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## Three Essays in Forest Resource Management: Landowners' Considerations in Ecosystem Services, Forest Certification, and Timber Supply

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To the Graduate Council:

I am submitting herewith a dissertation written by Nana Tian entitled "Three Essays in Forest Resource Management: Landowners' Considerations in Ecosystem Services, Forest Certification, and Timber Supply." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Natural Resources.

Neelam C. Poudyal, Major Professor

We have read this dissertation and recommend its acceptance:

Donald G. Hodges, Timothy M. Young, Wenjun Zhou

Accepted for the Council:

Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

**Three Essays in Forest Resource Management: Landowners' Considerations  
in Ecosystem Services, Forest Certification, and Timber Supply**

**A Dissertation Presented for the  
Doctor of Philosophy  
Degree  
The University of Tennessee, Knoxville**

**Nana Tian  
May 2017**

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## **ABSTRACT**

Forest ecosystems provide a wide range of timber and non-timber ecosystem services that play a vital role in supporting human health, well-being, and economy. Sustaining forest ecosystem will depend on landowners' interest and willingness to responsibly manage forests, and provide timber and non-timber services for public benefit. Despite a substantial research in understanding how forest resources are managed by landowners, several literature gaps still exist regarding how landowners' behavior/activities associated with sustaining the supply of ecosystem services and timber, and participating in best management practices such as forest certification. By applying methods grounded in economic and human dimension theory, this dissertation finds empirical evidences to answer key questions relevant in landowners' perspectives in supply of timber and non-timber benefits and adoption of certification practices.

The first essay investigates the interest of nonindustrial private forest (NIPF) landowners in managing their forests for provision of ecosystem services (carbon storage, water quality protection, and aesthetics) and summarizes the corresponding influencing factors by using the survey data collected from the Cumberland Plateau, Tennessee. The second essay analyzes the landowners' perceived barriers and opportunities in adopting forest certification in China. Using a meta-analysis method, the third essay highlights how price responsiveness of timber supply responds to market price, and other factors representing landowners' characteristics.

The essays in this dissertation provide some insights in understanding the decision-making behavior of landowners relative to providing both timber and non-timber services and sustaining forest management. Findings add significantly to the forest economic and

management literature. In addition, conceptual frameworks and estimation techniques adopted in some of these essays could be extended or improved upon in future studies.

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# **CHAPTER I INTRODUCTION**

## **1.1 Background**

Forests are the primary source of timber and many non-timber products (e.g., paper and rubber). Many services provided by forest ecosystems can be measured by economic benefits (e.g., timber production), but some services cannot be directly valued in monetary terms such as recreation, aesthetic, water quality protection etc. These timber and non-timber benefits have been key motivations for owning forests for many landowners. In addition, forest ecosystems provide a wide range of ecosystem services that serve a variety of ecological, economic, and cultural purposes and play a vital role in health, livelihood and survival of human as well as non-human beings. Despite these benefits, the total forest cover area all over the world decreased from 4,128 million ha to 3,999 million ha in about 25 years between 1990 and 2015, as reported by the global forest resources assessment 2015 (FAO, 2015). Considering their ecological, economic, and social significance and the threats they face, it becomes critical to study how forests resources are managed by landowners, and how their management decisions (e.g., decision to manage for ecosystem services, adoption of management practices such as certification, and harvest/supply timber) relate with market (e.g., price) and non-market (e.g., personal, legal) conditions.

Ecosystem services, which are defined as the benefits that society obtains (directly or indirectly) from the functions and services of natural ecosystems, is an important forest ecosystem value comprising provisioning, regulating, cultural, and supporting services needed to maintain other services. Unfortunately, the Millennium Ecosystem Assessment (2005) and

Costanza et al. (2014) indicated that the global supply of several of these ecosystem services is in decline and therefore, sustaining the supply of such services in future will be important.

Nevertheless, emerging literature on ecosystem services is yet to answer a lot of questions to help us understand the relationship between landowners' decision making and the provision of ecosystem services.

Forest certification, a voluntary market-based mechanism to promote responsible forestry and wood production, has been viewed as an effective instrument of forest sustainability. Forest certification assures consumers that forest products are from an environmentally-friendly and sustainably managed forest. Forest certification has gained popularity among forest landowners and industry stakeholders in European and North American countries. In contrast, it is yet to take momentum in the developing world. For example, China, which is one of the major exporters of forest products to the world (Campbell et al., 2008), only started engaging in certification programs in the late 1990s or early 2000s. Therefore, certification and sustainability of forests in countries like China becomes an issue of international concern, especially considering the extent of those countries' wood product export to other regions including North America and Europe.

With growing population and economic growth worldwide, demand for timber is likely to increase in the future. Taking the U. S. as an example, annual timber demand per capita is estimated at about 816.5 kilogram (1,800 pounds) (Haynes, 2003) and the total annual timber harvests currently is approximately 1.9 billion m<sup>3</sup> which is about 20% of the global timber harvests (Sedjo and Sohngen, 2015). Moreover, timber production from all forests depends on the decisions of landowners whose management plan and decision-making is influenced by various factors including public policies and programs. Therefore, a variety of forestry incentives

(e.g., cost-share, tax credits, etc.) may be required to encourage appropriate management on these lands to increase forest productivity. On the other hand, market price is the most important economic incentive to promote the timber supply and hence, understanding the market dynamics of timber supply with respect to price to stabilize the long-term timber supplies has become an important issue in the forest resource analysis.

## **1.2 Problem Statement**

Sustaining supply of ecosystem services from private forestlands has become an important issue, especially in the U.S., where approximately 63% of the forestlands are privately owned and most of them are classified as nonindustrial private forests (NIPFs) (Butler et al., 2016). A handful of studies have consistently reported that human activities and behaviors affect the provisioning of ecosystem services and management of forest systems. For example, the motivation of owning forestland (e.g., recreation, timber production) and associated characteristics of landowners (e.g., age, education etc.) influence landowners interest in supplying ecosystem services. In addition, incentive-based mechanisms are believed to promote landowners' willingness to manage forest for many public benefits. Many previous studies, however, have focused on exploring the efficacy of incentive-based programs (e.g., Conservation Reserve Program) to motivate landowners' interest. Fully understanding whether and how personal and market-related circumstances faced by landowners impact their level of interest in supplying ecosystem services is important. Thus, there is a critical need to answer these questions so that findings can inform outreach and management decision making.

