. Heterogeneity with various methodologies and diversified assumptions in carbon research is included into modeling by using methodology and design variation variables. Last but not least, study quality variables are designed to examine publication bias and outliers of primary studies.

Error term should be distinguished because of the properties of meta-analysis. Part of the errors is correlated to a specific study, which can't satisfy the assumption of independent and identical distribution (i.i.d.). According to this property and the four groups of variables mentioned above, a meta-regression model can be formulated as follows:

$$Rotation_{ij} = f(c_{ij}, p_i, m_{ij}, q_j) + \mu_j + e_{ij} \quad (1)$$

where Rotationij is estimated rotation age i for study j, cij is forest characteristics variables, ps is economics variables, mij is methodology and design variations variables, qj is study quality variables, μj is study-specific errors, and eij is i.i.d. observation-specific errors. To be specific, subscript i implies explanatory variable is homogenous; subscript j indicates explanatory variable is completely determined by specific studies and does not vary within observations from one primary study. Whereas, subscript ij means explanatory shows both heterogeneity and within study variations, which is the situation with species, geographies, study designs and methodologies.

Before model estimation, heteroskedasticity and autocorrelation are examined to obtain properties of the original data. Heteroskedasticity is tested with the Breusch-Pagan/Godfrey Lagrange multiplier (LM) test (Greene 2002), which can be calculated by:

$$LM = \frac{1}{2}[\boldsymbol{g}'\boldsymbol{Z}(\boldsymbol{Z}'\boldsymbol{Z})^{-\mathbf{1}}\boldsymbol{Z}'\boldsymbol{g}] \quad (2)$$

where Z is the matrix of observations, and $\boldsymbol{g}$ is the vector of observations of $g_i = e_i^2/(\boldsymbol{e}'\boldsymbol{e}/n) - 1$ with ei as the residual and e as the vector of residual. When the value LM test is greater than critical value, data shows heteroskedasticity. Within autocorrelation can be examined with LM test for panel data and Durbin-Waston test.

When the three problems are confirmed by the tests, weighted least squares (WLS) model with White robust standard errors and panel-data model are adopted to solve the problems. In existing meta-analysis studies, heteroskedasticity is regarded to be correlated with number of observations provided in each primary study, which can be set as the weight. Therefore, WLS can be estimated by

$$\hat{\beta} = \left[\sum_{i=1}^{n} w_i \boldsymbol{x_i} \boldsymbol{x'}_{\boldsymbol{i}}\right]^{-1} \left[\sum_{i=1}^{n} w_i \boldsymbol{x_i} y_i\right] \tag{3}$$

where wi = 1/ ωi with ωi as the weight for observation i, xi and yi as the explanatory variables and dependent variable for observation i, respectively. When robust error is preferred, covariance matrix is also weighted by number of observations as dependent and independent variables.

Both fixed and random effect panel-data models are estimated in this study, and the difference between the two is whether the individual effect is fixed for a specific primary study or not. Model of random effect model can be formulated as:

$$Rotation = \boldsymbol{x_{ij}}'\boldsymbol{\beta} + \alpha + \mu_j + e_{ij} \tag{4}$$

while fixed effect model can be formulated as:

$$Rotation = \boldsymbol{x_{ij}}'\boldsymbol{\beta} + \alpha_i + e_{ij} \tag{5}$$

where α is the intercept. In random effect model there is only one α as intercept, the random effects in primary study j is modeled as a study specific random element μj. It is similar to error term eij except that for each study, there is a single draw that enters the regression identically in each estimated results in study j (Greene 2002). For fixed effect model, individual effect is embodied into an estimable conditional mean αi, which is a study-specific constant term. To be noticed, fixed effect model has one plus number of primary studies intercepts, which implies it will consume the degree of freedom quickly. This is the reason why it does not fit data of small sample size. Model fit between random and fixed effect can be examined by Hausman's specification test.

4 DATA COLLECTION AND DESCRIPTION

38 studies were collected by searching important databases such as JSTOR, Scopus, and Business Source Complete by matching three groups of key words related to forestry, rotation and carbon, respectively. To obtain grey literature sources, Google Scholar, Dissertations and Theses and important paper's citations (for example, van Kooten et al. 1995) were also used to get related reports, book chapters, theses and dissertations. Only articles with rotation ages as final or partial results and with carbon benefit in modeling process were selected and reviewed. Rotation ages that are unclearly shown on figures are obtained by contacting corresponding authors; only one article was dropped because the data of the figure is untraceable. Some scenarios have exactly same dependent and independent variables as another observation because the differences between the two are not set as variables. When this situation happens, one scenario will be

dropped, leaving every observation in estimated data unique to mitigate the problem of within study dependency.

Table 1. Forest Carbon Studies with Harvest Rotation Ages as Results or Partial Results

Study	Observations	Mean rotation	Median rotation
Englin and Callaway (1993)	15	35.3	33
Binkley and van Kooten (1994)	148	46.5	39
van Kooten, Binkley and Delcourt (1995)	145	46	40
Hoen and Solberg (1997)	6	121.7	120
Romero and Diaz-Balteiro (1998)	2	80	80
Reddy and Price (1999)	4	30.2	30.4
Murray (2000)	27	47.6	46
Wayburn et al. (2000)	324	29.1	28
Appels (2001)	7	33.9	34
Creedy and Wurzbacher (2001)	15	73.1	67
Alavalapati, Stainback and Carter (2002)	10	38.4	38
Bjørnstad and Skonhoft (2002)	20	103.9	88.3
Cacho, Hean and Wise (2003)	8	31.4	17.5
Caparrós, Campos and Martín (2003)	10	90	90
Stainback and Alavalapati (2004)	10	51.4	51.5
Cacho, Wise and Macdicken (2004)	2	14	14
Stainback and Alavalapati (2005)	2	35	35
Yemshanov et al. (2005)	7	39	45
Spring, Kennedy and Nally (2005) a	55	66.3	68
Spring, Kennedy and Nally (2005) b	5	110.8	120
Huang and Kronrad (2006)	90	32.3	29.5
Chladná (2007)	39	79.2	80
Pohjola and Valsta (2007)	4	94.8	94
Gutrich and Howarth (2007)	5	87	58
Thompson, Adams and Sessions (2009)	9	46.1	45

Daigneault, Miranda and Sohngen (2010)	18	59.4	58
Köthke and Dieter (2010)	510	144.5	107.5
Olschewski and Benítez (2010)	4	22.8	22.5
Couture and Reynaud (2011)	5	48.2	49
Galinato and Uchida (2011)	24	20.9	19.5
Wise and Cacho (2011)	2	43.5	43.5
Price and Willis (2011)	9	69	65
Dwivedi et al. (2012)	4	20.3	20
Asante (2012)	17	94.9	89
Gharis (2012)	4	39.3	39.5
Manley and Maclaren (2012)	15	32.5	31
Susaeta et al. (2013)	6	35.3	31.5
Shrestha (2013)	32	47.8	47
Mean	42.6	56.4	53.0
Minimum	2	14	14
Maximum	510	144.5	120

All the remaining 38 studies have been listed in Table 1 with the time range 1993 – 2013. The articles published in the first half ten years have taken around only 1/3, and another 1/3 were published between 2010 and 2013. It suggests that this issue has drawn expanding concern in recent years when severe climates are becoming more frequent. The total number of observations is 1619, with 510 as the largest number of observations from a single primary study, and 2 as the smallest number. Because the distribution is biased by several studies with large number of observations, the mean of sample size in each study is 42.6 in spite of 9.5 as the median.

Studies have shown heterogeneity on estimated harvesting rotation ages. Means of estimated rotations in primary study varies from 14 to 144.5 years. The large gap is partially due to the forests' characteristics: rotation age differs a lot on species and geographic environment. Different designs and assumptions of the primary studies also play an important role.

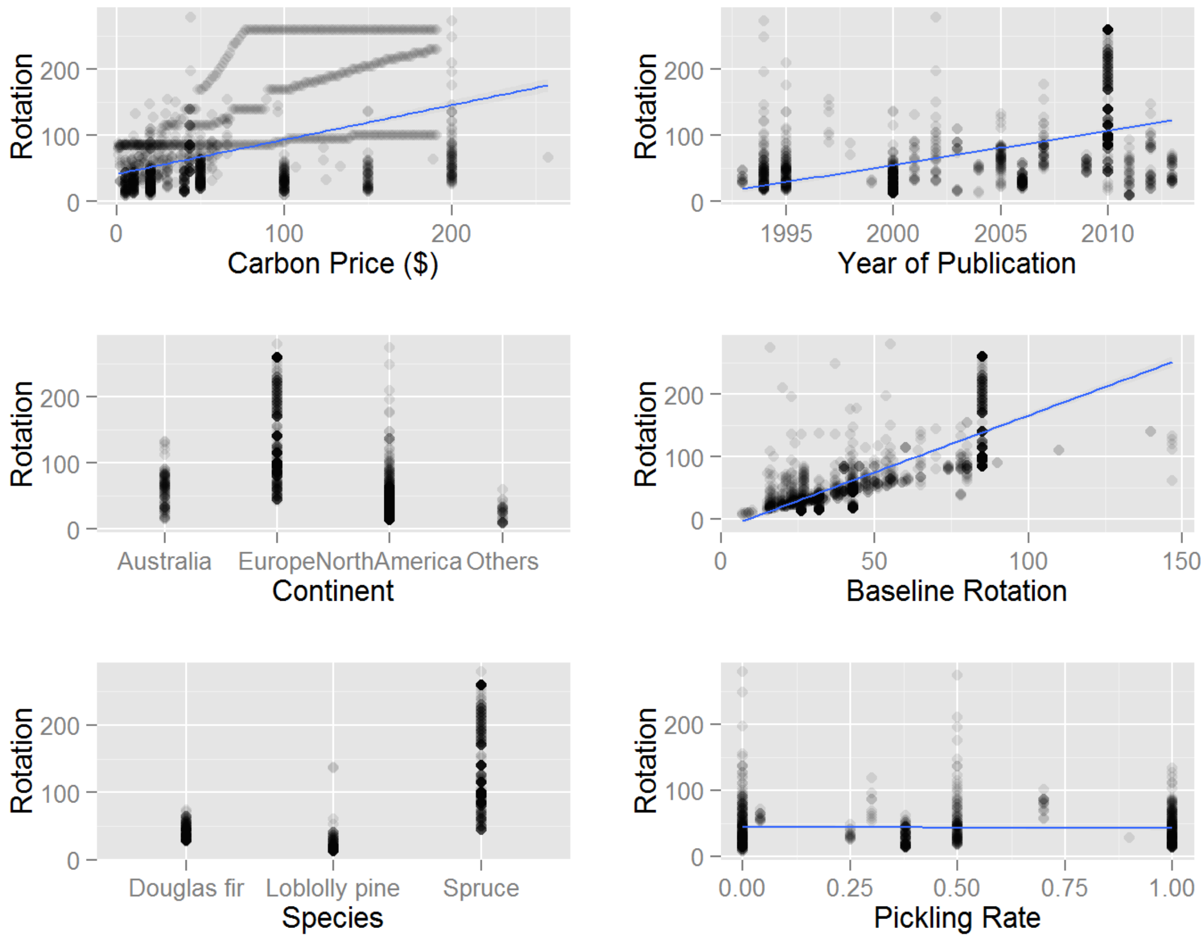

Figure 1: Plots for rotation against six important factors

Relationships between estimated rotation age and other six important factors are shown in Figure 1. Because some primary studies did not report carbon price, baseline, or pickling rate, only the proportion with the required information is plotted. Furthermore, only three important and universally distributed species are plotted. Estimated rotation ages show positive correlation with carbon price, year of publication and rotation baseline. For carbon prices, it is the first sign that higher carbon price can lead to longer estimated rotations, which is consistent with traditional views in existing studies. Baseline rotation in the primary study contains information of species, geographic environment and designs of the article, so it is closely related to the estimated rotations. However, it is interesting to find out that when the year of publication is later, estimated rotation ages tend to be longer. Because year of publication is not highly correlated with either carbon price or baseline, it will be revealing if the reason of this relationship can be deciphered.

From the perspective of geography, estimated rotations in Australia and North America are generally between 20 and 100 years. Comparing to those two, estimated rotations in Europe are widely distributed from 40 years to more than 250 years. That is probably because Europe is a relatively old continent with traditional species and patterns of management, and landowners there have put more weight on the conservation and recreation when comparing to the new continents. Countries in other continents, i.e. Asia, Africa and South America, have concentrated and short estimated rotations between 10 and 50 years, because all the countries in that group are in tropical areas for this article. From the perspective of species, loblolly pine has the most centralized and shortest rotations distributed with the mean of 25 years; it is also the similar situation with Douglas fir with 50 years as the mean. Estimated rotations of spruce are spreader and longer than the other two species.

Another interesting discover from the figure is that pickling rate does not influence estimated rotation ages. Pickling rate is the percentage of forest carbon that is assumed to be stored in wood products after harvesting. It is expected to be positively related with harvesting rotations based on its concept, because higher proportion of carbon stored in forest products implies fewer penalties on carbon release. This phenomenon may explain the diminishing adoption of this concept in recent studies to some degree.

Because carbon prices and discount rates are two important numerical factors affecting estimated rotations, scenarios without numerical discount rates or carbon prices are dropped, leaving total number of observations for estimation as 1582 from 35 primary studies. The range of the leaving estimated rotations are from 8 to 279.6 years with 76.2 years as the mean. Primary studies were summarized into numerical and categorical variables according to their designs and assumptions.

5 EMPIRICAL RESULTS

5.1 Variables selection

All the variables adopted in the estimation are listed in Table 2 with mean, standard deviation and expected sign of each variable. The dependent variable is the log form of harvest rotations indicated in primary studies. Log form is used because distribution of the rotation ages have shown right skewed due to some long estimated rotation ages.

Table 2. Meta-analysis Variables and Descriptive Statistics

Variable	Form	Description	Expected Sign	Mean (SD)
Dependent variable				
logR	Continuous	Log form of harvest rotations indicated in studies	N/A	4.011 (0.802)
Forest characteristics variables				
Tropical	Binary	1 if the site under study is illustrated to be in tropical area; 0 if it is not	-	0.023 (0.149)
Boreal	Binary	1 if the site under study is illustrated to be in boreal area; 0 if it is not	+	0.159 (0.365)
Conifer	Binary	1 if the selected species is coniferous; 0 if it is not	-	0.906 (0.292)
Economics variables				
logCP	Continuous	Log form of carbon prices in American dollar	+	3.701 (1.092)
DiscountR	Continuous	Discount rate in estimation	-	0.063 (0.048)
Methodology and design variations				
Faustmann	Binary	1 if the rotation age is obtained by a Faustmann-based model; 0 if it is not	±	0.838 (0.368)
TPfunction	Binary	1 if the timber price is not treated as constant, but a distribution or a estimated function; 0 if it is a constant	+	0.340 (0.474)
Penalty	Binary	1 if taxes are charged for the released carbon when harvesting; 0 if no penalty on carbon release when harvesting	+	0.604 (0.489)
OneTimePay	Binary	1 if the payment is made only once during a rotation period; 0 if payment is periodical	±	0.122 (0.327)
ProductDecay	Binary	1 if carbon is assumed to have a lasting decay in products after harvesting; 0 if all carbon is assumed to be released into atmosphere after harvesting	±	0.815 (0.388)
FossilReplace	Binary	1 if total or partial harvested trees are used as bio-energy and reduced carbon release for fossil fuel replacement is estimated; 0 if it is not the case	-	0.009 (0.094)
OtherMarket	Binary	1 if forests can provide other market values than timber and carbon sequestration, such as bio-energy production ; 0 if it is not the case	±	0.037 (0.188)
OtherNonMarket	Binary	1 if forests can also provide non-market values, such as conservation and construction material replacement; 0 if it is not the case	±	0.015 (0.120)
MonitorCost	Binary	1 if monitoring cost for auditing carbon sequestration is included in estimation; 0 if it is not.	+	0.019 (0.136)
Thinning	Binary	1 if thinning is included in estimation and affects the amount of sequestered and/or released carbon; 0 if it is not the case	±	0.433 (0.496)
Fire	Binary	1 if fire 1 if either wild or prescribed fire is included in estimation and affects the amount of sequestered and/or released carbon; 0 if it is not the case	-	0.052 (0.223)
Underground	Binary	1 if underground carbon is included in estimation; 0 if is not	±	0.015 (0.120)
Study quality variables				
Publication	Binary	1 if the study is a peer-reviewed journal article or book, 0 if it is a thesis, dissertation or report	+	0.768 (0.422)
Cacho03	Binary	1 if the study is Cacho, Hean and Wise's publication in 2003; 0 if it is not	-	0.005 (0.071)
Susaeta13	Binary	1 if the study is Susaeta et al.'s publication in 2013; 0 if it is not	-	0.004 (0.061)

Explanatory variables are distributed into four groups mentioned above. Forest characteristics variables have considered geographic environment and species. Temperate forestlands and broadleaf species are set as baselines, leaving three variables in this group: Tropical, Boreal and Conifer. Forests are distributed to be tropical or boreal only when the authors have clearly illustrated it in the primary studies. To be specific, temperate forestlands (82%) and conifer species (91%) are majorities among all observations. Continents were considered to be included in the estimation in early design, but were abandoned later because countries beyond North America, Europe and Australia are all tropical countries, causing the problem of multicollinearity with Topical. Site index was also designed as an important variable, but was dropped later because it is only reported in around 2/3 reviewed articles with inconsistent systems.