While incentive-based best management practices such as forest certification can ensure forest sustainability on private lands, there exists a notable gap in the literature regarding what

factors are related to landowners' interest in forest certification. Prior research tells us little about the opportunities and constraints in promoting forest certification in developing nations like China. As a result, it is unknown whether and how certification mechanisms can be devised to increase social acceptance and adoption of certification program in those countries. Specifically, there is a critical need for research to guide planners and policy makers in understanding what kind of certification schemes are acceptable or unacceptable to landowners, and what kinds of opportunities exist in promoting adoption. Therefore, need for a study to examine the relationship between landowners' attitudes and knowledge of behaviors and their interest in forest certification is realized.

Supply of timber could be influenced by many factors such as market price, environmental regulations (e.g., the Endangered Species Act to protect wildlife resulting in reductions in wood production), and forestland ownership characteristics (e.g., landowners interest in non-timber goods). Previous research has shown that price is an important influencing factor in timber supply, but the conclusion is mixed and considerable variation exists in literature as to whether and to what extent timber supply responds to market price. Substantial literature on timber supply is focused on analyzing supply models using various econometric functions and reported the price elasticity of supply (PELS). Little research has been undertaken to explore the factors resulting in the variation of timber supply to price. It is essential for market participants and policymakers to understand the dynamics of price signaling in timber market to improve the future prediction of timber supply. Therefore, a study examining how timber supply responds to price and what factors contributing to this variation is appropriate.

In order to fill the above-mentioned gaps in knowledge, this dissertation compiles three related but different essays addressing questions on how landowners make decisions about the provision of ecosystem services, adoption of best management practices like certification, and supply of timber in response to market signals.

### **1.3 Objectives**

The objectives of this dissertation are to:

- 1) Explore the factors that explain NIPF landowners' interest in supplying various ecosystem services from private forests in Cumberland Plateau, Tennessee,
- 2) Examine landowners' perceived barriers and interests in forest certification in China and identify the factors that influence their willingness to participate in forest certification programs,
- 3) Examine the heterogeneity in price elasticity of timber supply and explore the contributing factors.

Those objectives were achieved by employing individual study approaches specific to the related research questions. Study details for each objective are presented in individual essays (Chapter 2 - 4) within which include literature review, theoretical framework, methodology, and results and discussion and conclusions. A brief overview of each chapter's focus is summarized in the next section.

### **1.4 Essay Overview**

The first essay (Chapter 2) is on landowners' interest in the provision of ecosystem services from forests. Previous studies (Blatner et al., 1991; Butler and Leatherberry, 2004) have reported that private forests are playing significant role in supplying ecosystem services (i.e.

aesthetics, privacy etc.). In addition, most of the forests in the Cumberland Plateau in Tennessee are privately owned and hence, forest management decision-making of private landowners is a key to sustaining the ecosystem service supply. Existing studies (e.g., Jack et al., 2008) mainly focused on exploring the efficacy of incentive-based programs (e.g., Conservation Reserve Program) in motivating landowners for participation. Therefore, this research attempts to assess how NIPF landowner interests in supplying various types of ecosystem services including carbon storage, water quality, and aesthetics are related to personal characteristics, management objectives, ownership structure, and availability of financial incentives. Using data collected from a mail survey of NIPF landowners on the Cumberland Plateau of Tennessee, this study provides useful information in understanding the potential suppliers of those services and in designing appropriate outreach programs to encourage landowners in provision of such services.

The second essay (Chapter 3) investigates the landowners' perceived barriers and interests in forest certification in China. Forest certification has become a preferred strategy in forest industry to promote sustainable forest management across the world. Yet China, as the world's second largest producer of wood product (Campbell et al., 2008), began engaging in forest certification relatively late (late 1990s or early 2000s). Certification and sustainability of forests in China becomes an issue of international concern considering China's wood product export to other regions including North America and Europe. However, very little was understood about the opportunities and challenges faced by forest landowners and the relationship between landowners' willingness to participate in forest certification and their personal and forestland characteristics. This research attempts to examine whether and how ownership motivations, management objectives, ownership structures and motivations, socio-



demographic characteristics, and other factors defending certification schemes influence landowners' willingness to participate in certification programs. Data for this study were collected from the Shandong province in China through a household survey in 2016. Results from this study reveal some interesting findings that will be useful in understanding and promoting market for forest certification in China.

The third essay (Chapter 4) examines the variation in price elasticity of timber supply and explores the factors that contribute to the variation. Although the market price is considered to have the most important role in determining timber supply (Kuuluvainen et al., 1996; Kuuluvainen and Tahvonen, 1999; Prestemon and Wear, 2000; Bolkesjø and Baardsen, 2002; Bolkesjø and Solberg, 2003), a mixed conclusion exists in literature as to whether and to what extent timber supply responds to market price (i.e. price elasticity of timber supply or PELS). To meet the research objective of examining contributing factors for different supply responsiveness to price, a meta-analysis of published studies on price elasticity of timber supply was conducted by reviewing a total of 51 studies published in 25 articles during the period of 1980 to 2015. A vote count method and meta-regression method were employed to study how elasticity varied and what factors (e.g., forest product type, region, model specification, data type etc.) contributed to the variation in PELS. Findings may provide a theoretical basis to assist practitioners and policymakers to develop a deeper understanding of the dynamics of price signaling in timber markets.

Finally, conclusions and appropriate policy implications of those findings are discussed in detail at the end of respective essays. Moreover, the fifth chapter of this dissertation

summarizes all conclusions and recommendations from each essay in a concise form and highlights the ideas that add to forestry resource management literature.

**CHAPTER II**  
**UNDERSTANDING THE FACTORS INFLUENCING NONINDUSTRIAL**  
**PRIVATE FOREST LANDOWNER INTEREST IN SUPPLYING**  
**ECOSYSTEM SERVICES IN CUMBERLAND PLATEAU, TENNESSEE**

A version of this chapter has been published as follows:

Tian, N., Poudyal, N. C., Hodges, D. G., Young, T. M., Hoyt, K. P. “Understanding the Factors Influencing Nonindustrial Private Forest Landowner Interest in Supplying Ecosystem Services in Cumberland Plateau, Tennessee.” *Forests* 6 (2015): 3985 – 4000.  
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Nana Tian, Neelam Poudyal, Donald Hodges, and Timothy Young prepared the manuscript. Nana Tian conducted data analysis and interpretation of results. Donald Hodges and Kevin Hoyt designed the questionnaire and implemented the survey (The survey instruments, Cumberland Plateau Landowner Survey, 2007).

### **Abstract**

Private forests provide a range of ecosystem services for society including provisioning, regulating, cultural, and supporting services. Sustaining the supply of such services depends on the interest of nonindustrial private forest (NIPF) landowners in managing their forests for such services. Assessing factors that influence NIPF landowner intentions would be useful in identifying potential suppliers of ecosystem services and in designing and implementing outreach and education programs to elevate the interests of less interested landowners. Using data collected from a mail survey of NIPF landowners on the Cumberland Plateau of Tennessee, this study examined how landowner interest in supplying ecosystem services was influenced by socio-demographic characteristics, economic and market factors, land management objectives, and ownership motivations. To that end, a multivariate logistic regression model was employed to analyze the supply of three types of ecosystem services: carbon storage (regulating service), water quality (provisioning service), and aesthetics (cultural service). Results revealed that

landowner interest in managing forests for ecosystem services were significantly related to socio-demographic factors, management and ownership characteristics, and availability of financial incentives. These findings will improve the understanding of the market segment of landowners as related to ecosystem services. The findings may facilitate the development of market protocols and outreach programs that promote payments for ecosystem services in Tennessee and elsewhere.

**Keywords:** Ecosystem service; Multivariate logistic regression; Nonindustrial private forest landowners (NIPF)

## 2.1 Introduction

Forests are traditionally treated as a source of timber and other wood products, but are traditionally undervalued for the provision of ecosystem services (ES). By definition, ES are benefits that people obtain (directly or indirectly) from the functions and services of natural ecosystems, and these benefits mainly refer to provisioning, regulating, cultural, and supporting services needed to maintain other services (MEA, 2003, 2005). Common provisioning services include non-timber forest products, water quantity and quality, and production of food, fuel, and fibers. Regulating services include carbon sequestration and environmental hazard (e.g., pests and pathogens) control, with cultural services mainly referring to recreational and aesthetic benefits. Unfortunately, the Millennium Ecosystem Assessment (2005) and Costanza *et al.* (2014) indicated that global supplies of several of these ES are in decline. Recent studies have revealed that private forests play important role in providing immeasurable ES such as aesthetic enjoyment, privacy, and closeness to nature (Blatner et al., 1991; Butler et al., 2004). Approximately 63% of the forestlands in the U.S. are privately owned and most of them are classified as nonindustrial private forests (NIPFs) (Butler et al., 2004; Butler et al., 2016). The USDA Forest Service estimates that 69% of the forestland in the southern U.S. is owned by NIPF landowners (Wear et al., 2002) and this percentage reaches as much as 81% in Tennessee (Oswalt et al., 2009). Therefore, the interest of NIPF landowners in managing their forests for ES significantly affects the forest sector's ability to provide ES to society.

To better understand the potential supply of ES from private forests, it is important to know what factors influence landowners' decision-making in favor of ES supply. Pattanayak *et al.* (2002), for example, indicated that efficient forest policy depends on an accurate

understanding of the factors influencing landowner management decisions. Studies (Butler et al., 2004; Salmon et al., 2006; Majumdar et al., 2008) have shown that personal beliefs and motivations are crucial factors in affecting private forest management decisions. Berta *et al.* (2012) found that lifestyle-oriented landowners are more interested in managing their forests for cultural over regulating services. Moreover, previous studies of landowner behavior have demonstrated that landowner characteristics (e.g., age, gender, education, income, etc.) and ownership characteristics (e.g., ownership size, tenure, mode of acquisition, etc.) play important roles in forest management decisions (Erickson et al., 2002; Elwood et al., 2003; Joshi et al., 2009; Thompson and Hansen, 2012, 2013; Sorice et al., 2014; Knoot et al., 2015). Likewise, motivations of land ownership and land management objectives have also been found to be associated with landowners' attitudes regarding alternative forest management practices (Tornqvist, 1995; Kuuluvainen et al., 1996; Nagubandi et al., 1996; Karppinen, 1998; Conway et al., 2003; Finley et al., 2006; Schaaf et al., 2006; Kaetzel et al., 2009). Thus, prior research demonstrates that a clear link exists between NIPF management decisions and factors such as landowner demographics, ownership characteristics, and management objectives. These factors have been used in predicting NIPF management practices (Binkley, 1981; Kilgore et al., 2008). In addition, landowner perception of risks associated with alternative management activities is a key predictor of their adoption of new management practices such as carbon sequestration (Hardner et al., 2000; Thompson and Hansen, 2013).

In addition to understanding the factors that affect landowner attitudes toward ES provision, knowing how to provide appropriate incentives to motivate those owners with little interest in ES is equally important (Goldman et al., 2007). Numerous studies explored the

efficacy of incentive-based programs to motivate landowners for ES supply. Jack *et al.* (2008), for instance, showed that payments for ecosystem services (PES) policies increase the provision of ES such as water purification, flood mitigation, and carbon sequestration in U.S. Nevertheless, a knowledge gap still exists in fully understanding the relationship between the interest of NIPF landowners in supplying ES and the circumstances landowners face. To bridge that gap, this paper presents the results of a study to assess how NIPF landowner interests in supplying various types of ES including carbon storage, water quality, and aesthetics are related to personal characteristics, management objectives, ownership structure, and availability of financial incentives. Through identifying the characteristics of NIPF landowners associated with an interest in managing forests for ES provision, we provide useful information in understanding the potential suppliers of those services and in designing appropriate outreach programs to encourage owners to provide more services.

## **2.2 Conceptual Framework**

Given that the majority of forestland in the southern U.S. is under NIPF ownership, the management decisions they make are critical to future of ES supplies. According to the economic theory of utility-maximization, landowners that are also considered utility-maximizers take non-pecuniary benefits such as biodiversity, flood control, carbon sequestration, aesthetics, and recreation into consideration along with or without the timber benefits produced from their forestlands. The theory suggests that a landowner's forest management decision-making depends on both timber and non-timber benefits. Studies have demonstrated that the vast majority of NIPF landowners are generally utility-maximizers (Max and Lehman, 1988; Hyberg and Holthausen, 1989; Amacher et al., 2003).