There are two variables are regarded as economic variables in this study: carbon prices and discount rates. Carbon price is in the log form of carbon dioxide price per ton in American dollar. If a price is reported in the form of per ton of carbon instead of per ton of carbon dioxide, it is converted to the standard form by multiplying 3.67, i.e. 22/6. If a carbon price is in other currencies instead of American dollar, it will be converted into American dollar by the exchange rate in the year the paper is published based on the information provided by US Internal Revenue Service. To be noticed, carbon price is not adjusted into real price because of the declining trend of carbon price. Moreover, carbon prices in most studies are assumed to be integrating numbers, i.e. $5, $10, $50 or $100, instead of citing carbon prices from real carbon market. Mean of adopted discount rate is 0.06, standard deviation is relatively large as 0.048 since it is usually treated as the varying variable in sensitivity analysis. If carbon and other benefit and costs are discounted with different rates, the economic discount rate is adopted because rotation ages adopted in this study are all estimated by economic model instead of ecological model. Timber price was also considered in the early design, but was dropped later to keep the articles without numerical timber prices.

There are 12 explanatory variables in the group methodology and design variation variables, all of which are binary dummies. It is the most important group that is closely related to the objective of this article. In this group, two variables are considered to be close to methods of primary study: Faustmann and TPfunction. The former represents whether the model to estimate rotations are based on Faustmann or Hartman model. The percentage of all observations estimated by Faustmann-based models is 84%. It is higher than expectation because most studies with large sample size are estimated by the Faustmann-based model. Other employed models include real option, NPV maximization and Bellman equation, none of which has dominated percentage among the rest observations. The other variable TPfunction is whether timber price is constant, or otherwise, assumed as a distribution or a function, which can be regarded as stochastic. Around 1/3 of total rotation ages are estimated with stochastic timber prices. This proportion is relatively higher when the year of publication is later.

The other ten variables are all about whether a design or an assumption of forest timber production or carbon sequestration is included in the primary study. Some aspects are frequently considered by the reviewed articles. For example, in most cases, penalty will be implemented when carbon is released back into atmosphere in harvesting; when it is the case, rotation age is expected to be longer to avoid the penalty, the effect of which is similar to higher regeneration cost. Correspondingly, 81.5% of the total estimations have assumed lasting decaying process of forest product carbon, which is supposed to have mitigation effect to the penalty of carbon release. Another widely considered factor is thinning, which is included in 43% total observations. Pickling rate is not included because it is not frequently reported in the articles published in most recent 10 years.

There are some other factors that have been frequently visited in most recent studies. Bioenergy's replacement of fossil fuel is one among them. Although only 17 observations have considered it in the modeling process, 30% articles after 2010 have assumed this effect in analysis. It is also the same percentage of articles that have considered other non-market value such as construction material replacement in the estimation when the year of publication is after 2010. Other variables in the group of methodology design and variations include pattern of carbon payment, other market values than timber and carbon, monitor cost for auditing carbon sequestration, fire and underground carbon.

The last group of explanatory variables concerns study quality. Publication is the most important variable in this group, with which publication bias will be examined. Publication bias is a form of sample selection bias that happens when authors are less likely to submit and publish relatively weak, insignificant or abnormal results (Nelson and Kennedy 2009). It is a commonly employed to distinguish study quality in meta-analysis. Other variables in this group are special for the outliers when estimating the random effect model. Year of publication was also considered to be an examination variable of study quality; it was excluded from the estimation because it may cause the problem of multicollinearity with features recently adopted, such as TPfunction and FossilReplace.

5.2 Estimation results

At first, autocorrelation and heteroskedasticity have been tested to examine the dependency of observations within one primary study and heterogeneity among different studies. According to the result of Dubin-Watson test and LM test, independency among observations have been rejected, which implies autocorrelation among observations from one primary study. Result of LM test with null hypothesis of homoskedasticity on number of observations of primary study is 32.93, which can be rejected with significance level of 0.001. Therefore, original data have also shown heteroskedasticity. Under this situation, OLS estimator will lead to biased and inconsistent results. Therefore, more advanced econometric techniques as weighted OLS and panel data models should be applied to conduct the meta-analysis.

The baseline model is WLS model weighted by sample size in primary study with White robust standard error. As tested before, heterogeneity and dependency has been found out among different studies and heteroskedasticity has been shown to be related to sample size, both WLS and White standard error can help solving the problem of heterogeneity and heteroskedasticity. Robust variances can deal with the problem of within study autocorrelation.

Both random effect and fixed effect model have been applied to the data. There are not any variations on some variables within any single primary study, especially some binary variables in the group of methodology and study design. Therefore, some variables have to be dropped in fixed effect model, such as Tropical, MonitorCost, Fire, PeerReview and two dummy variables for outlier studies. In other words, variations of those variables are enrolled into the intercept for each panel in fixed effect model. Result of Hausman's specification test with null hypothesis of no fixed effects is 5.14, leading to the preference to fixed effect model. When R-squares of the two panel data models are examined, random effect model can explain 45.77% of the total variation, while fixed effect model can explain 93.53%. Both F-test and R-square support the conclusion that fixed effect model fits the data better.

Model fit can be analyzed further with residue analysis. Figure 2 have shown residues of all three models against dependent variable, study ID, and the two numerical variables. It can be deciphered from the figure that fixed effect model fits the data best without obvious trends in any of the four plots. It means the model have explained most variations and the residues are randomly distributed around mean zero. The WLS model also fits the data well, except that there is a positive relationship between residues and the dependent variable, implying that the problem of heteroscedasticity has not been solved thoroughly. All the other three plots are randomly distributed around mean zero. For random effect model, there are positive relationship between residues and the dependent variable, and negative relationship between residues and the discount rate. Therefore, random effect model does not fit data properly.

The judgment of model fit drawn from Figure 2 is also supported by tests for normality of residues. Null hypothesis that mean of the residues equals to zero is not rejected by either t-test or signed-rank-test when fixed effect model is concerned, but is rejected when residues from WLS and random effect model are examined. That is to say only residues from fixed effect model are normally distributed. However, results of all three models are reported because WLS and random-effect model have more explanatory variables than fixed-effect model.

The WLS model can explain 83.82% variations of estimated rotations. Estimated results of the three models are reported in Table 3. All variables are significant under significance level of 10% except ProductDecay and OtherNonMarket. Besides those variables with ambiguous expected signs, all signs of variables are consistent to expectations. For variables in the forest characteristics group, forests in boreal area tend to have longer forest

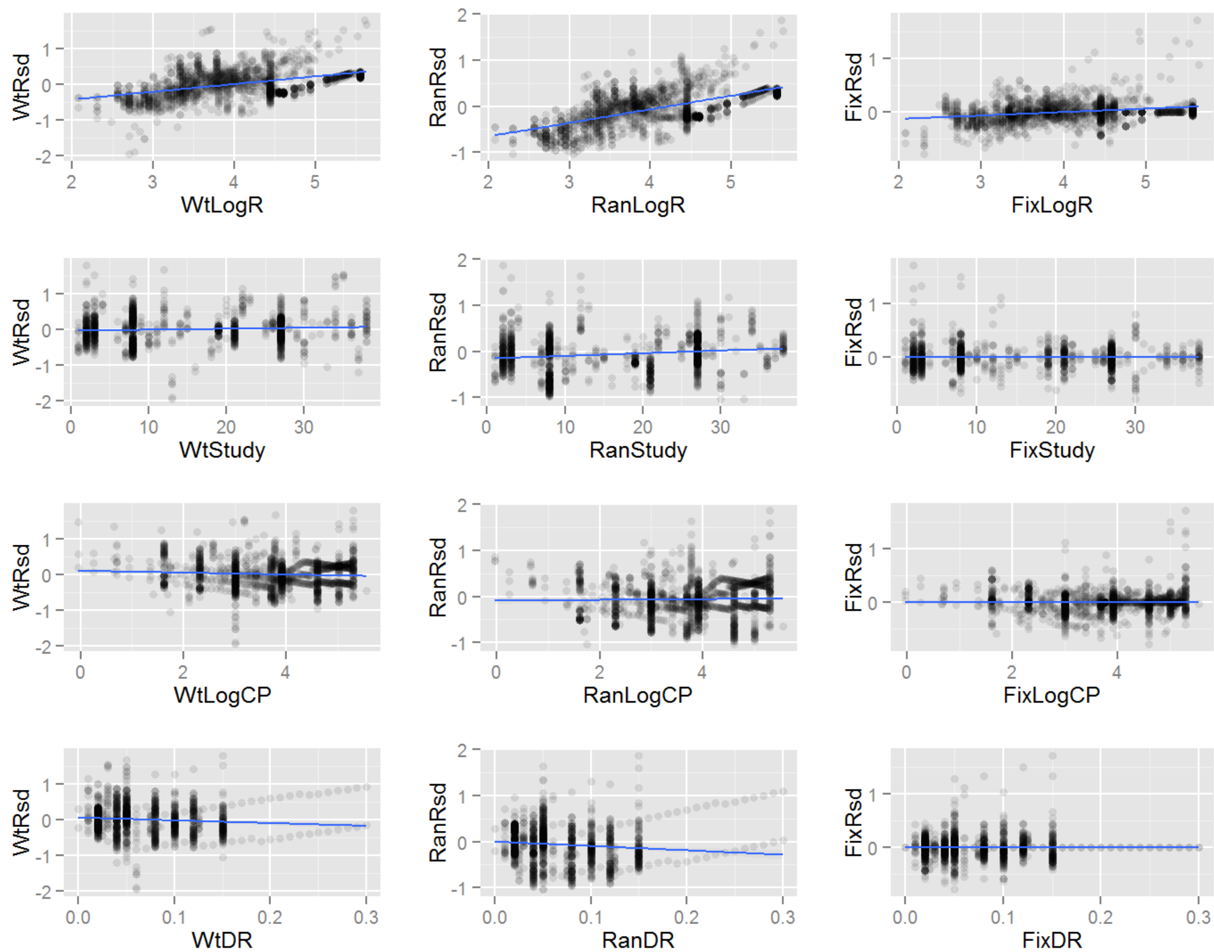

Figure 2: Residual plot for weighted, random and fixed effect models.
Note: Prefixes of *Wt*, *Ran* and *Fix* imply WLS, random-effect and fixed-effect models, respectively. Suffixes of *Rsd*, *LogR*, *Study*, *LogCP* and *DR* imply Residues, log form of rotation age, study ID, log form of carbon price and discount rate, respectively.

rotation age when comparing to temperate forest, but forests' rotation ages in tropical areas tend to be shorter. When broadleaf is set as the baseline, conifer species have relatively shorter estimated harvesting rotations.

Both economic variables are highly significant and of expected signs. It confirms that higher carbon price can pull up estimated rotations but higher discount rates lead to shorter estimated rotations. The former is consistent with Figure 1 and the latter is consistent with comparative statistics with traditional Faustmann model. Publication is significant at 1% level and has a positive sign, which means WLS supports the idea that there is publication bias in articles of this issue. Other variables also have expected signs with highly significant level, in spite of the possible reason of large sample size.

Although fixed effect model fits data better than random effect model, both estimations have similar results. All the signs of forest characteristics and economic variables

Table 3. Meta-regression Results of Three Models

Variable	Model 1: Weighted GLS with White s.e.	Model 2: Random Effect	Model 3: Fixed Effect
Intercept	2.73124***	3.860185***	5.87662***
Forest characteristics variables			
Tropical	-0.85484***	-1.06477***	
Boreal	0.09479**	0.09241**	0.11011***
Conifer	-0.34367***	-0.53626***	-0.59829***
Economics variables			
logCP	0.2034***	0.19002***	0.16276***
DiscountR	-4.00669***	-4.58523***	-5.4303***
Methodology and study design variables			
Faustmann	0.30158***	-0.25097*	-0.21509
TPfunction	0.70270***	0.78655***	0.90622***
Penalty	0.25510***	0.19628***	-0.04858*
OneTimePay	0.50953***	0.48196***	0.14204***
ProductDecay	0.05182	0.01659	-0.09706***
FossilReplace	-1.34058***	-0.6105**	0.06008
OtherMarket	0.36682***	-0.04643	0.00189
OtherNonMarket	0.01767	0.32064**	0.46156***
MonitorCost	0.17138***	-0.05387	
Thinning	0.09613*	-0.07224	-0.11747*
Fire	0.21814***	-0.32736	
Underground	0.88460***	0.09363	-0.03391
Study quality variables			
Publication	0.34436***	0.14701	
Cacho03		-2.1951***	
Susaeta13		-1.38883***	
Model summary			
Study number	35	35	35
Difference	1563	1561	1024
R^2	0.8382	0.4577	0.9353

are significant and within the expectation as results of WLS model. Based on random effect model, conifer species' rotation ages are around 60% shorter, but boreal forests' rotations are about 11% longer. From economics perspective, 1% more carbon payment can increase estimated rotation 0.16%. On the other hand, 1% expansion in discount rate decreases estimated rotations 5.43%. These numbers can be regarded as a summary of the sensitivity analysis among different discount rates to a certain extent.

Relatively less consistent results have been found among methodology and study design variables when comparing results from random effect and fixed effect models. Both models support that when timber price is estimated by distributions or models, rotation ages are longer, which is consistent to results of existing studies with assumption of stochastic prices. Another consistent result of the two models is that one-time payment at the beginning or end of a rotation tends to lengthen rotation ages when comparing to periodical payments. Consideration of other non-market value than carbon sequestration can also prolong estimated rotation ages. Neither of the panel data models supports that differentiations on other market values than timber or on underground carbon can significantly impact estimated rotations.

When results based on two panel data models are different, those from fixed effect model are preferred due to its better model fit. Fixed effect model supports the point of view that adoption of Faustmann-based model does not significantly change the estimated results, though random effect model argues that there is a negative relationship when significance level is set at 10%. Although random effect model and WLS both support that penalty on carbon release can bring to longer rotation ages, fixed effect model argues a weak or insignificant connection between this assumption and estimated results. Different from the other two models, fixed effect model also shows that the consideration of product decaying process can decrease estimated rotation ages, which may be because it can compensate the penalty on carbon release to some degree. However, fixed effect model fails to reject the null hypothesis that inclusion of bioenergy's fossil fuel replacement does not significantly impact the estimated results, which is different than the negative relationship estimated by the other two models. Three models have three contradicted views on the effect of thinning, which is probably a sign of insignificant relationship.

For the variables that are not included in fixed effect model, random effect model does not provide significant results either. In other words, panel data model supports that neither extra monitoring cost for carbon credit nor consideration of fire impacts estimated rotation ages. Fixed effect model also rejects the idea of publication bias concluded by the WLS model.

6 SUMMARY AND DISCUSSION

This article has reviewed 38 studies concerning about harvesting rotations under the scheme of forest carbon sequestration with meta-regression. When comparing the three models adopted, fixed effect model fits the data best, followed by WLS and fixed effect model. All geographic, species and economic variables are highly significant with expected signs for all three models. From the perspective of study designs, the assumptions of stochastic timber prices, one-time carbon payment and the inclusion of other non-market values tend to prolong estimated rotations. The considerations of forest product decaying process and bioenergy's replacement of fossil fuel are inclined to shorten estimated rotations. The effects of using Faustmann-based model and including thinning and underground carbon are insignificant.