In addition, related theories in social psychology, including the Theory of Planned Behavior (TPB) (Ajzen, 1991) in particular, provide a basis for examining landowner management intentions. TPB “explains human behavior based on their attitudes to a behavior, subjective norms, and perceived behavioral control.” The main idea behind TPB is that the best predictor of future behavior is the intent to a specific behavior (Ajzen, 1985). Behavioral intentions indicate one’s willingness and preparedness to perform a given behavior and are assumed to be a direct antecedent of actual behavior. The TPB theory states that a landowner’s attitude toward a management practice, subjective norms, and perceived risk could guide him/her in making a management decision for his/her forestland. A number of studies on landowners’ behavior have been based on the TPB theory. For instance, Thompson *et al.* (2013) applied TPB to explore private landowners’ attitudes towards participating in carbon sequestration. Similarly, Leitch *et al.* (2013) used the TPB theory to explore private landowners’ intentions to supply woody feedstock.

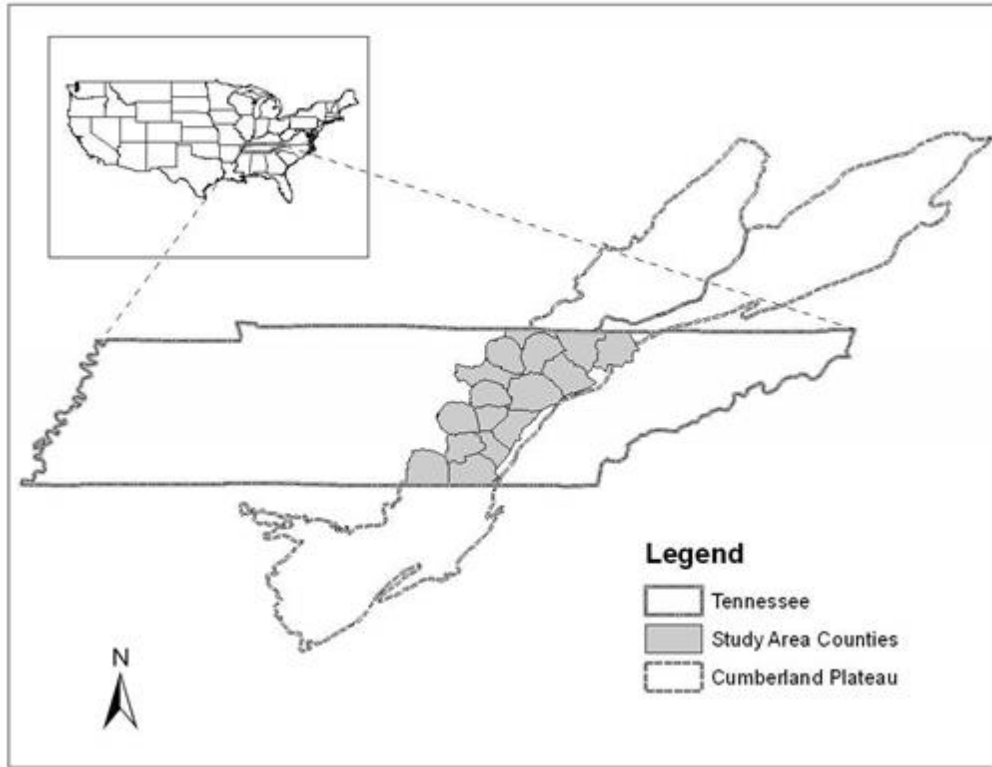
## **2.3 Methodology**

### ***2.3.1 Study Area and Data Collection***

The study area covered 16 counties located in the Tennessee portion of the Cumberland Plateau (Figure 2.1): Bledsoe, Campbell, Cumberland, Fentress, Franklin, Grundy, Marion, Morgan, Overton, Pickett, Putnam, Scott, Sequatchie, Van Buren, Warren, and White. The Plateau is one of the “largest temperate hardwood plateau systems” and has remained largely undeveloped until recently due to the rugged terrain (The Nature Conservancy). Most of the forests on the Plateau are under private ownership (Hoyt, 2008) and forested areas in some counties (e.g., Cumberland) have recently seen a surge of amenity migration and retiree growth.

Sustaining the ecosystem and quality of life on the Plateau therefore will require cooperation of thousands of landowners in protecting and efficiently managing forests in the long run. With timber markets struggling in recent years, ES could serve as new markets for the forests.

Data required were collected with a mail survey (Cumberland Plateau Landowner Survey, 2007) of randomly selected forest landowners in the study area. The questionnaire was mailed to more than 1700 NIPFs in 2007 following the Total Design Method (Dillman, 2000). Two hundred and forty-six names were eliminated from the survey results because of the bad addresses, death, or having sold the land. As a consequence, a total of 590 completed surveys were returned, yielding an adjusted return rate of 41%. Survey questions included Likert scale items regarding their level of interest (1 = no interest at all, 4 = high interest) in managing forests for three types of ES: carbon sequestration, water, and aesthetics. Besides, other questions included in this survey were grouped into six different categories (Table 2.1): sociodemographic, forest ownership and management objective, attitudes towards incentives, motivation of owning forestlands, future ownership plan, and other factors (perceived risk of damage and return from forest). Besides the survey questions, the secondary data regarding per acre return from forests in the respective county of each respondent was obtained from the *Tennessee Statistical Abstract* which was published by the Center for Business and Economic Research at the University of Tennessee. We divided the total dollar value of agriculture or forest product by the average farm size of the respective type to get the return on a per acre basis (Poudyal et al., 2014).