Results of this article share some common points of view with van Kooten's meta-analysis on carbon offset cost (2009), but also provide some different ideas. Both studies have confirmed the locations of forests significantly impact the results. Two studies also agree that inclusion or exclusion of soil sinks do not impact estimated results significantly. For the year of publication, van Kooten et al. concluded that carbon offset costs declined slightly with time trend, and this study finds rotation increases with time trend based on the figure. Nevertheless, year of publication is excluded from the latter so time trend is not statistically significant. When the differences are concerned, although van Kooten et al. found products sinks and discount rates are insignificant variables when estimating carbon offset costs, this article finds out they have negative relationship with harvesting rotations. As higher discount rate is a typical factor to shorten rotations, and accounting of carbon decaying process in products can mitigate penalty of carbon release, both negative relationships estimated by this study are confirming the expectations.

Based on the results of this study, some concerns can be alleviated. For example, Faustmann based model is not significantly influencing estimated results, which can be regarded as a neutral-effect model. Underground carbon is a factor under disputes for a long time but is widely accepted as a stable pool recently. Its insignificant sign is probably a verification of this opinion.

Furthermore, some implications can be discovered and discussed according to the results of the meta-analysis. To be specific, some methods and assumptions that are frequently raised in most recent studies have shown significant relationships with estimated results, such as stochastic timber price and bioenergy's replacement of fossil fuel. The consideration of stochastic price adds flexibility to the time of harvesting and makes the waiting more valuable, hence may lengthen harvesting rotations (Newman et al. 1985, Brazee and Mendelsohn 1988, Alvarez 2004). As stochastic price models real world better, and can significantly influence results, it should gain more attention and applications in future research. Bioenergy is also playing an enhancing role in reduction of carbon emission, and is more cost-effective than afforestation (Baral and Guha 2004). When harvesting under the consideration of forest carbon is investigated, role of bioenergy's replacement effect is worthy of better development.

Some other variables are under debate and development, but are estimated as insignificant factors in this analysis, such as monitor cost for auditing carbon sequestration and fire risk. High monitoring cost is regarded as a barrier to bring forest carbon trade into real market but is an insignificant variable in this study. Fire connects to investment risk, timber production and sequestered carbon but does not significantly impact estimated rotations. The insignificance of the two factors may be due to small proportion in total observations and can be treated as a sign they have been neglected in existing studies.

There are some other variables that have obtained unexpected signs. For example, inclusion of other market value such as bioenergy production does not influence estimated results. Although it is possible that the power of this variable is weakened by the variable fossil fuel replacement, it also shows bioenergy production does not offer much economic incentive to landowners to change their forest management pattern. On the contrary, carbon payment pattern can significantly influence harvesting rotations as they tend to be longer when payment is one-time instead of being periodical. Although the result can be brought by the compulsory contract signed when the payment is made on the minimum rotation of harvesting, it still offers a hint on how to encourage landowners to take forest carbon sequestration into their consideration when making management decisions.

In summary, research on estimated harvesting rotations under forest carbon sequestration is a complicated issue that comprehends economics, policy science, ecology and silviculture. Therefore, it is impossible to include every aspect of this issue into a single model. A meta-regression study can help analyzing the impact of factors comprehensively with a concise method. Every study concerning about this issue is a trade-off between modeling the real world precisely and retraining the complexity of the model and the number of variables. This article can help researchers to examine and select designs and factors according to their own research demand, with the baseline to avoid making an assumption without knowing its potential effect on estimated results.

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ISSUES IN FOREST ECONOMICS: YESTERDAY, TODAY, AND TOMORROW

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ABSTRACT

This paper looks at some important technical issues in forest economics. It examines the development in the literature of several issues. These are: the optimal harvest rotation question, timber supply issues including both the optimal drawn-down of old growth forests and issues related to planted forests, multiple-use and non-timber outputs questions, questions of large forest models. Additionally, it discusses optimal control approaches as a tool to providing a long-term timber supply curve. Finally, it speculates with respects to what are likely to be important future issues focusing on forest and carbon, forests as bioenergy questions, and forest sustainability.

Keywords: forest economics; optimal control; optimal rotation; timber supply; harvests

1 INTRODUCTION

This paper reviews some issues in forest economics. First, I will looks back briefly over several issues that have dominated in the past. Then I will address current issues with a focus on current forest modeling efforts. Finally, I will touch briefly where I think forest economics will be going over the next decade or two.

2 METHODS

Important issues in the past have included: The harvest rotation issue; timber supply generally; optimal drawn-down of old growth and optimal rotation of managed and planted forests; multiple-use and non-timber outputs; large forest models and finally optimal control and long term timber supply.

3 RESULTS & DISCUSSION

3.1 The Harvest Rotation Issue

As foresters, most of us know that the science of forestry was developed in Central Europe largely in response to challenges faced on the wood supply side. The notion of a regulated forest recognized that if the periodic harvest equaled forest growth, that both the forest stock and a conforming level of harvest were, in concept, maintainable indefinitely. Faustmann (1849) provided the beginning of a rational (economic) way to assess forest value and thereby determine the optimum harvest rotation. Note that it took non-renewable resource economics almost a centry before Hotelling (1931) developed a corresponding rule for the drawing of a non-renewable resource.

Foresters also developed the concept of silviculture, whereby forest could be managed for selected outcomes as in certain levels of timber production. As these practices became understood, they were adopted fairly quickly in Europe where the land was viewed as fixed and largely claimed. However, Europeans struggled for some time with questions such as the optimal rotation in forestry and Ohlin (1921) confirmed Faustmann's earlier (1849) results. These were revisited in the US by Samuelson (1957).

3.2 Timber Supply: Planted Forest and the Optimal Draw-down Question

But America was different from Europe. The continent contained huge areas of wild unclaimed forest. New stands of timber could be obtained merely by moving over the next ridge and beginning to log. Indeed, the forest was viewed as an impediment to agricultural development. So as Europe was moving toward sustainable management, American was trying to rid itself of is huge excess of forestland to make way for agriculture. As late as the 1970s forestry papers continued to address the question of the optimal rate of drawn-down of the surplus forest (Walker 1971, Berck 1979, Lyon 1981).

3.3 Multiple-use and Non-timber Outputs

As the forest drawdown continued concerns arose regarding non- timber forest outputs and values. Legislation was directed to provide for multi-use forestry (1960). Gregory (1955) made and early attempt to look at the question through economics. Bowes and Krutilla (1989) spend over 10 years in an effort to tie down the multiple-use management approach. Jack Ward Thomas, forestry chief, put on a full press to codify Ecosystem Management for the Forest Service. Much work has focused on biodiversity, species preservation and more recently, carbon.

3.4 Large Forest Models

Simultaneously to efforts at multiple-use, forest management models were growing increasingly sophisticated over the years. With the help of increasingly powerful computer systems, the sophistication of the models increased, from simple linear projections to increasingly sophisticated solution techniques.

Around this time the Forest Service was also beginning to use models to address questions of managing the public forests. They used a number of different relatively large forest models. To name a few: the TAM (Adams Haynes 1980) was used to project future forest stocks and timber levels, while the FORPLAN model (Johnson and Scheurman 1977) was developed to help the Forest Service make decisions about harvest levels and their impact on non- timber values. Other models looked at timber (Hyde 1980) and fiber, PAPYRUS, (Gilless and Buongiorno 1988) as well as land use for forests and agriculture, FOSUM (ALIG et al. 1997). Toward the end of the 20th Century models increasingly began to view forests in an international context as with the "Global Trade Model" (Kallio, Dykstra and Binkley 1987) the "Timber Supply Model" (Sedjo and Lyon 1990; Sohngen et al. 1999) modeling the global forest system.

3.5 Some Current Issues with Forest Models: Solution Approaches

These larger models are now increasingly being used to address global environmental issues, particularly carbon. I have no doubt that carbon issues will continue to dominate much of forestry and forest economics research. I want to address some of the aspects of these models with a look at the introduction of a forward looking (rational expectations) modeling capacity. Over the last decade of the 20th Century forest models began to incorporated rational expectations approaches (Sedjo and Lyon 1990, Alig et al. 1997; Sohngen et al. 1999). I want now to look at the difference between the rational expectations approach and some of the earlier, and still common, approaches.

Most of the commodity- focused models use a supply and demand approach. The supply is developed by looking at the forest, its stock and how that stock may change through time due to the effects of growth (yield curves), forest management and land area expansion. Since sequestered carbon is tightly related to the forest stock, models that examine the forest stock and changes in over time can easily be useful in addressing issues of the effects of forest carbon changes on atmospheric carbon.

Super imposed on the supply from the forest stock is a demand, usually for forest products but it might include biomass or carbon sequestration. In many projection models a judgment is made of how that demand is expected to change through time. Commonly, the future prices of the wood commodity are estimated exogenously, using a variety of approaches. Note these projections represent future equilibrium positions. Future harvest levels are often based on these projections. Does the model build these future exogenous expected prices into an investment function? Often not. Commonly the level of forest investments, e.g., management and expansion (or contraction) of forest stock is also exogenously determined and does not explicitly consider future prices. Thus, commonly the future forest stock and thus supply is only loosely, if at all, related to expectations of future prices.

3.6 Rational Expectations and the Long-run Timber Supply Curve

Fortunately, the use of optimal control techniques now allow for a more sophisticated rational expectations (see Muth 1992) approach to forest management. As with other approaches, rational expectations (forward looking) models begin with a given stock of forest. Superimposed on this system is a demand function for the wood commodity and an expectation (exogenously determined) of the demand's future growth through time. The system is then solved (simultaneously) for the vector of future prices that maximized the discounted present value of the forestry activity. Unlike earlier models, prices are now endogenously determined. In addition, on the supply side, investments in the forest, both management and expansions are now a function of that same vector of future prices. So on the supply side, both management level and forest area changes are determined endogenously, through their future expectated economic returns as related to the vector of future prices. Thus, we now have a long term supply curve based on future expectations. Given demand and the forest conditions, the prices, harvest levels, investments levels including management inputs and land areas are all endogenously determined to maximize present value. Articulated differently, they are all maximized consistently with market signals.

Changes in the forest stock through time are based on yield projections, as effected by management. In addition, there is a function relationship between current and a maximizing vector of future prices, and investments in forest management and forest expansion (or contraction).

Finally, you may say we don't know future demand. That is correct. But none of the earlier models knew future demand or price either. Rather than dealing with a demand function, they guessed at equilibrium points on the function. And most did not systematically relate these "guesses" back to the stock on the supply side of the equation.

4 CONCLUSIONS - TOWARD THE FUTURE OF FOREST ECONOMICS

Forecasting is difficult, especially if it is directed at the future. And, I must admit I am not very sure of where forest economics is headed over the longer term. We know however, that its techniques tend to follow those of general economics and its issues are often similar to those of agricultural economics and, more recently, environmental economics.
Forest economics will need to continue addressing emerging issues related to forests, water, biodiversity, carbon, etc. Although these issues are important in themselves, these issues are increasing being driven by the broader concerns with climate change and its impact on the environmental and natural systems.

Let me be a bit more specific. I believe that the changes in forestry over the next decades are likely to include issues related to: a) the move away from integrated forest products operations to TIMOs; b) forest certification, both in the developed and also in the developing world; c) bioenergy; and d) the growing pressures for forests to provide an increasing array of environmental services, particularly those related to climate change.

Let me suggest that for the immediate and intermediate term, the dominate focus, at least for economists, is likely to continue to be on issues related to climate change. The interaction of forest and carbon has been important. What influence do forests and forest management have on climate? Can forest contribute to the control of GHGs? By sequestering more carbon? By providing an alternative energy source to fossil fuels? These issues have been under examination since the late 1980s, driven in part by the activities of the IPCC. To examine these issues even more thoroughly is likely to require more modeling work. This work needs to more completely capture the essence of the underlying forest production function and its relations to the operations of markets, and of policies upon the system.

Indeed, these concerns go beyond the forests of the industrial world and raise questions about the forests of the developing world. I have been involved in issues regarding tropical deforestation and more broadly the development of a more comprehensive ability to monitor and measure these forests. However, I am not sure what economics alone can bring to the solution of these issues. We can see an increased role of remote sensing and the like. Also, voluntary "forest certification" can play a role. Perhaps new econometric techniques and models can contribute here.

Finally, with the new and likely focus of forests on carbon and sustainable systems, a more careful and comprehensive modeling approach has become particularly important in a world trying to wean itself from fossil fuels and looking toward renewables including biomass energy. The great plantation boom of the last half of the 20th century created of plethora of timber. We now have a "green wall" extending well into the 21st century that can capture carbon while providing a substitute for fossil fuel energy and continuing the production wood products.

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WOOD BIOMASS CONSUMPTION OUTLOOK IN THE U.S. NORTH

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ABSTRACT

Using historical trend analysis and econometric models, this study forecasts Northern U.S. regional wood energy consumption for high, baseline, and low demand scenarios. In the next 30 years, the total wood energy consumption in the Northern U.S. is forecasted to increase respectively 170%, 4% and -43% under high, baseline, and low demand scenarios.

Keywords: Biomass demand, prediction, forest industry, residents, electric power

1 CURRENT WOOD ENERGY CONSUMPTION BY SECTORS

Wood energy in the U.S. is consumed by four energy consumption sectors: Industrial, residential, electric utility sector and commercial sector that used 66%, 21%, 10%, and 3% respectively (U.S. DOE 2013). Majority of such energy is used by the industrial and residential sectors. The electricity and commercial sector used a total 13% of the national wood energy although they enjoy more policy promotion than the other two sectors (Aguilar et al. 2010).

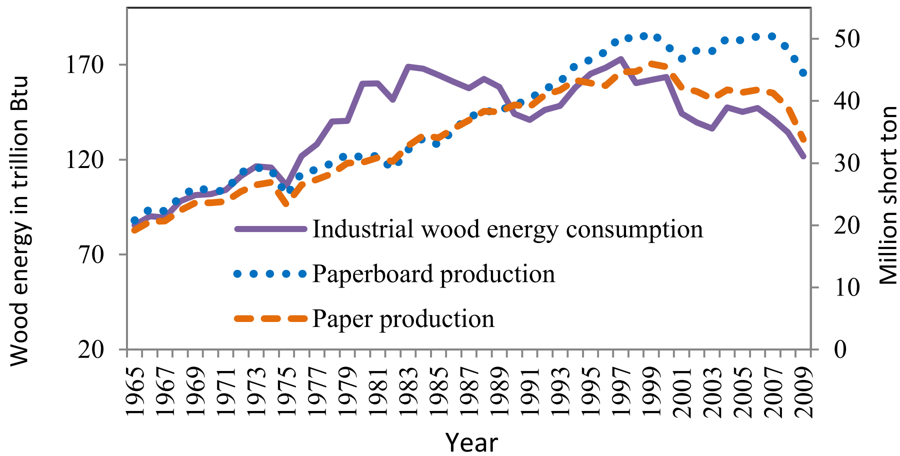
2 FUTURE WOOD ENERGY CONSUMPTION IN THE INDUSTRIAL SECTOR

The drivers for the wood energy consumption in the industrial energy consumption sector were first identified through graphic analysis. An estimated model was chosen to forecast wood energy consumption in the U.S. and scale down to the Northern region.

2.1 Drivers and the indicator for the industrial wood energy consumption

Wood residues from paper production and wood products manufacturing are the major source of wood energy of the industrial sector, and wood products industry (NICS 321) and pulp and paper industry (NICS322, U.S. DOE 2010) consume most of the wood energy in this energy sector. Major domestic products, lumber, paper and paperboard are candidate variables that drive wood energy consumption in the industrial sector.

Paper production and paperboard production from 1965 to 2009 show that paper production has a pattern similar to that of wood energy consumption by the industrial sector (Graph 1). The correlation between the two time series is 0.80 while the correlation between wood energy consumption and paperboard production is 0.65.

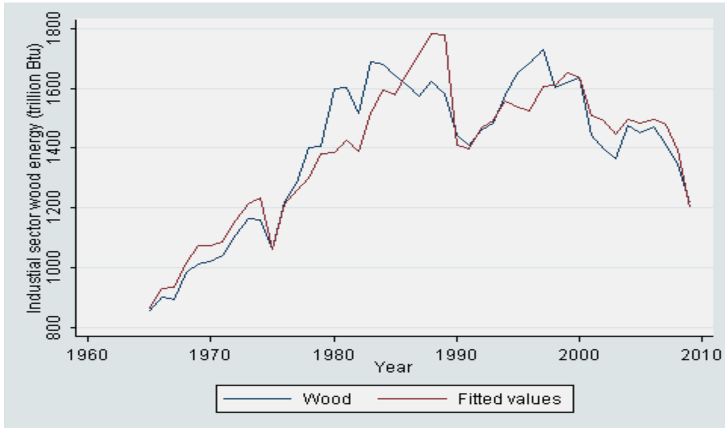


Graph 1. Wood energy consumption by U.S. industries, paper and paperboard, and lumber production (Data: U.S. Census Bureau 1968-2011, Howard 2007)

2.2 Model estimation for the industrial sector

The industrial wood energy consumption was regressed on paper production, paperboard production, and lumber production. Historical national wood energy consumption data for the industrial sector from 1965 to 2009 were from U.S. DOE (2010), national paper and paperboard production numbers and lumber production data were from the U.S. Statistical Abstracts (U.S. Census Bureau 2013) and Howard (2007). To represent the regime change in around late 1980s and early1990s (Graph 1), a dummy variable for years since 1990, named D90, was included. An interactive term *paper*D90* was also included to capture possible interaction effect.

The variables of the forecast model for wood energy consumption in the industrial sector was selected by backward step-wise variables selection method that started with all the five regressors and a constant. The final model includes only constant, paper production, D90, and the interactive term paper*D90. Unit root test rejected the hypothesis of one unit root in the residual. We, therefore, are confident that the estimation is valid even though some of the time series data for paper production may be nonstationary. Graph 2 shows the fitness of the estimation.



Graph 2. U.S wood energy consumption in the industry sector and fitted values from 1965 to 2009

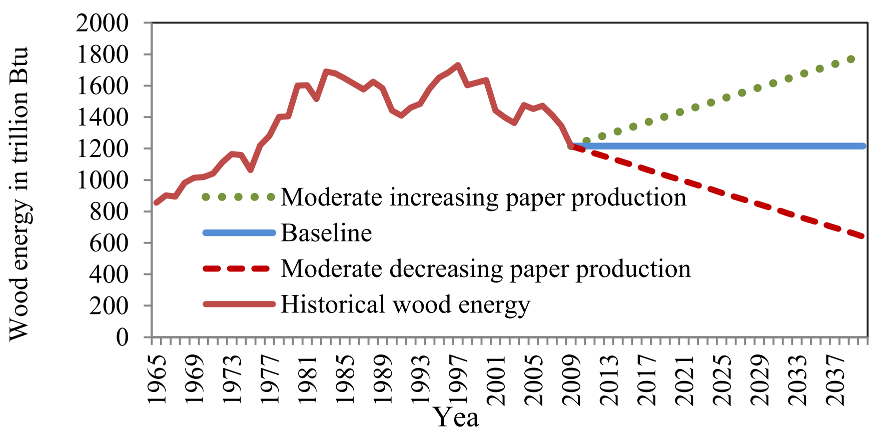
2.3 Prediction for the industrial sector

Paper production had been increasing 0.75 short-tons per year averagely during the 35 years period from 1965 to 2000. Since then it has been on declining path in recently, and we do not expect it to have a 0.75 million short-tons increase per year in the next 30 years (Ince 2000). The three scenarios for our prediction are as follow:

I. High demand scenario: paper production increases 0.5 million short-tons each year.

II. Baseline scenario: paper production maintains 2009 level in the next 30 years.

III. Low demand scenario: paper production decreases 0.5 million short-tons.



Graph 3. Predicted wood energy consumption in the industrial sector, 2010 to 2040

Forecasts for industrial wood energy consumption by scenarios using estimated model are shown in Graph 3. Suppose the amount of paper production in the U.S. North is proportional to its production cost whose data for the year of 2010 are available from U.S. Census Bureau, then 44.3% of the total U.S. paper is produced in this region.

3 FUTURE RESIDENTIAL WOOD ENERGY CONSUMPTION

3.1 Model

Residential energy consumption sector is the second largest wood energy consumption sector. The amount of U.S. national wood energy consumption was first estimated with a published econometric model (1) (Song et al 2012), then the forecasts for the U.S. North wood energy consumption in this sector were estimated as a fraction of national consumptions.

$$LWOOD_t = 1.82LPNW_t - 2.12LWAGE_t - 0.03t + 66.48 + \varepsilon_t \quad (1)$$

Where *LWOOD* is the logarithm of wood energy consumption by U.S. residents; *LPNW* is the logarithm of composite non-wood energy price; *LWAGE* is the logarithm of wage rate of U.S. production workers; t is time in years; ε_t is a random term.

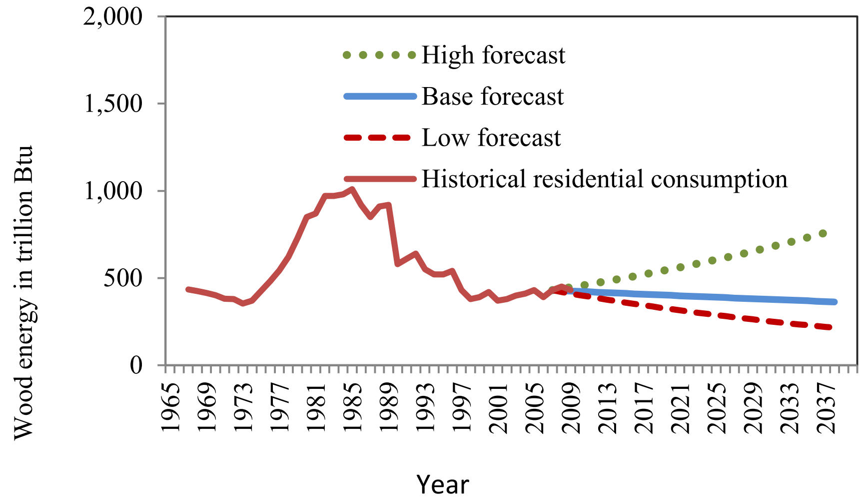
3.2 Scenarios prediction for the residential sector

Historical data have shown that non-wood energy price had a positive trend. Over 42 years from 1967 to 2009 the annual change in energy price (*LPNW)* is 0.0134, and it could be as high as 0.0817 (from 1973 to 1983). The wage rate of production workers in 1967 was almost the same as it was 42 years later, but it has been increasing most of the time since 1993 with an annual rate of change in *LWAGE* 0.008. We expect the wage rate to be at least as high as it was in 2009, and likely to increase in the next 30 years. The U.S. national wood energy consumption was forecasted with model (1) for the following three scenarios.

I. High demand scenario: moderate increasing paper production. High increase in non-wood energy price with *LPNW* increasing 0.0268 per year (two times of the historical average 0.0134); no change in wage rate.

II. Baseline: moderate increase in non-wood energy price *LPNW* increasing rate 0.0134 per year; No change in wage rate.

III. Low demand scenario: moderate decreasing paper production. Low increase in non-wood energy price with *LPNW* increasing rate 0.0067 per year, high increase in wage rate with 0.80% per year or *LWAGE* with 0.0080 per year.



Graph 4. U.S. wood energy forecasts in the residential sector, 2010 to 2040

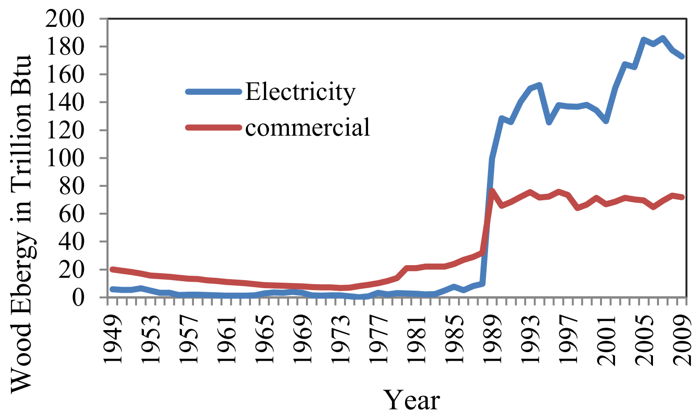
Graph 4 shows the U.S. national forecasts in the residential sector for the three scenarios using equation (1). The residential wood energy consumption values in the 20 Northern States were predicted to be 42% of the U.S. total, where 42% is the ratio of U.S. North residential wood energy consumption to that of U.S. total based on U.S. Residential Energy Consumption Survey (RECS) 2005.

4 FUTURE WOOD ENERGY CONSUMPTION IN THE ELECTRIC UTILITY SECTOR

4.1 Historical changes

Wood energy consumption by the electric utility sector increased from 10 trillion Btu in 1988 to 172 trillion Btu in 2009. Such dramatic changes were shown to be a result of preferential public policies such as the Public Utility Regulatory Policies Act (PURPA) (Aguilar et al 2011).

The biomass capacity in the U.S. North is 1,099 MW, 44% of the total U.S. capacity 2,508 MW in 2009 (Oak Ridge National Laboratory 2011). The wood energy consumption by the U.S. North in 2009 was estimated to be 44%×172 = 76 trillion Btu. The biomass power capacity in the U.S. North increased 22.5 MW per year from 1967 to 2009 based on available data from Oak Ridge National Laboratory (2011).



Graph 5. Historical wood energy by electricity and commercial energy consumption sectors

4.2 Scenarios prediction for the residential sector

Among major woody biomass consumption states in the U.S., Maine has the highest forest inventor to biomass power ratio: for each billion cubic feet of timber, there is 13.1 MW of biomass power capacity in Maine Based on forest inventory data from Smith et al. (2010) and biomass power capacity data from ORLN (2011). The U.S. North has a total of 268 billion cubic feet of timber, and it may support up to 3,511 MW of biomass power capacity if each acre of forest will support biomass power as high as Maine does. About 69 million Btu of wood energy (other biomass is not included) is needed for each MW of electric power based on the total wood biomass consumption and the total U.S. biomass electricity capacity.

The three scenarios for the electric utility sector are as follow.

I. High demand scenario: the U.S. North will gradually build 3,511 MW of biomass power by 2040, reaching the forest inventory to biomass power ratio of Maine State. A total 242 trillion Btu of wood energy will be needed annually by then; annual increment of wood energy consumption in this sector in the U.S. North is 5.35 trillion Btu.

II. Baseline scenario: the demand for wood energy from biomass power will grow as it did from 1967 to 2009. The demand will increase $22.5 \times 69/1000 = 1.55$ trillion Btu per year (assuming a constant thermal efficiency and constant non-wood biomass proportion used in electric power generation).

III. Low demand scenario: there will be no increase in wood energy consumption, and the consumption will stay at 85 trillion Btu, the estimated 2009 level in the North.

Wood energy consumption by the electric power sector in the US North were predicted to increase from 76 trillion Btu in 2009 to 242, 124, and 76 trillion Btu under high, baseline and low demand scenarios.

5 FUTURE WOOD ENERGY CONSUMPTION BY THE COMMERCIAL SECTOR

Because the similarity of historical wood energy consumption patterns in the commercial sector and the electric utility sector, the later sector was used as a reference to estimate the future consumption in former sector.

Majority of the current wood energy consumption in the commercial sector was gained from 1976 to 1990 as in the electric utility sector, but wood energy consumption in the former sector has increased at less than half of rate of that in the later sector (Graph 5, Aguilar et al 2011). In 2009, the wood energy consumption by the commercial sector was 42% of that in the electric utility sector. Increment in wood energy consumption in the commercial sector in recent years was very small, and there is no sign that this ratio will change. So 42% of the high demand scenario consumption in the electric utility sector is our high demand scenario for the commercial sector. The wood energy consumption in this sector in 2009 in the U.S. North is assumed to be 32 trillion Btu, 42% of 76 trillion Btu of wood energy consumption in the electric utility sector. The three scenarios for this sector are as follow.

I. High demand scenario: 42% of high scenario consumption in the electric utility sector.

II. Baseline scenario. The consumption for wood energy in this sector increases 0.33 trillion Btu per year (half of 42% of the 1.55 trillion Btu)

III. Low demand scenario. There will be no increase in wood energy consumption, and the consumption stay at 32 trillion Btu.

The predicted future wood energy consumption by the commercial sector increases from 32 trillion Btu in 2009 to 102, 42 and 32 trillion Btu in 2030 under high, baseline and low demand scenarios.

6 OVERALL FORECASTS FOR THE U.S. NORTH

Adding all the forecasts for the four sectors, we obtained the total forecasts for high, baseline, and low demand forecasts for the U.S. North in Table 1. The wood biomass energy forecast for the U.S. North under high demand scenario is 1,463 trillion Btu by 2030, higher than any estimated historical wood energy consumption in this region, assuming 44% of U.S. wood energy is consumed in the U.S. North (US DOE 2012). The baseline forecasts represent the historical trend in recent decades and will only moderately increase by 3% in 30 years. The low demand forecast represent a decline in wood energy uses it may only happen when energy price is low, paper industry remains declining, and biomass electric power receives less preferential policy support. The current economic recovery may produce more funding for biomass programs and promote woody biomass energy. Higher than baseline wood energy consumption forecasts are more likely when energy price is high.

Table 1. Forecasts for wood energy consumptions of the U.S. North by three scenarios

	U.S. North (Trillion Btu)		
Year	I High demand forecast	II Baseline forecast	III low demand forecast
2009	827	827	827
2010	847	828	815
2011	866	829	803
2012	885	830	791
2013	905	831	779
2014	925	832	767
2015	944	833	755
2016	964	834	744
2017	984	835	732
2018	1,004	836	720
2019	1,023	837	709
2020	1,044	838	697
2021	1,064	838	686
2022	1,084	839	675
2023	1,104	840	664
2024	1,124	841	652
2025	1,145	842	641
2026	1,165	843	630
2027	1,186	844	619
2028	1,207	845	608
2029	1,228	846	598
2030	1,248	847	587
2031	1,269	848	576
2032	1,291	849	565
2033	1,312	850	555
2034	1,333	851	544
2035	1,354	852	534
2036	1,376	853	523
2037	1,398	854	513
2038	1,419	855	502
2039	1,441	857	492
2040	1,463	858	482

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ANALYSIS OF IMPORT DEMAND FOR LIGHTWEIGHT THERMAL PAPER IN THE UNITED STATES

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ABSTRACT

Lightweight thermal paper (LWTP) is a noteworthy import commodity with wide usage and large import value in the United States. In this study, the trade pattern and market dynamics of the LWTP import market in the U.S. has been examined based on almost ideal demand system. The results revealed that both the trade volume and import source of LWTP had changed during last decade. Competition relationships were found among major suppliers in both the short run and long run, and the long-run competition is stronger than that in the short run. The repeal of restriction on conducting countervailing investigation against non-market economy temporarily stimulated the import of LWTP products from China, but the following antidumping/countervailing investigation and the corresponding punitive duties generated trade depression effect on the imports. In addition, positive trade diversion effect was found on German products, which raises doubt on the effectiveness of this trade remedy policy.

Keywords: antidumping; countervailing; cointegration; demand elasticity; paper product

1 INTRODUCTION

As a widely used paper product, the lightweight thermal paper (LWTP) product typically refers to a type of paper products with thermal active coating on one or both side, and can be used in point-of-sale applications such as credit card receipts, gas pump receipts, and retail store receipts. In the U.S., a large portion of the LWTP products consumption is met by imported products. For instance, based on the total value of shipments, the percentage of imported LWTP products in total U.S. domestic consumption is 30.91% in 2007, and the ratio between imports and domestic value of shipments is 44.73% in the same year (U.S. ITC. 2008). During last decade, the import of LWTP products has been increased greatly in the U.S. In detail, the annual total import value of LWTP products in the U.S. increased from 160 million U.S. dollars to more than 350 million U.S. dollars in 2012. Besides the large increase in import value, the suppliers in the import market of the United States have also changed. Among traditional major suppliers, Japan and United Kingdom lost most of their market shares to Germany. China has also emerged as a new power and finally become the second largest supplier in this market during this period. Obviously, the fast increases of LWTP products imported from Germany and China generated great pressure to U.S. domestic LWTP manufacturers. Therefore, as an response to the increasing

LWTP import from China and Germany, an antidumping/countervailing (AD/CVD) investigation against Chinese and German LWTP manufacturers was conducted in 2007, and various AD and CVD duties were imposed to subject products eventually in late November 2008.