**Figure 2.1 Sixteen-county area of the Cumberland Plateau of Tennessee.**

**Table 2.1 Explanatory variables used to explain landowners' interest in managing forests to supply ecosystem services**

Variable	Description	Mean (S.E.)
<b>Sociodemographic</b>		
Age	Age of the landowner	68.99(12.63)
Female	Dummy variable, 1 if female, 0 otherwise	0.23 (0.42)
Education	Dummy variable, 1 if landowner has more than college education, 0 otherwise	0.39 (0.49)
Income	Dummy variable, 1 if landowner has > \$75,000 in annual income, 0 otherwise	0.34 (0.47)
Occupation	Dummy variable, 1 if white-collar occupation, 0 otherwise	0.17 (0.38)
<b>Forest ownership and management objective</b>		
Tenure	Number of years the property has been with landowner's family	43.06(41.92)
Acquisition	The mode of acquisition of forest by landowners. (1 if purchased, 0 otherwise)	0.72 (0.45)
Ownership size	Categorical variable, 1 if the landowner owns < 10 acres of forestland, 2 if owns between 10 and 100 acres, and 3 if owns > 100 acres	2.22(0.49)
Timber harvesting	Dummy variable, 1 if the landowner recently harvested timber or planning to harvest soon, 0 otherwise	0.22(0.41)
Advice	Dummy variable, 1 if the landowner received advice from professionals, 0 otherwise	0.04(0.19)
<b>Attitudes toward Incentives</b>		
Property tax	Reported usefulness of property tax as incentive (1 = not useful, 5 = extremely useful)	3.65(1.27)
Payment of individuals/companies	Reported usefulness of payment from private individual/company as incentive (1 = not useful, 5 = extremely useful)	2.85(1.50)
Payment of government	Reported usefulness of payments from government as incentive (1 = not useful, 5 = extremely useful)	3.05(1.49)

**Table 2.1 Continued.**

Variable	Description	Mean (S.E.)
Motivations of owning forestlands		
Financial investment	Importance placed by landowner on “financial investment” as ownership motivation (1 = not important, 5 = extremely important)	3.03(1.36)
Hunting/fishing	Importance placed by landowner on “hunting and fishing” as ownership motivation (1 = not important, 5 = extremely important)	2.71(1.48)
Farm/Home site	Importance placed by landowner on “farm” as ownership motivation (1 = not important, 5 = extremely important)	3.53(1.45)
Inheritance	Importance placed by landowner on “pass on to heirs” as ownership motivation (1 = not important, 5 = extremely important)	2.46(1.67)
Peacefulness/tranquility	Importance placed by landowner on “peacefulness and tranquility” as ownership motivation (1 = not important, 5 = extremely important)	3.94(1.20)
Future ownership plan		
Inherit	Dummy variable, 1 if landowner plans to pass the forests to heirs, 0 otherwise	0.76(0.43)
Develop	Dummy variable, 1 if landowner continues to manage the forests, 0 otherwise	0.06(0.24)
Sell	Dummy variable, 1 if landowner plans to sell the forests, 0 otherwise	0.19(0.40)
Donate	Dummy variable, 1 if landowner plans to donate the forests to others, 0 otherwise	0.03(0.17)
Other factors		
Perceived risk of damage	Landowner’s perception of risks of environmental damage associated with harvesting timber (1 = no risk at all, 5 = extreme risk)	3.34(0.91)
Return from forest	Land productivity from forest use as measured by per acre value (\$) of timber products for landowner’s county	10.51(3.87)

### 2.3.2 Empirical Model

Researchers typically have relied on logistic regression to model forest landowner management decisions due to the categorical nature of dependent variable (e.g., harvest or not harvest) (Arano et al., 2004; Joshi and Mehmood, 2011; Becker et al., 2013; Leitch et al., 2013; Knoot et al., 2015; Young et al., 2015). Since our study also involves modeling the landowner's level of interest, as measured by a Likert scale, a multivariate logistic regression was used. The dependent variable was the respondents' level of interest in managing forests to provide a given ES (*i.e.*, carbon sequestration, water quality, and aesthetic beauty). To examine whether specific factors related to NIPF landowner interest varied with different types of ES, each of the three dependent variables were separately regressed against explanatory variables. In each ES case, the dependent variable was hypothesized to be a function of the independent variables shown in Equation (1).

$$\text{Level of interest in supplying ES} = f(\text{Sociodemographics, Ownership and Management Objectives, Attitudes toward Incentives, Motivations for Owning Forestlands, Future Ownership Plans, Perceived Risk of Damage, Return from Forest}) \quad (1)$$

Mathematically, the multivariate logistic regression model is presented in Equation (2):

$$Y = \sum \beta'_k x_k + \varepsilon_k \quad (2)$$

Where:  $Y$  represents the level of respondents' interest in supplying selected ES,  $x_k$  is the matrix for all independent variables and  $\beta'_k$  indicates the associated parameters;  $\varepsilon_k$  is the error term of stochastic (unobserved) variation.

The sociodemographic group consisted of age, gender, education, income, and occupation. With respect to the relationship of age and gender with landowner interest in

supplying ES, previous studies revealed that older and female landowners exhibit more interest in non-timber values and are more concerned for the environment (Kline et al., 2000; van Herzele and Gossum, 2009; Knoot et al., 2015). Therefore, we expected a positive sign between age and landowner interest in providing ES. Moreover, income, education, and white-collar occupations were hypothesized to be positively related with landowner interest in managing forests for provisioning ES.

The second category included tenure, mode of acquisition, ownership size, timber harvesting history, and whether landowners received advice from professionals. Results regarding the relationship between tenure and forest management activities from previous studies are mixed (Germain et al., 2007; Mendham and Curtis, 2010) and therefore it is difficult for them to guide expectations for this study. In terms of mode of acquisition, we hypothesized that purchasers would be more interested in supplying ES than those who inherited forest from their parents. The reason behind this is that those who have invested resources in purchasing the land might be motivated by the potential benefit of incentives from provision of ES. In addition, compared to landowners who receive forestlands through inheritance, landowners who purchase their forestlands might be keener in managing the property with a specific interest. Previous studies also provided mixed results regarding the relationship between landholding size and interest in providing ES. Knoot *et al.* (2015) and Jacobson *et al.* (2002) concluded that there is no relationship between the land size and attitudes toward ES supply, whereas Thompson *et al.* (2012) reported a negative correlation between increasing tract size and landowner interest in carbon sequestration. Hence, it is difficult to speculate on the relationship between landholding size and landowner interest in providing ES here. Nevertheless, we expected a negative

relationship between timber harvesting and landowner intentions to supply ES because landowners who harvested or are planning to harvest timber might have less interest in non-timber products. By contrast, a positive sign for the advice variable was expected because landowners who received management advice from professionals were more motivated to manage their forests for ES. The reason is that the professional consulting could help the landowners meet their management objectives.