The change of trade pattern of imported LWTP products in the U.S. indicates that the import demand of LWTP products in the U.S. has been affected by various factors such as competition, consumer behavior, and trade remedy policy and corresponding trade remedy measures. However, no study has been conducted in terms of the mechanism of how those factors affect the import demand of LWTP products in the U.S., which is an interesting topic that merits a detailed analysis.

Driven by the motivation to fill this knowledge gap, the overall objective of this study is to assess the growing import demand of LWTP products in the U.S. from January 2002 to June 2013 by source, and to examine the mechanism of how this import demand has been affected by relevant economic and non-economic factors. Thus, both static and dynamic specifications of the Almost Ideal Demand System (AIDS) are used to access the results in the long run and short run, respectively. In detail, the dynamic AIDS model is constructed with techniques from time series econometrics (Enders 2008), the Engle-Granger two-stage method has been adopted to conduct the cointegration analysis and evaluate the long run equilibrium for each supplier in this market. The product scope is determined under the Harmonized Tariff Schedule (HTS) classification system (U.S. ITC. 2013). Monthly import price and quantity of LWTP products for five major supplying countries from January 2002 to June 2013 is collected from the online data base of U.S. ITC. (2013).

In this study, the main reasons for using AIDS model as the base model are its feature as a consumer dimension model (Yang and Koo 1994) and wide applications in evaluating market competition and import demand (Henneberry and Mutondo 2009). Based on the AIDS model, both the economic and non-economic factors affecting this market are examined. In terms of the effects from economic factors, consumer behavior and market competition in this market are examined in this study. At first, the effects from expenditures and own-prices are examined to reveal the consumer behavior related to imported LWTP products in the U.S. Five supplying countries which take more than 85% market shares in total are considered as the major choices that U.S. consumers have. Expenditure and Marshallian own-price elasticities are calculated to evaluate the consumer choices over the different supplying countries. In this case, the results in terms of consumer behaviors become more informative by differentiating them by time-range, (i.e. short run and long run). Other than the consumer behavior, market competition among major supplier of LWTP products in the U.S. import market is measured by analyzing the calculated Hicksian cross-price elasticity (Deaton and Muellbauer 1980). From the estimates of cross-price elasticity, the substitutability and complement relationship between major suppliers are revealed (Feleke and Kilmer 2007). Overall, various elasticities are calculated to examine the mechanism of how economic factors affect the import demand of LWTP products in the U.S.

Furthermore, in terms of the non-economic factors, the repeal of restriction on countervailing (CVD) investigation against Non-market economy (NME) on March 2007 and the following antidumping/countervailing (AD/CVD) investigation against LWTP products from China and Germany are considered as the two major events which affecting the import demand of LWTP products in the U.S. At first, the CVD investigation policy change was announced in the preliminary determination of the investigation against Coated Free Sheet Paper from China on March 2007 (U.S. ITC. 2007). This affirmative determination dramatically increased the possibility of being investigated for the products imported from China, especially for the paper products. This event is supposed to affect the import of LWTP products from China since importers in the U.S. may adjust their strategies of importing Chinese LWTP products in case of the possible investigation and punitive duties in the future. On the other hand, since some types of Coated Free Sheet Paper is similar to LWTP, they may be imported under the HTS classification of LWTP to avoid the punitive tariff temporally (U.S. ITC. 2007).

Other than the investigation policy change, the effects from the AD/CVD investigation six months after this policy change also need to be evaluated. As common offset measures, the AD/CVD duties are imposed to protect domestic industry by offsetting the "unfair low price" and the government subsidy given by the subject country. In general, the impositions of AD and CVD duty on a commodity have similar outcomes of decreased import quantity from subject countries (Kelly 2011). However, due to the flexible strategies that can be used by market participants, this duty effect may not be attainable (Staiger and Wolak 1994). Additionally, other than the imposition of duty, the development of the investigation per se generates an impact on the import demand of a commodity due to the length of an investigation, which can be as long as 18 months. Thus, the investigation effect and the duty effect need to be evaluated together (Lloyd, Morrissey, and Reed 1998). In this study, the AD/CVD investigation has lasted for 15 months and experienced several stages. Thus, dummy variables representing three key time points are set and estimated to evaluate the effects from them. The empirical findings of the effectiveness of the U.S. trade policy for the LWTP products on the import market from this study are supposed to be informative to the policy makers and market participants, in either the supplying countries of LWTP products or the U.S. per se.

The rest of this paper is organized as follows. An overview of the import market, relevant trade policy, and AD/CVD investigation is presented in Chapter 2. Then the detailed methodology adopted by this study is displayed in Chapter 3. The descriptions of data source and variables need to estimate are presented in Chapter 4. At last, the empirical findings are reported in Chapter 5, and conclusions and discussions are showed in Chapter 6.

2 OVERVIEW OF MARKET, INVESTIGATION, AND RELEVANT POLICY

2.1 Market Overview

As required materials for thermal printers which are widely used in printing receipts, the lightweight thermal paper (LWTP) products are commonly used in almost every point of sale (POS) and gas stations all over the U.S. Due to the vast demand, import of LWTP products in the U.S. has experienced a significant increase in recent years. In detail, the import value of LWTP products in the U.S. has increased from 160 million U.S. dollars in 2002 to 350 million U.S. dollars in 2012. Other than the increase in trading value, the pattern of import sources has also shifted.

Historically, the major suppliers of lightweight thermal paper in the U.S. import market are Germany, Japan, and United Kingdom. According to the detailed data reported in Table 2.1, in

2002, each of these three countries took more than 10% market share and totally took 79.58% of the market share. By ranking of import value, the first three major suppliers were Germany (62.21 million U.S. dollars), Japan (49.12 million U.S. dollars), and United Kingdom (16.34 U.S. dollars), which accounted for 38.78%, 30.62%, and 10.18% of the market share, respectively. However, in 2012, the first three major suppliers were Germany (170.68 million U.S. dollars), China (70.86 million U.S. dollars), and Japan (43.00 million U.S. dollars), and corresponding market share were 48.92%, 20.31%, and 12.31%. United Kingdom, which was the third largest supplier in the market in 2002, only left 2.69% of the total market share and no longer existed among the top three suppliers in 2012. Similarly, even though the trade value appears steady, the market share of Japan also dropped dramatically. In contrast, with rapid growth during 2002 to 2012, Germany consolidated its position as the largest supplier of LWTP products in the U.S. import market. Specifically, the import value of LWTP products from Germany was 62.21 million U.S. dollars in 2002, but it increased to 170.7 million dollars in 2012, and the market share of German imported LWTP products in the U.S. also increased from 38.78% to 48.90% accordingly.

Table 1. Comparison of the U.S. LWTP Import Market in 2002 and 2012.

Country	Import Value ($ million)	Market Share	Ranking
2002			
Canada	4.66	2.90%	5th
China	2.82	1.76%	6th
Germany	62.21	38.78%	1st
Japan	49.12	30.62%	2nd
United Kingdom	16.34	10.18%	3rd
2012			
Canada	24.51	7.01%	4th
China	70.86	20.31%	2nd
Germany	170.68	48.92%	1st
Japan	43.00	12.31%	3rd
United Kingdom	9.43	2.69%	7th

Note: All values were the import cost-insurance-freight values of the lightweight thermal paper products with HTS code 4811.90.80. Source: U.S. ITC (2013).

Other than Germany, China is another country which gained great increase in this market. The market share of Chinese LWTP products in the U.S. increased from only 1.76% in 2002 to 20.31% in 2010. After a 15-year long journey started from 1986, China eventually joined the World Trade Organization (WTO) in December 11, 2001. Since then, as policy restrictions were released gradually, Chinese companies started to get deeply involved in the international trade. Likewise, China began to increase its export of LWTP products to the U.S. since 2002, especially during the period between 2002 and 2004. Specifically, the import value of Chinese lightweight thermal paper was 2.82 million U.S. dollars in 2002, but during the study period this value boosted to a peak during study period of 97.95 million U.S. dollars in 2004, which has increased more than 30 times. Since then, even though there remained some fluctuations, China was always among the top three suppliers of lightweight thermal paper products in the U.S. Compared to China, the growth of Germany was more steady. Before reaching the peak of 184.5 million U.S. dollars import value in 2008, the average growth rate of the U.S. import value of German lightweight thermal paper was 25%. Specifically, Germany had displaced Japan as the largest supplier on the U.S. imported lightweight thermal paper market since 1999, and its market share exceeded 50% in 2008 (52.6%) for the first time. After that, the market share of Germany had decreased a little to 47.7% (in 2010), but it remained the largest foreign supplier of lightweight thermal paper product in the U.S. market until the end of study period. Overall, some traditional major suppliers such as Japan, Canada, and United Kingdom lost considerable market share, and this part of demand has been met by some emerging countries in this market (i.e. Germany and China). The trade pattern during study period is reported in Figure 1.

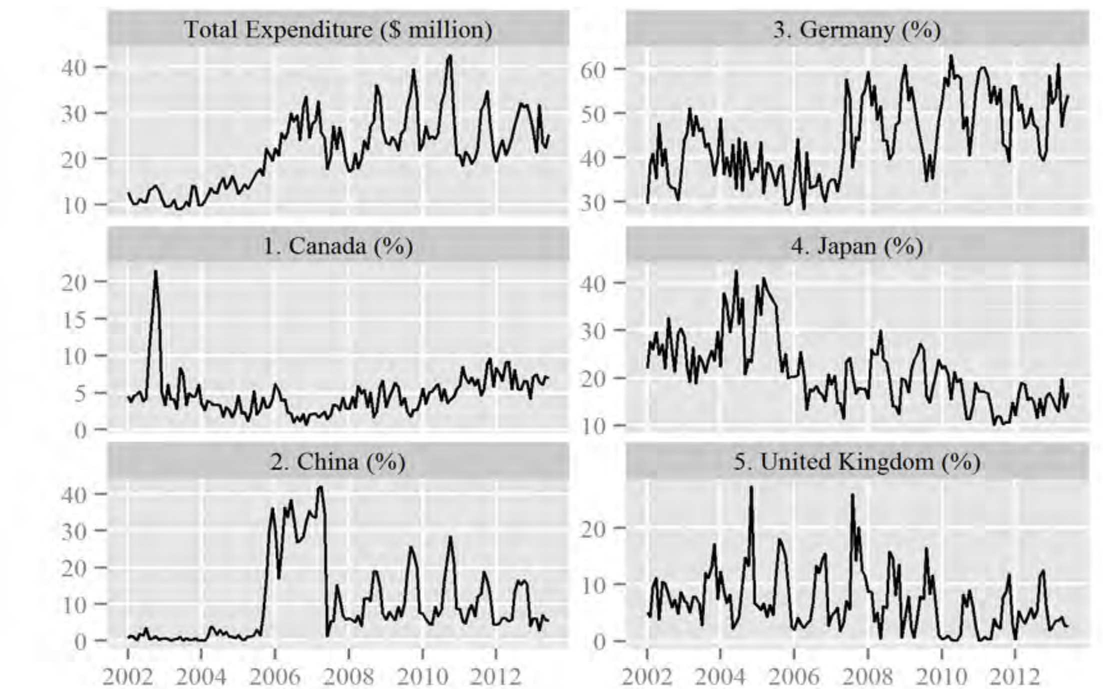

Figure 1: Monthly Total Expenditure of Imported LWTP in the U.S. and the Import Share by Country from January 2002 to June 2013.

2.2 Overview of Antidumping and Countervailing (AD/CVD) Investigation and Relevant Policies

Except the market per se, change has also taken place on the trade policy level, especially with regards to the protective trade policy toward some non-market economies (NMEs) such as China. Before discussing the detail of trade policy change, it is necessary to briefly summarize the concept and development of relevant policies and trade remedy measures.

In general, a variety of measures are used by nations to protect their domestic industry from the pressures of foreign competitors. Although most of them were claimed by the economists as inefficient (Blonigen and Prusa 2003) or unjustified (Deardorff and Stern 2005), antidumping and countervailing (AD/CVD) duties are the most commonly used due to their special political status. In general, the AD/CVD duties are viewed as the measures which are able to correct unfair market competition by offsetting the unfair price margin and subsidization but without creating distortion in trade (Kelly 2011). From the perspective of mechanism, countervailing duties are

imposed in response to subsidies, while antidumping (AD) duties are imposed in response to "dumping", which means selling products in a foreign market at less than "fair" value (LTFV). Once the named category of imported products has been determined to be sold at LTFV in the U.S. market, such products can be subject to a punitive AD duty. Likewise, if certain imported products are found to receive a subsidy from foreign governments and materially injure or threaten the domestic industry, this product will be subject to the CVD duty. Accordingly, the punitive tariff rate will be calculated based on the margin of underselling or margin of subsidy, and expected to offset the effect of dumping or subsidization, respectively.
Theoretically speaking, the AD and CVD investigation can be conducted against any countries and these two measures have similar effects. Similarly, according to the WTO agreement, AD and CVD actions against the same set of products from the same country are permitted to be conducted simultaneously. However, during the time period between 1980 and 2007, the U.S. Department of Commerce determined that they could neither identify nor measure grants or subsides in non-market economies (NMEs). In this case, the subsidies to producer in an NME country were not countervailable because the purpose of the countervailing duty is to offset the unfair competitive advantage that foreign producers received from government subsidies (Prusa and Vermulst 2013).

In detail, in a typical "non-market economy" country, the companies which export products are controlled or operated by the government per se, and thus the subsides were considered to be impossible to exist (Durling and Prusa 2013). Starting in 2007, the U.S. Department of Commerce changed this policy and began to argue that a firm or industry may be viewed as "market oriented" within an NME and China was considered as the leading example in this practice. On April 9, 2007, in the Department of Commerce's preliminary countervailing duty determination for China, amended (72 FR 17484), the U.S. government officially made an affirmative determination on the countervailing duty against a NME country (China), and repealed the restriction of carrying out countervailing investigation against NME countries since then (U.S. ITC. 2007). This policy change provided another possible trade offsetting measure to Chinese products and affects the initiation of relevant investigation cases greatly. Till June 2013, since the announcement of this policy change, 28 out of 37 following AD investigations against Chinese products are filed with CVD investigations simultaneously. Obviously, this new policy stimulated American companies to initiate more countervailing duty investigation against China and put Chinese products on the volcano of being investigated, which may have generated an impact on the import pattern of either named commodity or related commodities.

2.3 The AD/CVD Investigation against LWTP Products from China and Germany

The large increase in imports from China and Germany, along with the new policy, has resulted in strong reaction among the domestic lightweight thermal paper manufacturers. Six months after the policy change, on September 19, 2007, Appleton Paper, Inc. ("Appleton"), a U.S. domestic producer of LWTP, filed a petition in the investigation. This petition claimed that the imports of certain LWTP products from China and Germany were sold at "less than fair value (LTFV)", and that imports of certain lightweight thermal paper from China were subsidized by the Chinese government. During the hearing stage, Kanzaki Specialty Papers, Inc. ("Kanzaki") also appeared in support of imposition of duties. These two companies (Appleton and Kanzaki) account for all U.S. production of jumbo roll lightweight thermal paper. Besides, this petition was also supported by another 20 U.S. firms that convert jumbo rolls of LWTP into slit rolls of the product. These 20 firms account for 62.1 of the conversion activities in the U.S. in 2007 (U.S. ITC. 2008). In contrast, there were only two Chinese firms (Paper Resources, LLC, and Shanghai Hanhong Paper Co., Ltd.), and one German firm (Koehler AG Inc.) that responded to the investigation. This AD/CVD investigation was following the typical investigation process according to U.S. Laws. However, although the results of both investigations were released at almost the same time, the AD and CVD investigations were conducted separately. Major events within this investigation include the petition filed on September 2007, the affirmative preliminary determination on December 2007, and the final imposition of duties on November 10, 2008. Based on the results collected during the period of investigation (July 1, 2006 to June 30, 2007), several conclusions had been reached through this investigation by the U.S. ITC. (2008). Both in absolute terms and relative to consumption in the U.S., the volume of subject imports was considered to be very large (U.S. ITC. 2008). Beside, even the products from Germany and China were not functionally interchangeable, and both of them have a very high substitutability with relative U.S. domestic products. Therefore, price was the critical factors for U.S. consumers in decision-making. Additionally, the capacity utilization had been found to decrease 5.1%, and the value of operation loss for the whole U.S. domestic industry was 11.9 million U.S. dollars during the period of investigation. Therefore, the department of Commerce and the U.S. ITC concluded that the U.S. domestic lightweight thermal paper industry was materially injured, or threatened with materially injury, by reason that the imports of certain lightweight thermal paper from China and Germany which were sold at LTFV and the Chinese products were subsidized.

Based on the degree of injury to the U.S. domestic industry, the final duty rates vary by country and category. Since Koehler was the only supplier of German lightweight thermal paper in the U.S., the AD duty rate for the German firm was set at 6.50%. However, the AD duty rate for Chinese firms ranged from 19.77% to 115.29%, and CVD duties ranged from 13.17% to 137.25%. The imposition of duties affected not only the imports from China and Germany but the whole market of imported LWTP products in U.S.

Overall, the market dynamics of imported LWTP products in the U.S. raised interesting questions with regard to the consumer preference, competition among suppliers, and relevant policy effects. In addition, due to the features of this product, the development of U.S. imported lightweight thermal paper market also provide a great opportunity to conduct empirical research on these questions by using a demand system, such as Almost Ideal Demand System (AIDS).

3 METHODS

In this study, both static and dynamic Almost Ideal Demand Systems (AIDS) are used to analyze the consumer demand over LWTP products from various sources in the U.S. To achieve this goal, the mechanism of how the trade pattern of U.S. imported lightweight thermal paper (LWTP) can be affected by economic factors and non-economics factors is examined. Specifically, economic factors include price and total expenditure; non-economic factors include the antidumping/countervailing (AD/CVD) investigation and relevant investigation policy change in 2007. Accordingly, the effects from economic factors are measured by various calculated elasticities, and those from non-economic factors are measured by dummy variables representing those events. What’s more, other than those factors outside the market, the error terms in dynamic models are used to reveal the self-adjust mechanism of the market per se.

3.1 Rationale and Application of Almost Ideal Demand System (AIDS)

As a representative consumer theory based demand system, Almost Ideal Demand System (AIDS) was first derived by Deaton and Muellbauer (1980) under the assumption of maximized consumer utility, and can be considered as the most common specification of demand systems since the 1990s (Karagiannis, Katranidisb, and Velentzasb 2000). The popularity of AIDS model comes from several inherent advantages of this model. First of all, it provides an arbitrary first-order approximation of any demand system and allows aggregation over consumers without maintaining homothetic preferences. Therefore, theoretic properties of homogeneity and symmetry can be imposed and tested via linear restrictions on parameters (Wan, Sun, and Grebner 2010). Moreover, AIDS has a functional form which can be linearly approximated to enable a relatively easy estimation. In additional, AIDS model can be applied combining with error correction techniques (Engle and Granger 1987) to construct a dynamic AIDS model. This dynamic model takes the time-series properties of data into consideration and can reveal the market dynamics in the short run.

The linearization of price index remains a hot topic in model specification of AIDS model. Derived from price-independent generalized logarithm (PIGLOG) expenditure function, the original form of AIDS has a problem of nonlinearity-in-the-parameter which was caused by existence of the translog price index on the right hand side of the function. Thus, in many cases economists have used a linear price index to approximate the real price index. Deaton and Muellbauer (1980) recommended using the Stone price index to replace the original translog price index. Although there remains a problem of simultaneity because either right or left side of the model has the budget share parameter (Eales and Unnevehr 1994), this approximation won't cause any problems in either model specification or estimation. Indeed, many studies revealed that the demand elasticities derived from the linearized AIDS are able to approximate the "true" elasticities perfectly (Alston et al. 1990; Buse 1994; Chen 1998). Therefore, in this study, the Stone price index is used to replace the real price index.

Another problem that merits more attention is the incorporation of dynamic factors in the AIDS model. According to the economic theory, the consumer behavior can be considered as always in equilibrium in the long run. In this case, the static model is enough to generate reliable results, and valid to be estimated by conventional regression methods such as Ordinary Least Square (OLS). However, in the short run, many factors such as consumer habit persistence, imperfect information, and incorrect expectation will lead to the problem of "out of equilibrium" until a full adjustment has been imposed (Anderson and Blundell 1983). This means that assumptions of static AIDS model no longer exist in short run. In this case, the static AIDS model is not reliable enough due to lack of dynamic elements (Chambers and Nowman 1997). Moreover, due to the properties of time-series data, directly using conventional regression methods to estimate a model with non-stationary time-series data set would lead to a spurious regression and biased results. To overcome these shortages of the static AIDS model, the concept of cointegration was introduced into the AIDS model by Balcombe and Davis (1996) for the first time. Since then, the error-correction of almost ideal demand system (EC-AIDS) or dynamic AIDS has been developed and widely adopted in recent years. For example, Karagiannis, Katranidisb, and Velentzasb (2000) presented an empirical study based on error-correction AIDS models and estimated the demand elasticities of various meats in Greece, both in short run and long run. Gil et al. (2004) analyzed the import demand for virgin olive oil in the European Union by imposing dynamic technologies upon a linearized AIDS model. Additionally, in the forest economics area, a study conducted by Wan, Sun, and Grebner (2010) is a representative study conducted with EC-AIDS model. In which paper, the static and dynamic AIDS models were imposed together to access the import demand for wooden beds in the U.S. in the long run and short run, respectively. In general, in most of the relevant studies concerning dynamic econometrics, both short run and long run conditions have been analyzed and reported together because the residuals from the long run static model need to be imported into the short run dynamic model to serve as error-correction terms.

3.2 The Static Model

The static form of AIDS model in this study can be presented as follows:

$$w_{it} = \alpha_i^s + \beta_i^s \ln\left({m_t}/{P_t^*}\right) + \sum_{j=1}^{N} \gamma_{ij}^s \ln p_{jt} + \sum_{k=1}^{K} \varphi_{ik}^s D_{kt} + \sum_{h=1}^{H} Q_{ih} q_{ht} + u_{it} \quad (3\text{-}1)$$

where w_{it} is the budget share for country i in time period t; m_t is the total expenditure for imported LWTP in time t; P_t^* refers to the Stone price index in time t; p_{jt} refers to the average unit price of LWTP from source j in time t; D_{kt} represent the policy dummy variables imposed in the model. Q_{ih} denote the seasonality dummy variables in quarter. u_{it} is the disturbance terms, and α_i^s, β_i^s, γ_{ij}^s, and φ_{ik}^s are parameters, the superscripts s denotes static AIDS model. In this study, i and j represent the name of source from 1 to 6 (five countries plus the rest of world as a whole supplier), but j is different from i because it is specially set for unit price variables. Furthermore, the range of t is from 1 to 138 (monthly data from January 2002 to June 2013), the range of k is from 1 to 4 (One policy change dummy variable plus three investigation dummy variables), and the range of h is from 1 to 3 to represent the seasonal effect from the first three quarter of a year.

In terms of the definition of variables, the total expenditure m_t is defined as the sum of the product of price and quantity from each source: $m_t = \sum_{i=1}^{N} p_{it}\, q_{it}$, in which q is the quantity of LWTP in kg. In addition, the stone price index is calculated as $\ln P_t^* = \sum_{j=1}^{N} w_{jt} \ln p_{jt}$.

To be consistent with economic theory, some constraints need to be applied on the static AIDS system, which includes:

(1) Adding-up: $\sum_{i=1}^{N} \alpha_i = 1, \sum_{i=1}^{N} \beta_i^s = 0, \sum_{i=1}^{N} \gamma_{ij}^s = 0, \sum_{i=1}^{N} \varphi_{ij}^s = 0$, those restrictions indicate that the total expenditures must equal to the sum of expenditures on all the goods.

(2) Homogeneity: $\sum_{j=1}^{N} \gamma_{ij}^s = 0$, which means demands are homogenous of degree of 0 in price and income.

(3) Symmetry: $\gamma_{ij}^s = \gamma_{ji}^s$, which means the system satisfies Slutsky symmetry.

During the estimation process, restrictions (1) can be satisfied by dropping one equation (Feleke and Kilmer 2007), and restriction (2) and (3) are imposed through likelihood ratio tests (Wan, Sun, and Grebner 2010).

3.3 The Dynamic Model

The static AIDS model assumes that the consumer behavior is considered to be always in equilibrium. In long run condition, this assumption is true. However, when it comes to the short run condition, this consumer equilibrium will no longer exist and the static model would be inaccurate to represent the reality. Moreover, there is a high possibility of non-stationary for time-series data, which means using conventional estimation technologies would become inappropriate. Therefore, deployment of dynamic econometrics is required in this situation.

Engle and Granger (1987) proved that once all variables in consideration are cointegrated, an error-correction model can be established. This can be used in analyzing short run market behavior. Therefore, the first step of dynamic AIDS is to ensure if the cointegration relationship exists by imposing a cointegration test. Generally speaking, Engle-Granger two-stage approach and Johansen approach (Johansen 1988) are two most common cointegration analysis methods. Specifically, the Engle-Granger two-stage approach focusing on the time-series property of the residuals from the static model is relatively easy to carry out (Enders 2008), whereas the Johansen approach is concentrating on the relationship between the rank of matrix and its characteristic roots in a vector auto-regression system, and is good at handling multiple cointegration relationships. According to previous research, for an auto regression system with a moderate number of observations, the Johansen approach is only able to reach convergence for systems with no more than three groups (usually countries in trade research) and can handle no more than four commodities (Kaabia, Angulo, and Gil 2001). Since the proposed study is an analysis of competition between different suppliers of single commodity, the Engel-Granger approach is more suitable than the Johansen approach in imposing cointegration test because it can handle more import sources.

The Engel-Granger approach starts by checking the stationarity of the data used in the static model. Augmented Dickey-Fuller (ADF) test is conducted in this study to serve as the unit root test to examine if the data is stationary. Specifically, in order to eliminate the possible serial correlation problem in the regression residuals, the start number of lags in the ADF test is chosen following the method provided by Schwert (1989), and the actual lags used are selected according to the Akaike Information Criterion (AIC) in this study. If these variables are found to be integrated in the same order, a cointegration test should be used to check whether the residual terms collected from the static model are stationary. Once stationarity in residuals is confirmed, the long run equilibrium and cointegration relationship are proved to be exist (Karagiannis and Mergos 2002), and the error-correction model (ECM) can be constructed by importing residuals from the static model as the error-correction terms.

The dynamic form of AIDS model used in this study is showed as follow:

$$\Delta w_{it} = \psi_i \Delta w_{i,t-1} + \lambda_i \hat{u}_{i,t-1} + \beta_i^d \Delta \ln \left({m_t}/{P_t^*} \right) + \sum_{j=1}^{N} \gamma_{ij}^d \Delta \ln p_{jt} + \sum_{k=1}^{K} \varphi_{ik}^d D_{kt} + \sum_{h=1}^{H} Q_{ih} q_{ht} + \xi_{it} \qquad (3\text{-}2)$$

where Δ denotes the first difference of certain variable, $\hat{u}$ is the residual imported from the static AIDS model to serve as the error-correction term. All other variables have same definitions as the static model. Other than β, γ, and φ, there are other two parameters, i.e. ψ and λ, need to be estimated in dynamic model. Accordingly, ψ indicates the relationship between current consumption and past consumption, thus the consumer behavior can be assessed by determining the sign of this variable. Usually, this sign is expected to be negative for durable goods and positive for nondurable goods. The parameter λ measures the speed of adjustment backing to equilibrium in the short run. Moreover, similar to static model, the superscript d here in this specification indicates that they are parameters in dynamic model. What's more, dynamic AIDS also need to satisfy the theoretical restrictions of adding-up, homogeneity, and symmetry as well as the static model. The requirement of adding-up is fulfilled by dropping the "rest of world" equation, the homogeneity and symmetry restriction are imposed on the parameters and then tested by likelihood ratio tests.

3.4 Estimation and Diagnostic Tests

In this study, both the static and dynamic AIDS models are estimated by the seemingly unrelated regression (SUR) using software R (R Develop Core Team 2013). The SUR adjusts for cross-equation contemporaneous correlation and consequently takes the optimization process behind the demand system into account (Karagiannis, Katranidisb, and Velentzasb 2000). Six suppliers including five major countries exporting LWTP to the U.S. and the rest of world as one single group ("ROW") are incorporated in this system, but the rest of world group was dropped during the estimation process for the purpose of imposing the adding-up restriction.
Since the left hand side of AIDS model is constructed by using budget share which may correlated with the expenditure term, a problem that commonly comes with the AIDS model is endogeneity of the expenditure terms (LaFrance 1991). Once the expenditure terms are correlated with the error terms, estimates of AIDS models will be biased and inconsistent. Therefore, an endogeneity test must be performed to determine whether the expenditure terms are exogenous in the model, and the Durbin-Wu-Hausman test is often adopted to conduct this test (Henneberry, Piewthongngam, and Qiang 1999). An auxiliary regression was run as the first step of this test, which regressing the expenditure term on a set of instrumental variables. In this study, the instrumental variables include personal consumption expenditures for nondurable goods in the U.S., the first difference of expenditure term, and the import price variables by source. Then the residuals of this auxiliary regression were included in the static AIDS model as an additional explanatory variable in each equation. Afterward, a likelihood ratio test is imposed to test the null hypothesis that whether the parameters of the residuals are jointly equal to zero. If this null hypothesis can be rejected, the residual term is confirmed to be correlated with the expenditure term and the endogeneity problem exists in the model. In this case, the endogeneity problem is corrected by replacing the real total expenditure terms with the predicted value from the auxiliary regression.

In addition, several diagnostic tests are adopted on both static and dynamic models to assess the adequacy of the model specification (Shukur 2002). Specifically, the Breusch-Godfrey (BG) test is adopted to test the hypothesis of no serial correlation in the variables (Edgerton and Shukur 1999). The heteroskedasticity is examined by the Breusch-Pagan (BP) test (Holgersson and Shukur 2004). The functional misspecifications are examined by Ramsey's Regression Specification Error Test (RESET) (Shukur and Edgerton 2002). Finally, the normality of error term is tested by Jarque-Bera (JB) LM test (Holgersson and Shukur 2001).

3.5 Demand Elasticities

To examine the effect from economic factors, various elasticities are calculated both in static and dynamic models. In this study, expenditure elasticity, Marshallian own-price elasticities, and Hicksian cross-price elasticities are calculated to explore the effects from the additional expenditure, the price of product from this source itself, and the price of products from other sources, respectively. In detail, for the static AIDS model, the long run elasticities are calculated as following:

$$\eta_i^s = 1 + (\beta_i^s / \bar{w}_i) \quad (3\text{-}3)$$

$$\varepsilon_{ij}^s = -\delta_{ij} + \left(\gamma_{ij}^s / \bar{w}_i\right) - (\beta_i^s \, \bar{w}_j / \bar{w}_i) \quad (3\text{-}4)$$

$$\rho_{ij}^s = -\delta_{ij} + \left(\gamma_{ij}^s / \bar{w}_i\right) + \bar{w}_j \quad (3\text{-}5)$$

where η, ε, and ρ are the expenditure elasticity, Marshallian own-price elasticity, and Hicksian cross-price elasticity, respectively; β and γ are parameters, and δ_{ij} is the Kronecker delta which equal to 1 when $i = j$ (own-price elasticity) and 0 if $i \neq j$ (cross-price elasticity). $\bar{w}_i$ is the average budget share of LWTP from source i in the U.S. import market over the study period from January 2002 to June 2013. The elasticities for dynamic AIDS model can be calculated in the similar way, and the only difference is that the variables in static models with superscript s need to be replaced with the variables in the dynamic models with superscript d. What's more, delta method (Greene 2003) is employed for both static and dynamic model to compute the standard errors of the elasticities calculation.