Attitudes toward incentives (for providing ES) of various types were also included in the model. Three types of incentives were included: payments from government, payments from private individuals/companies, and property tax incentives. Jack *et al.* (2008) reported that payment for ES increases the supply of water purification and carbon sequestration. By the same token, a landowner's favorable view of incentives is expected to be positively related to landowner interest.

Ownership motivation variables included the importance placed on financial investment, hunting/fishing, farm/home site, inheritance, and peacefulness/tranquility for owning the forest. We expected that those placing higher importance on recreation (e.g., hunting/fishing), the site of their farm or home, and tranquility were more likely to manage forests for ES. On the contrary, landowners whose main purpose was to obtain financial benefits from their land would be less interested in ES. Majumdar *et al.* (2008) noted that inheritors are more likely to manage forests for both timber and non-timber products than non-inheritors. Hence, we expected landowners who inherited land to exhibit more interest in ES provision.

We also expected that future ownership plans would affect landowner willingness to supply ES. Hence, variables for landowner plans to inherit, develop, sell, and donate were



included. Kendra *et al.* (2005) and Finley *et al.* (2006) reported that “plan to sell” owners are less interested in engaging in forest management. Conversely, landowners who were willing to bequeath the forestlands to future generations are more concerned about both timber and non-timber values (Amacher *et al.*, 2003). Thus, we expected that owners who were planning to bequeath the forests to their descendants were more willing to supply ES than those who were planning to sell or donate forestlands.

The final category was composed of two variables: perceived risk of damage by harvesting and financial return from forestland use as measured by the per-acre value of wood products sold. The perceived risk and liability variable was developed by combining landowners’ responses to seven different items characterizing the risk and liabilities that may be associated with the logging of a forest area. Using a 5-point Likert scale (1 = no risk at all, 5 = very high risk), their perception of the level of risk in terms of timber being stolen, property damage, water quality impacts, damage to residual trees, landowner liability, poor utilization of wood and waste, and beauty of the area affected were measured. Individual scores were added and then divided by seven to get the average score of perceived risk and liability. It is reasonable to expect that some landowners may not appreciate the aesthetic damage from timber harvesting (Franklin *et al.*, 2002). Hence, the perceived risk of damage associated with timber harvesting can be significantly related to interest in non-timber services. As a result, private owners who perceived high risks from harvesting were expected to be willing to manage forests for non-timber services. Considering the Ricardian land rent theory (Bidard, 2014), we hypothesized that landowners would be less interested in managing forests for ES if the per acre return from wood products (or the timber productivity) is high.

## 2.4 Results

Summary statistics of the independent variables are presented in Table 2.1. The average age of respondents was 68 years. About 76% of the respondents were male, two-thirds (69.7%) reported some college education, and the reported mean annual income was \$50,000. In terms of forest ownership size, approximately 71% of the sample reported between 10 and 100 acres; 25% reported more than 100 acres, and about 4% indicated less than 10 acres. On average, the respondents owned the property for approximately 45 years: specifically, 70% of the sample owned their property less than 50 years and 23% between 50 and 100 years, as well as 7% over 100 years. Referring to acquisition, 72% of the sample reported that they purchased the land. Regarding the three incentives options, 82% preferred property tax incentives, with a relatively smaller percentage indicating that a direct payment from private individuals or companies (60%) and government (65%) would be useful. Approximately 79% of the respondents indicated that pursuing peacefulness/tranquility was the primary reason for owning their forests, whereas 76% expressed a willingness to bequeath their land to their descendants.

Collinearity among explanatory variables was tested by computing variance inflation factors (VIF) index (Table 2.2) and they were far less than critical threshold of 10 (Ghimire et al., 2014), suggesting that multicollinearity was not an issue of concern in our model. Results of the multivariate logistic regression are presented in Table 2.2. Both age and gender were significantly ( $p < 0.01$ ) related to respondents' interest in managing their forests for protecting water quality and storing carbon. The positive and significant coefficient on age implies that a landowner's interest in managing forests for water quality and carbon sequestration increases with their age. Similarly, female respondents exhibited a higher level of interest in managing

their forests to protect water quality and sequester carbon than their male counterparts. By contrast, gender was not significant in the case of aesthetics. Similarly, those with a white-collar occupation were less likely to indicate an interest in carbon sequestration. In addition, education and income were both not significantly related with respondents' interests in providing any of the three ES examined.

The results of the forest ownership and management objective group revealed that tenure was significantly ( $p < 0.01$ ) and positively related to a respondent's interest in managing forests for carbon sequestration. Similar results were observed for aesthetic maintenance as an ES ( $p < 0.1$ ). The dummy variable indicating whether the respondents recently harvested timber was significantly and positively ( $p < 0.1$ ) related to their level of interest in managing forests to protect water quality. Other variables in this category (ownership size, whether or not the landowner purchased the forest or received management advice from professionals) were insignificant.

Among the variables related to landowners' attitudes toward usefulness of incentives, a favorable view of property tax incentives or direct payment from the government were positively and significantly related to an interest in managing forests for selected services. Specifically, coefficients for property tax incentives were significant for aesthetic beauty ( $p < 0.01$ ) and water quality ( $p < 0.1$ ). A significant ( $p < 0.1$ ) coefficient was also observed for direct payment from the government for carbon storage. Direct payments from private individuals/companies were not significantly related to interest in managing forest for any of the ES examined.

**Table 2.2 Results from multivariate logit model explaining factors related to landowners' interest in managing forests for selected ecosystem services (n = 590)**