4 DATA SOURCES AND VARIABLES

According to the scope of merchandise investigated by the United States International Trade Commission (U.S. ITC.), the lightweight thermal paper (LWTP) products are defined as the thermal paper with a basis weight of 70 grams per square meter (g/m^2) (with a tolerance of 4.0 g/m^2) or less. Within the framework of Harmonized Tariff Schedule (HTS), although certain lightweight thermal paper products may have been entered under HTS subheading 4811.90.90, 4811.59.20, or even 3703.10.60, HTS subheading 4811.90.80 is the legal subheading covering majority of certain lightweight thermal paper products involved in the trade dispute. Therefore, the commodity considered in this study is certain LWTP products with the HTS subheading 4811.90.80. Both import value and quantity data of such commodity are available on the website of the U.S. ITC. (2013).

The period between January 2002 and June 2013 is selected as the study period for several reasons. Foremost, China joined the World Trade Organization in December 2001, and started to deeply participate in the international trade since then. Consequently, the pattern of international trade was greatly affected since 2002, so does the LWTP products. Since 2002, the annual average cost-insurance-freight (CIF) value (import value) of import LWTP products exceeds 100 million U.S. dollars. Due to the repaid increase in imports, corresponding antidumping/countervailing (AD/CVD) investigation happened within this study period. Specifically, the period of investigation ("POI") for those investigations were concentrated between January 2006 and June 2007, and slightly varied by case and country. In addition, the import market for the LWTP products in the U.S. has undertaken a dramatic change during this study period. Some traditional foreign suppliers such as Japan and United Kingdom lost much of their market share to China and Germany. Particularly, China boosted from a small supplier holding of less than 2% market share to be the second largest foreign supplier of LWTP products in the U.S. The market share of Chinese LWTP products ever reached 40% at the peak during this period, and then fell to a current stage of lower than 20% after the AD/CVD case. On the contrary, Germany kept holding the position of the largest foreign suppliers of LWTP products in the U.S., as both the import value and market share gained additional increases during this study period.

Major suppliers are selected according to the statistical data from U.S. ITC. (2013). The aggregated import value of the top five suppliers represents more than 85% of the total import during the study period of January 2002 to June 2013. These countries are 1- Canada (4.757%), 2- China (10.382%), 3- Germany (44.387%), 4-Japan (21.347%), and 5-United Kingdom (6.900%). All other countries are aggregated into a group called the 6-Rest of World (12.281%). The data of monthly cost-insurance-freight (CIF) values in U.S. dollars and quantities in kilogram (kg) by country are collected from the website of U.S. ITC. (2013).The variables of import shares, gross import prices, total expenditure, and aggregated price index were calculated by using these data. The descriptive statistics of these variables are reported in Table 2. In aggregate, the monthly average import value by the U.S. is $21.514 million U.S. dollars over the study period. The LWTP products imported from Japan are most expensive with an average price of $4.513/kg. On the contrary, the lightweight thermal paper products from Germany are the cheapest with an average price of $1.957/kg. The price range for LWTP from other countries is between \$2.335/kg and \$3.358/kg. The price variation may be due to the type and grade of such commodity produced by different countries.

Table 2. Descriptive Statistics for Lightweight Thermal Paper Product from January 2002 to June 2013

Variable	Mean	Stand Deviation	Minimum	Maximum
w_{1t}	4.757	2.879	0.649	21.527
w_{2t}	10.328	10.936	0.073	42.132
w_{3t}	44.387	8.927	28.388	63.256
w_{4t}	21.347	7.172	10.117	42.636
w_{5t}	6.900	5.157	0.098	27.372
w_{6t}	12.281	5.261	3.552	38.095
p_{1t}	2.335	0.656	0.960	5.481
p_{2t}	3.003	1.169	0.947	7.034
p_{3t}	1.957	0.147	1.673	2.353
p_{4t}	4.513	2.297	0.848	8.978
p_{5t}	3.358	1.669	1.465	13.294
p_{6t}	2.583	0.755	1.332	5.015
m_t	21.514	7.803	9.046	42.703

Note: Variable units are percentage for import shares (w_{it}), \$/kilogram for import prices (P_{jt}), and \$ million for total expenditure (m_t). The subscripts of country *i* and *j* refer to 1 - Canada; 2 – China; 3 – Germany; 4 – Japan; 5 – United Kingdom; and 6 – the rest of world.

The impacts from the non-economic factors are evaluated by corresponding policy dummy variables. The new investigation policy which repealed the restriction of conducting countervailing (CVD) investigation on non-market economy (NME) was revealed in the preliminary determination of AD/CVD investigation against Chinese coated free paper products on late March 2007 then publicized on April 2007. Thus, a short step dummy variable from March 2007 to April 2007 is set to represent the extensive effect generated from this policy change. Other than this investigation policy change, the real AD/CVD investigation against certain LWTP products from China and Germany is considered as another main non-economic factor affecting the import demand of LWTP products in the U.S. This AD/CVD investigation lasted from September 2007 to November 2008. Due to the duration of the investigation period, this investigation has been divided into several different stages, and the effect from each stage of the investigation is revealed individually. To consider both the investigation effect and duty effect, three pulse dummy variables are set to account for the major events within this AD/CVD investigation, which are the initiation of the petition in September 2007, the affirmative preliminary determination in December 2007, and final imposition of the AD/CVD duties in December 2008. Specifically, the dummy variable representing the initiation of the petition is equal to one in September 2007 and zero for other months. The dummy variable representing the affirmative preliminary determination is equal to one in December 2007 and zero for other months. Similarly, the dummy variable accounts for the final imposition of the AD/CVD duties is equal to one in December 2008 and zero for other time period.

5 EMPIRICAL FINDINGS

5.1 Model Fit and Diagnostic Tests

Due to the requirement of constructing the most appropriate form of dynamic (error-correction) model, the properties of the time-series variables need to be examined beforehand. In this study, the results of Augmented Dickey-Fuller (ADF) test reported in Table 3 shows that the null hypothesis that all variables including price, expenditure, and budget share in the equation contain at least one root was failed to be rejected at 10% level. However, when first differences are used, the null hypothesis of unit root non-stationary was able to be rejected at 1% level, which means that the level of all the variables are an I(1) process but the series of their first differences is an I(0) process. Afterward, the cointegration test has been conducted following the Engle-Granger methodology, and the results are reported in Table 3 as well as the unit root test. According to the results of Engle-Granger cointegration test on residuals, the null hypothesis of nonexistence of cointegration relationship can be rejected which indicates the long-run equilibrium relationship exist in this market. Therefore the dynamic AIDS model can be constructed to exam the short run dynamics.

Another common problem associated with the AIDS model is the endogeneity of the model, which will lead to biased results. In this study, the Durbin-Wu-Hausman test (Hausman test) has been conducted to test the endogeneity problem of model, and the results are reported in Table 4. Accordingly, the results of Hausman test reveal that the null hypothesis of all the residuals are jointly equal to zero can be rejected at the 10% level, which means the error terms are correlated with the expenditure variables and the endogeneity problem exists in this model. Thus, the predicted values of the total expenditure imported from the auxiliary regression of the Durbin-Wu-Hausman test have been used to replace the real values of total expenditures to correct the problem of endogeneity.

Table 3. Results from Unit Root Test and Cointegration Test

Variable	Unit root test		Cointegration Test	
	Level	First difference	Variable	
sCA	-0.581 (7)	-8.372 (6)	Resid.CA	-5.798
sCN	-1.576 (3)	-8.422 (2)	Resid.CN	-5.781
sGE	0.214 (13)	-3.676 (12)	Resid.GE	-6.201
sJP	-0.889 (9)	-6.371 (8)	Resid.JP	-5.406
sUK	-0.782 (13)	-4.552 (12)	Resid.UK	-6.423
ToExp	1.062 (10)	-4.145 (9)		
lnpCA	-0.276 (12)	-3.864 (11)		
lnpCN	-0.799 (2)	-10.476 (1)		
lnpGE	-0.251 (2)	-11.547 (1)		
lnpJP	-1.138 (3)	-12.209 (2)		
lnpUK	-0.319 (11)	-5.648 (10)		

Note: ADF test with constant by equation, critical value are -3.51 at 1%, -2.89 at 5%, and -2.58 at 10%, respectively. *sCA, sCN, sGE, sJP, sUK* represent the market share variables of Canada, China, Germany, Japan, and United Kingdom, respectively. *ToExp* represents the variable of Total Expenditure of imported LWTP in the U.S. *lnpCA, lnpCN, lnpGE, lnpJP, lnpUK* represent the log values of the gross price of LWTP products from Canada, China, Germany, Japan, and United Kingdom.

Table 4. Results from Durbin-Wu-Hausman Test and Likelihood Test

Durbin-Wu-Hausman Test								
Estimated Coefficients:								
Intercept	Lagexp	lnpCA	lnpCN	lnpGE	lnpJP	lnpUK	lnpRW	ndg
6.369	0.751	-0.019	-0.159	-0.151	-0.115	0.057	-0.125	-0.257
Likelihood Test on Residuals								
Test Statistic		P (> Chisq)						
10.566*		0.0607						

Note: *lagexp* represents represent the lagged value of total expenditure, *ndg* represents the personal consumption expenditures for nondurable goods in the U.S. *LnpCA*, *lnpCN*, *LnpGE*, *LnpJP*, and *lnpRW* represent the log values of the gross price of LWTP products from Canada, China, Germany, Japan, United Kingdom, and the rest of world, respectively.

In addition, some diagnostic tests have been conducted on the estimated model and the results of them are reported in Table 5. For the Breusch- Godfrey (BG) test of no serial correlation, only one equation passed the test from five equations of static AIDS model, but all five equations of the dynamic AIDS model passed the test. For the Breusch- Pagan (BP) test for heterogeneity, four out of five equations passed the test in static AIDS model while three out of five equations passed the test in dynamic model. For the Ramsey's Regression Specification Error Test (RESET) for the functional misspecification, there are two equations in static model passed the test but only one equation passed the test in dynamic model. Additionally, for the Jarque-Bera (JB) test of normality in error terms, three passed in static model while two in dynamic model. Overall, compared to the static model, the specification of dynamic AIDS model shows significant improvement in serial correlation problem, but shows no improvement in other perspectives.

Table 5. Results from Diagnostic Tests on the Static and Dynamic Almost Ideal Demand Systems

Equation	BG		BP		RESET		JB	
	Statistic	p-Value	Statistic	p-Value	Statistic	p-Value	Statistic	p-Value
Static AIDS								
Canada	46.242	0.00	23.152	0.06	3.301	0.04	1208.830	0.00
China	9.301	0.00	28.519	0.01	27.683	0.00	0.005	1.00
Germany	1.169	0.28	11.313	0.66	1.575	0.21	1.516	0.47
Japan	16.107	0.00	15.362	0.35	4.554	0.01	5.666	0.06
UK	0.609	0.44	20.922	0.10	0.220	0.80	41.724	0.00
Dynamic AIDS								
Canada	0.660	0.42	35.071	0.00	5.266	0.01	271.898	0.00
China	6.881	0.01	34.069	0.00	18.307	0.00	204.457	0.00
Germany	0.152	0.70	13.244	0.58	0.697	0.50	1.840	0.40
Japan	0.009	0.92	10.377	0.80	4.966	0.01	5.581	0.06
UK	0.226	0.63	14.757	0.47	4.547	0.01	20.550	0.00

Note: The null hypothesis is no serial correction for the Breusch-Godfrey (BG) test, no heteroskedasticity for the Breusch-Pagan (BP) test, no functional misspecification for the Ramsey's Regression Specification Error Test (RESET) test, and normality of the error terms for the Jarque-Bera (JB) LM test.

5.2 Results from Estimated Coefficients

Coefficient estimation results of the static AIDS model are presented in Table 6 and the results for dynamic AIDS model are reported in Table 7. For the coefficients of real total expenditure, all five estimates are significant in the static model and two are significant in dynamic models. For the price variable, due to symmetry restriction, 20 estimated coefficients are presented and the results for the rest-of-world equations are omitted. Among those coefficients, eight are significant for the static model and six are significant for the dynamic model. Based on these estimates for expenditure and price variables, the elasticities are calculated and more detailed information can be provided for the competition and consumer behavior of lightweight thermal paper in U.S. import market.

Table 6. Estimated Parameters from the Static Almost Ideal Demand Systems for Imported Light Weight Thermal Paper Products

Parameter	Canada	China	Germany	Japan	UK
α_i	0.371***	-1.701***	-0.103	0.930***	0.467***
	(-2.930)	(-8.947)	(-0.392)	(-5.043)	(-2.949)
β_i^s	-0.019**	0.116***	0.033**	-0.049***	-0.023**
	(-2.479)	(-10.002)	(-2.053)	(-4.362)	(-2.394)
γ_{i1}^s	0.012	0.004	0.016	-0.020***	-0.005
	(-1.209)	(-0.557)	(-1.202)	(-3.479)	(-0.903)
γ_{i2}^s	0.004	-0.116***	0.066***	0.033***	-0.006
	(-0.557)	(-10.702)	(-4.251)	(-4.242)	(-0.793)
γ_{i3}^s	0.016	0.066***	-0.039	-0.074***	0.006
	(-1.202)	(-4.251)	(-1.125)	(-6.305)	(-0.540)
γ_{i4}^s	-0.020***	0.033***	0.074***	0.056***	0.011*
	(-3.479)	(-4.242)	(-6.305)	(-6.395)	(-1.719)
γ_{i5}^s	-0.005	-0.006	0.006	0.011*	0.001
	(-0.903)	(-0.793)	(-0.540)	(-1.719)	(-0.060)
γ_{i6}^s	-0.006	0.019**	0.024	-0.006	-0.007
	(-0.853)	(-2.304)	(-1.591)	(-0.776)	(-0.983)
φ_{i1}^s	-0.005	0.149***	-0.048	-0.058	-0.002
	(-0.230)	(-4.229)	(-1.207)	(-1.623)	(-0.074)
φ_{i2}^s	-0.018	0.062	-0.031	-0.009	0.056
	(-0.671)	(-1.296)	(-0.570)	(-0.180)	(-1.290)
φ_{i3}^s	-0.023	-0.086*	0.116**	0.002	0.029
	(-0.836)	(-1.789)	(-2.100)	(-0.039)	(-0.652)
φ_{i4}^s	0.010	-0.133***	0.152***	0.057	-0.078*
	(-0.360)	(-2.760)	(-2.773)	(-1.176)	(-1.782)
Q_{i1}^s	-0.007	-0.044***	0.084***	0.027**	-0.054***
	(-0.947)	(-3.722)	(-6.069)	(-2.258)	(-4.998)
Q_{i2}^s	-0.006	-0.043***	0.066***	0.035***	-0.058***
	(-0.865)	(-3.641)	(-4.858)	(-2.890)	(-5.440)
Q_{i3}^s	-0.007	-0.012	0.026*	-0.001	-0.005
	(-1.020)	(-1.013)	(-1.886)	(-0.118)	(-0.447)
R^2	0.246	0.829	0.669	0.597	0.377

Note: ***, **, * denote significance at the 1%, 5%, and 10% level, respectively. *t* ratios are in parentheses. See text for parameter definitions.