Variable	Ecosystem Services			VIF
	Carbon	Water	Aesthetics	
	Coefficient (S.E.)	Coefficient (S.E.)	Coefficient (S.E.)	
<b>Sociodemographic</b>				
Age	0.03(0.01) ***	0.03(0.01) **	0.03(0.01) ***	1.42
Gender	0.76(0.31) **	0.80(0.36) **	0.40(0.33)	1.39
Education	-0.35(0.25)	0.01(0.29)	0.0007(0.1)	1.38
Income	-0.29(0.25)	0.07(0.28)	0.52(0.27) *	1.33
Occupation	-0.89(0.33) ***	-0.09(0.37)	0.005(0.35)	1.66
<b>Forest ownership and management objectives</b>				
Tenure	0.02(0.00) ***	0.01(0.00)	0.007(0.00) *	2.01
Acquisition	0.36(0.35)	-0.10(0.39)	0.17(0.36)	2.32
Ownership size	-0.24(0.27)	0.27(0.30)	0.02(0.28)	1.32
Timber harvesting	0.04(0.27)	0.54(0.31) *	-0.33(0.29)	1.23
Advice	0.63(0.63)	-0.04(0.69)	0.89(0.67)	1.23
<b>Attitudes toward Incentives</b>				
Tax property	-0.12(0.13)	0.25(0.14) *	0.40(0.14) ***	2.18
Payment of individuals/companies	-0.07(0.12)	0.11(0.14)	0.09(0.12)	2.82
Payment of government	0.51(0.14) ***	0.08(0.14)	-0.14(0.13)	2.75
<b>Motivations of owning Forestlands</b>				
Financial investment	0.03(0.09)	-0.19(0.10) *	-0.09(0.10)	1.34
Hunting/fishing	0.05(0.09)	0.25(0.10) ***	-0.05(0.09)	1.38
Farm/home site	-0.14(0.10)	-0.06(0.11)	-0.18(0.10) *	1.64
Inheritance	-0.10(0.09)	-0.10(0.12)	0.04(0.11)	2.54
Peacefulness/tranquility	0.58(0.12) ***	0.46(0.13) ***	0.61(0.12) ***	1.53
<b>Future ownership plan</b>				
Inherit	-0.71(0.31) **	-0.18(0.32)	-0.12(0.31)	1.41
Develop	0.20(0.48)	-0.21(0.55)	0.37(0.54)	1.11
Sell	-0.73(0.32) **	-0.17(0.35)	0.08(0.32)	1.50
Donate	-0.73(0.65)	-0.50(0.73)	-0.88(0.71)	1.18

**Table 2.2 Continued.**

Variable	Ecosystem Services			VIF
	Carbon	Water	Aesthetics	
	Coefficient (S.E.)	Coefficient (S.E.)	Coefficient (S.E.)	
Other factors				
Perceived risk of damage	0.83(0.30) ***	0.65(0.18) ***	0.38(0.20) *	3.15
Return from forest	0.003(0.03)	0.02(0.04)	-0.06(0.03) *	1.21

The importance placed on tranquility was significantly and positively associated with a willingness to provide carbon sequestration, water quality, and aesthetics. Additionally, the importance placed on hunting/fishing was positively related to an interest in protecting water quality. However, the importance of financial investment was negatively related to an interest in water quality. Moreover, the results revealed a negative association between the ownership motivation of farming and aesthetics.

Among the variables describing future ownership plan, respondents who plan to bequeath the forestlands to their descendants or sell their land were significantly ( $p < 0.05$ ) less interested in carbon sequestration. None of the future plan variables were significantly related to water quality or aesthetics.

As expected, a respondent's perception of the risk and liabilities associated with timber harvesting was positively related to their interest in managing for all three ES ( $p < 0.01$ ). The coefficient on the return from forests per acre was negative and significant ( $p < 0.10$ ) in the case of aesthetic beauty, and insignificant for the other two ES.

## **2.5 Discussion**

This study demonstrates that a landowner's decision to supply ES is influenced by a wide range of ownership and land characteristics. Older and female landowners were generally more likely to manage their forests for ES, results that are consistent with previous studies (Kline et al., 2000; van Herzele and Gossum, 2009; Mackerron et al., 2009; Knoot et al., 2015). Women are found to be more concerned than men about environmental issues, which perhaps relates to their higher level of interest in managing forests for ES (Tindall et al., 2003; Mcfarlane and Hunt, 2006; Mackerron et al., 2009). This observation is in line with the TPB theory, which

states that beliefs about environmental concern influence people's behavioral intentions, with regard to likelihood of managing forests to supply ES. The finding that higher income landowners exhibit a greater level of interest in managing forests for some ES agrees with the findings of Knoot *et al.* (2015), who reported that income was positively associated with landowner interest in protecting some ES, such as bird habitat and water protection. Landowner education was not significantly related to a willingness to supply any of the ES considered in our analysis, which is in line with the results reported by Miller *et al.* (2012), but Thompson *et al.* (2012) reported that education positively affects interest in carbon sequestration. Such information about basic demography of NIPF landowners who are interested in sustaining the ES provision would be helpful for effective communication and outreach to those segments assistance.

Landowners who owned their forest for a longer period of time were more interested in managing it for carbon sequestration and aesthetics. It is possible that keeping the family's forests in a natural state might have been a common belief or "family norm" among some legacy- or heritage-oriented landowners, who also might have higher level of interest in non-consumptive management including carbon and aesthetics. This observation is also consistent with the relationship between norms and behavior described in the TPB framework. Earlier, Poudyal *et al.* (2014) reported that tenure was negatively related to landowner intentions to convert forestlands. Furthermore, landowners who recently harvested timber or were planning to harvest soon were more likely to be interested in managing forests for water quality protection than those who neither harvested nor were planning to harvest anytime soon. Thompson *et al.* (2012) reported higher interest in carbon sequestration among landowners who planned to

harvest timber. Our survey did not ask a specific question in this regard, but it is possible that interest in protecting water quality might have also been motivated by the negative impact of recent harvests. As described in TPB theory, this observation probably explains the relationship between the landowners' negative attitude towards the consequences of logging on water quality and intention to manage forest for non-timber products, which does not require logging.

Attitudes toward incentives for ES provision varied in their effects on landowner interest in supplying selected services. Landowners who thought property tax would be useful exhibited more interest in managing forests for water quality and aesthetics, whereas those who favored a direct government payment were also interested in managing forest for carbon storage. The significance of a property tax incentive in motivating landowners is not surprising considering that property tax is one of the largest financial burdens that NIPF landowners face (Arano et al., 2004). Additionally, a landowner's previous experience with tax subsidies or exemptions (e.g., Tennessee Green Belt Program) and direct government payment (e.g., Conservation Reserve Program) may provide more familiarity and comfort with these incentives than other market-based PES mechanisms that are less common or nonexistent in the region. Landowners are probably less certain about the commitment from private individuals or companies as compared to government entities. These contrasting findings regarding the incentives could guide the design of new programs or demonstrate support for recently introduced programs that have been implemented across the nation. Such a mechanism of payment for ES exists in the form of tax credit for conservation easement (e.g., Virginia State Tax Credit, Colorado Conservation Easement Tax Credits, and Tennessee's Greenbelt Law). These programs are designed to protect the conservation values of a property such as wildlife habitat, outdoor recreation areas, and



agricultural lands, as well as scenic vistas or historic lands. Considering the success of many of these tax-based programs, the government could facilitate transaction of incentives and payment for ecosystem services like carbon, water, and aesthetics through similar innovative mechanisms, where beneficiaries (e.g., companies, households) pay the government, and government in turn pays landowners for ecosystem service credit.