Table 7. Estimated Parameters from the Dynamic Almost Ideal Demand Systems for Imported Light Weight Thermal Paper Products

Parameter	Canada	China	Germany	Japan	UK
ψ_i	0.162**	0.026	-0.116*	-0.112*	-0.162**
	(-1.996)	(-0.399)	(-1.907)	(-1.656)	(-2.161)
λ_i	-0.502***	-0.502***	-0.484***	-0.480***	-0.495***
	(-7.357)	(-7.370)	(-6.907)	(-7.047)	(-5.792)
β_i^d	0.009	0.104***	-0.107***	-0.009	0.006
	(-0.623)	(-3.200)	(-2.839)	(-0.319)	(-0.213)
γ_{i1}^d	0.016**	0.003	-0.012	-0.002	-0.008*
	(-2.246)	(-0.476)	(-1.148)	(-0.447)	(-1.806)
γ_{i2}^d	0.003	-0.051***	0.032**	0.025***	-0.006
	(-0.476)	(-3.823)	(-2.192)	(-2.707)	(-0.820)
γ_{i3}^d	-0.012	0.032**	-0.002	-0.041***	0.008
	(-1.148)	(-2.192)	(-0.065)	(-3.063)	(-0.725)
γ_{i4}^d	-0.002	0.025***	-0.041***	0.014	0.001
	(-0.447)	(-2.707)	(-3.063)	(-1.118)	(-0.091)
γ_{i5}^d	-0.008*	-0.006	0.008	0.001	0.012
	(-1.806)	(-0.820)	(-0.725)	(-0.091)	(-1.329)
γ_{i6}^d	0.004	-0.002	0.016	0.005	-0.006
	(-0.550)	(-0.161)	(-1.060)	(-0.511)	(-0.884)
φ_{i1}^d	-0.005	0.059*	-0.009	-0.038	-0.001
	(-0.352)	(-1.937)	(-0.252)	(-1.347)	(-0.023)
φ_{i2}^d	-0.004	0.064	0.034	-0.028	-0.035
	(-0.183)	(-1.429)	(-0.609)	(-0.656)	(-0.791)
φ_{i3}^d	-0.030	-0.042	0.069	0.008	0.008
	(-1.490)	(-0.977)	(-1.317)	(-0.189)	(-0.191)
φ_{i4}^d	0.005	-0.104**	0.108**	0.076*	-0.091**
	(-0.271)	(-2.434)	(-2.092)	(-1.889)	(-2.250)
Q_{i1}^d	0.002	-0.002	0.009	0.008	-0.013*
	(-0.452)	(-0.235)	(-0.994)	(-1.145)	(-1.754)
Q_{i2}^d	0.000	-0.006	-0.002	0.003	0.000
	(-0.077)	(-0.849)	(-0.285)	(-0.388)	(-0.006)
Q_{i3}^d	0.000	0.012	-0.013	-0.017**	0.023***
	(-0.056)	(-1.606)	(-1.350)	(-2.375)	(-3.061)
R^2	0.254	0.407	0.418	0.375	0.420

Note: ***, **, * denote significance at the 1%, 5%, and 10% level, respectively. *t* ratios are in parentheses. See text for parameter definitions.

Other than the estimates for price and expenditure, policy dummy variables are set to explain the effect from policy change in CVD duty, the AD/CVD investigation. At first, the dummy variable for the new policy announced on 2007 which released the restriction of imposing countervailing duty investigation on China is showed to generate significant positive effect on the market share of China in both static (0.149) and dynamic (0.059) model. On the other hand, for the three investigation dummy variables, the announcement of preliminary affirmative decision has a negative effect on China (-0.133); and the final implementation of the AD and CVD duties on November 2008 generates significant effect on trade pattern of most countries except Canada. Specifically, in the dynamic AIDS model, the final implementation of duties has a negative effect on China (-0.104) and United Kingdom (-0.091), and a positive effect on Germany (0.108) and Japan (0.076) in the dynamic AIDS model, and also shows a similar significant effect on China (-0.133) and Germany (0.152) in static AIDS model. However, the formal initiation of the investigation on September 2007 doesn't show any significant effect on the trade pattern of LWTP products on the U.S. import market. In addition, the seasonal dummy variables of the first quarter and second quarter are significant for all the major suppliers except Canada.

Overall, the impacts from the policy and investigation are effective in both the short run and long run. Firstly, for the policy change announced in March 2007 which allowed simultaneous CVD and AD actions again the same set of products from a non-market economy (NME) country like China, the positive effect from this event may come from two reasons: the expectation of the highly possible investigation on this product imported from China, and some similar products may be imported under the HTS subheading of LWTP temporarily. For example, U.S. ITC. (2008) indicated that coated free paper were found to enter the U.S. custom under the HTS subheading of LWTP products, especially when coated free paper product is subject to punitive tariff but LWTP still not. According to the estimates of dummy variables related to the AD and CVD investigation, trade depression effect occurs to China and United Kingdom, but trade diversion effect takes place to Germany and Japan at the same time, even though Germany is also a named country in the AD/CVD investigation and subject to the punitive AD duty. This may be due to the fact that the punitive tariff rates for German companies are far lower than their Chinese competitors who suffered from the high punitive tariff rate together with additional countervailing duty. In reality, this fact could benefit Germany and cause trade diversion happened on it. In general, these findings through dummy variables are consisting with the economic theories about investigation effect and trade diversion effect. They are also compatible with the real trade pattern over the time period covered by this study, as presented in Figure 1.

Furthermore, the coefficients of lagged share variable and the error correction terms also deserve explanation in detail. The coefficient estimates of the lagged share variable in the dynamic AIDS model indicate the inventory adjustment effect in consumer behavior. In this study, the coefficients for four out of five countries are significant and three of them are negative as expected in theory, i.e., Germany (-0.116), Japan (-0.112), and United Kingdom (-0.162). Which means the inventory adjustment effect exists in consumer behavior for the products imported from these three countries. What's more, the coefficient of error correction terms serves as an important indicator of market equilibrium and reveals the speed of adjustment toward the market equilibrium. Consisting with the theory, all of the five estimates are negative and significant at 1% level. The speed of adjustment varies by countries but similar in general. The coefficient for each countries are close to -0.5, which indicates it will take about two months ($1/0.5 \approx 2$) to get back to the market equilibrium. Therefore, this fact suggests that the U.S. import market for lightweight thermal paper products is very stable and the deviation from the long-run equilibrium for each country can be adjusted back to the equilibrium status in a very short time.

5.3 Results from Calculated Elasticities

The results of calculated long-run and short-run expenditure elasticities are reported in the Table 8. According to the results, all the estimates of expenditure elasticity are significant in 1% level, both in long run and short run. Specifically, the long-run elasticities for all the listed countries are positive as expected and the elasticity estimates for China (2.115) and Germany (1.073) are larger than one, while the elasticity estimates for Canada (0.599), Japan (0.770), and United Kingdom (0.663) are less than one. Besides, as for the short run elasticities, the estimates for Canada (1.188), China (1.996), and United Kingdom (1.086) are positive and larger than one and the estimates for Germany (1.073) and Japan (0.957) are positive but smaller than one. The magnitudes for the estimates in the short run are smaller than that in the long run for China and Germany, but are larger for Canada, Japan, and United Kingdom. In addition, in either long run or short run, China's expenditure elasticities are largest among all the countries and significantly larger than its competitors on the market. Overall, the results of expenditure elasticities indicate that the more consumers spend on the imported lightweight thermal paper products, the more money will be spent on imported from China and Germany and less from Canada, Japan, and United Kingdom in the long run. The large expenditure elasticities indicate the fierce market competition of the LWTP product from China and Germany in the long run, and also consistent with what the trade pattern shows.

Table 8. Estimates of the Expenditure Elasticity (η_i) and Marshallian Own-Price Elasticity (ε_{ii})

	Long-Run		Short-Run	
Country	η_i	ε_{ii}	η_i	ε_{ii}
Canada	0.599***	-0.737***	1.188***	-0.680***
	(-3.706)	(-3.602)	(-3.937)	(-4.654)
China	2.115***	-2.227***	1.996***	-1.599***
	(-18.974)	(-22.734)	(-6.413)	(-12.945)
Germany	1.073***	-1.119***	0.760***	-0.898***
	(-30.056)	(-12.895)	(-9.005)	(-10.567)
Japan	0.770***	-0.687***	0.957***	-0.927***
	(-14.571)	(-19.374)	(-7.150)	(-15.129)
UK	0.663***	-0.968***	1.086***	-0.837***
	(-4.714)	(-6.530)	(-2.690)	(-6.273)

Note: ***, **, * denote significance at the 1%, 5%, and 10% level, respectively. t ratios are in parentheses. See text for parameter definitions.

For better understanding of the effect of price change of imported lightweight thermal paper, the Marshallian own-price elasticities were calculated and presented in the Table 8 as well as the expenditure elasticities. As expected as theory, all the estimates for Marshallian own-price elasticity are negative, and all of them are significant in 1% level in both long run and short run. In the long run, the own-price elasticities for most countries are inelastic except China (-2.227) and Germany (-1.119). In the short run, China (-1.599) is the only one country still have elastic own-price elasticity. This result reveal that consumption of imported lightweight thermal paper from China is very changeable in both long run and short run, and consistent with the unstable import pattern of China which is sensitive to trade interventions. In additional, Germany has inelastic short-run own-price elasticity (-0.898) and elastic long-run elasticity (-1.119). Besides, the results also indicate that the market standing of Germany is stable in short run but flexible in the long run, which is consistent with the trade pattern within the research period. What's more, the inelastic price elasticity of the lightweight thermal paper imported from Japan, Canada, and United Kingdom suggest that the products from those countries are more necessary and relatively difficult to be substituted by other sources.

The Hicksian cross-price elasticities in both long run and short run are calculated to show the market competition among major suppliers, the results are reported in Table 9. According to the definition, positive cross-price elasticity between the products imported from two countries means they are substitute and a negative value indicates complements. Among the 10 pairs of cross-price elasticities among the five main suppliers, even though the signs and significance are same, the magnitudes, however, can be different. For example, as the price of LWTP products imported from China increase by 10%, the import demand for German product will increase by 2.53%. However, when the price of LWTP products imported from Germany increases by 10%, the imports demand for Chinese LWTP product will increase by 10.08%, which is a far larger than the prior one.

Table 9. Estimates of Long-Run and Short-Run Hicksian Cross-Price Elasticity (ρ_{ij})

Quantity of a Country	Price of a Country				
	Canada	China	Germany	Japan	UK
Long-Run					
Canada	—	0.183	0.791***	-0.209*	-0.043
	—	(-1.288)	(-2.748)	(-1.721)	(-0.349)
China	0.084	—	1.083***	0.527***	0.013
	(-1.288)	—	(-7.216)	(-7.127)	(-0.189)
Germany	0.085***	0.253***	—	0.046*	0.083***
	(-2.748)	(-7.216)	—	(-1.735)	(-3.169)
Japan	-0.047*	0.257***	0.096*	—	0.122***
	(-1.721)	(-7.127)	(-1.735)	—	(-3.960)
United Kingdom	-0.030	0.020	0.536***	0.377***	—
	(-0.349)	(-0.189)	(-3.169)	(-3.960)	—
Short-Run					
Canada	—	0.161	0.191	0.162	-0.089
	—	(-1.343)	(-0.867)	(-1.394)	(-1.015)
China	0.074	—	0.750***	0.452***	0.010
	(-1.343)	—	(-5.389)	(-5.133)	(-0.133)
Germany	0.020	0.175***	—	0.121***	0.086***
	(-0.867)	(-5.389)	—	(-3.977)	(-3.681)
Japan	0.036	0.220***	0.251***	—	0.072**
	(-1.394)	(-5.133)	(-3.977)	—	(-2.137)
United Kingdom	-0.061	0.015	0.554***	0.223**	—
	(-1.015)	(-0.133)	(-3.681)	(-2.137)	—

Note: ***, **, * denote significance at the 1%, 5%, and 10% level, respectively. t ratios are in parentheses.

In the long run, seven out of ten pairs of Hicksian cross-price elasticities at the upper triangle of the panel are significant at below 10% level. Most of them are positive indicate a substitution relationship except that the products from Canada and United Kingdom are complement. Among them, the largest cross-price elasticity is 1.083 between China and Germany. Meanwhile, the cross-price elasticity between Canada and United Kingdom is -0.043, which is a small value and not statistically significant and indicates the complement, even really exists, is very weak. Overall, in the long run, the prices of Germany and United Kingdom have larger impacts on the demand of the imported LWTP from other countries.

For the estimate results of Hicksian cross-price elasticity in the short run, five out of ten estimates in the upper triangle are significant. Similar to the long run results, except United Kingdom and Canada, cross-price elasticities among all other countries are negative indicates there is some degree of substitution between each pair of them. Specifically, the largest cross-price elasticity is 0.750 between China and Germany. Overall, the price of LWTP products imported China and Germany have larger impact on the demand for products from other countries, and the competition between these two suppliers is the strongest among all major suppliers. Besides, the comparison between long-run and short-run results indicates that the overall degree of substitution is smaller in the short run than in the long run.

6 CONCLUSIONS

In recent decade, the import of LWTP products in the U.S. has increased significantly as the annual import value of LWTP products by the U.S. was more than doubled. In 2012, the total import value of LWTP products in the U.S. exceeded 350 million U.S. dollars. Besides, other than the large increase in import, the pattern of import sources of LWTP products has also been greatly changed. Some of the traditional major suppliers of LWTP products such as Japan and United Kingdom have lost their market shares to Germany and China. Since 2002, the imports of LWTP from Germany and China have increased faster than from other countries. Due to the rapid increase of import, an antidumping/countervailing investigation against the LWTP products from Germany and China was conducted from September 2007 to December 2008. Consequently, various AD and CVD duties have been imposed on German and Chinese LWTP manufacturers since December 2008. To evaluate this market dynamic, both economic and noneconomic factors which affecting the market have been analyzed and the results in terms of consumer behavior, market competition, and effectiveness of policy are obtained through static and dynamic AIDS models. Monthly disaggregate data for the top five suppliers from January 2002 to June 2013 are used as the data to analyze in this study.

Several conclusions have been reached in terms of the consumer behavior, market competition, and policy effectiveness in the import market of LWTP products. First of all, the long run equilibrium in this market has been proved to be present by the Engle-Granger cointegration test. Once this equilibrium has been broken temporally, the equilibrium status in this market can also be regained by short-run adjustments of each supplier. The expenditure elasticities show that when U.S. consumers spend more money on imported LWTP, they buy more from China and less from Canada, Japan, and United Kingdom, and buy more German LWTP products in the long run but less in the short run. Therefore, China has the potential to lead the market in the future. In the long run, as indicated by the Marshallian Own-price elasticities, the imported quantities from

China and Germany are sensitive to their prices. However, in the short run, China is the only supplier that has elastic own-price elasticity, which indicates its response is more sensitive to price change among all suppliers.

Other than expenditure and own-price elasticity, the cross-price elasticities have revealed the competition among those countries. The imports among most countries can be substituted by each other, except that the LWTP products from Canada and United Kingdom are found to be complementary. However, all the cross-price elasticities are inelastic indicating moderate to low magnitudes, and implying most of them are far from perfect substitution. This fact indicates that the imported LWTP from different countries are meant to be differentiated to meet the diversity in preferences of the U.S. consumers. Overall, the analysis on effect from the economic factors shows the market competition on the LWTP import market in the U.S. will be continued in the future. Due to the relatively high competition level, the market will be even more changeable in the long run. Thus, all suppliers will be needing to face both opportunity and risk together in the future.

Severing as an impact from the non-economic perspective, the investigation policy change in 2007 did generate significant effect on LWTP products from China. In reality, this policy, which was supposed to be restrictive, stimulated the import of LWTP from China temporarily. This may be because of conducting faster contracts under risk of potential investigation, a rush by U.S. buyers to get more products to avoid potential price increase in the future, and the increase of coated free paper under the name of LWTP to avoid punitive tariff. On the other hand, the AD/CVD investigation against China and Germany as trade remedy instrument, however, has limited effects in reducing the import growth of LWTP products from these two countries. Specifically, the initiation of the investigation didn't generate any significant impact on the import of LWTP. The affirmative preliminary determination and the final imposition of the duties generate negative impact on China as expected, but trade diversion effect took place on Japan and Germany, even though German LWTP products are also subject to punitive tariff. This pattern is consistent with the fact that the market share of Chinese LWTP products dropped after the investigation while Germany continue to hold the largest market share on this market. Apparently, the effectiveness of this AD/CVD investigation on Germany need to be questioned because it didn't really reduce the import of LWTP to protect domestic industry as expected. In another word, the one who benefit from this trade offset measure may not be U.S. domestic industry but German LWTP manufacturers which is supposed to be punished in this case. Besides, the righteousness of AD/CVD duty is another extensive topic merits further investigation. Especially for the case comes with AD and CVD investigations together, the problem of "double remedies" can be even more controversial.

In conclusion, this study analyzed the consumer behavior in purchasing imported LWTP products in the U.S. as well as the trade pattern, market competition, and policy impacts in this market based on a demand system. It makes an important contribution to analyzing the import market of LWTP products with a differentiation of short run and long run consumer behavior. It also produces empirical evidence of the temporary stimulate and trade diversion in the paper manufacturing industry when there is an AD/CVD investigation or relevant policy event.

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