Landowners who highly valued tranquility were interested in managing their forests for all types of ES considered in our study. As shown in Butler *et al.* (2004), enjoying tranquility is one of the most important landownership motivations among private landowners, and hence, if landowners place high importance on this motivation, they seem more interested in managing forests to provide all types of ES. Those who value recreational opportunities such as hunting demonstrated more interest in protecting water quality which arguably could benefit habitat quality. Nevertheless, Ghimire *et al.* (2014) and Brenner *et al.* (2013) reported that hunters are less interested in placing land in conservation easement. The inconsistency of these results may be caused by the fact that the easement involves giving up the development rights. By contrast, landowners motivated by financial returns were less likely to manage forestlands for water quality protection, possibly because returns for this ES are hard to identify in the region. Landowners' underlying values (economic, recreational *etc.*) are probably related to their evaluation of expected benefits from managing land for select ES. Even though our study does not show a formal path analysis, the evaluative belief (attitude) of benefits might in turn have influenced their intention to manage forests for alternative ES, an observation consistent with the TPB.

Future ownership plans also influenced interest in supplying ES. Landowners who plan to sell forestland were less interested in managing for carbon sequestration. This corroborates the earlier findings of Kendra *et al.* (2005) and Finley *et al.* (2006), who concluded that “plan to sell” owners are unwilling to participate in forest management activities involving both timber and non-timber outputs. Nevertheless, those who were planning to bequeath forests to their descendants were also less willing to manage for carbon sequestration. A casual observation behind this result is that the carbon-offset programs generally require a long-term commitment, such as the California Climate Action Registry (CCAR) program (Pearson *et al.*, 2008; Dickenson, 2010), which is not well suited to changes in ownership.

Finally, the likelihood of supplying ES was high among landowners who perceive higher risks with timber harvesting. This finding was consistent with Hardner *et al.* (2000), who stated that landowners with high risk perception of forest degradation would be more willing to participate in carbon sequestration programs. According to the TPB theory, perceived risk as well as the behavioral control is an important predictor of behavioral intentions to undertake forest management practices. Therefore, TPB also explains why the landowners who have a higher risk perception of timber harvesting would be more likely to manage forests for carbon sequestration. Moreover, as indicated by Franklin *et al.* (2002), harvesting forests could increase habitat fragmentation and aesthetic damage; thus, if the landowners perceive such risks, they might be more willing to manage for non-consumptive services such as ES. Returns from traditional forest management affect landowner interest in managing ES except in the case of aesthetics.

## 2.6 Conclusions

In conclusion, this study sheds some light on the characteristics and motivations of NIPF landowners who are interested in managing their forests for a variety of ES. First, landowners seem genuinely interested in managing their forests for provision of ES even though some difference exists in preference for incentives. Second, government agencies and conservation groups that are trying to work with landowners to promote conservation and provision of ES may benefit from our findings, particularly in identifying the market segment that might constitute the potential suppliers of ES. The findings will also be beneficial in extension and outreach programs to promote ES interest among landowners. Third, landowners seem more comfortable with government-based incentives for ES than those from private individuals or companies. This might indicate the uncertainty and trust issues among landowners in participating in private sector or market-based mechanisms for ES, and therefore some sort of government assurance might be needed to encourage landowners. Information like this would be crucial in designing market protocols and incentive mechanisms to promote ES markets.

Finally, a few limitations of this study should be noted. First, the response rate for the survey was less than desirable, although it was on par with several recent landowners' surveys in the region. No follow-up survey was conducted due to budget constraints but considerable similarities were noticed between the sample and the population of study area in some key demographics. For instance, 22% in our sample had bachelor's degree or higher level of education, 54% had \$50,000 or higher in annual household income. The 2013 U.S. Census Quick Facts showed that roughly 24% of the state population had a bachelor's degree or higher level of education, and a median household income of \$44,298. Our sample had a relatively higher

proportion of males (76%) compared to the Tennessee population (49%), but this difference may also be attributable to the fact that our sampling frame included heads of the households. A second limitation is that a range of legal and logistic details surrounding ES contracts might have a great deal of impact on landowner interest and commitment to the ES project. Future studies could take an economic approach to investigate landowner interest, with the goal of estimating a minimum willingness to accept compensation for providing ES, and understanding their attitudes toward more specific details (e.g., time commitment, compliance requirement) of ES provision agreements. Finally, our regression model did not consider forest-characteristic-related variables (e.g., pine, hardwood) and site-characteristic-related variables (e.g., slope, loggability) that could arguably impact the supply and value of ES considered in this study. Future studies could combine survey data on landowners' interest with the spatially explicit land cover data of their parcels to address this.

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**CHAPTER III**  
**UNDERSTANDING LANDOWNERS' INTEREST AND WILLINGNESS**  
**TO PARTICIPATE IN FOREST CERTIFICATION PROGRAM IN CHINA**

This article hasn't been published anywhere, nor will it be before I turn in the final version of my ETD, so I didn't include a publication statement.

### **Abstract**

Forest certification is considered a viable market-based strategy to promote sustainable forest management by providing landowner with financial incentives and social recognition for responsible forest practices. Certification and sustainability of forests in China is an issue of international concern, especially considering China's wood product export to other regions including North America and Europe. However, the success of such programs may depend on opportunities and challenges faced by forest landowners. To examine landowners' perceived barriers and interests in forest certification in China, this study conducted a landowner survey in Shandong province in 2016. I analyzed whether and how ownership motivations, management objectives, ownership structures, socio-demographic characteristics, and characteristics of certification schemes influence landowners' willingness to participate in certification programs. Results indicate that majority of landowners in Shandong province are not currently familiar with forest certification programs but are willing to consider participating when provided with pertaining information (i.e. potential cost, benefits). Result suggests that there may be a potential market for certification program in China with appropriate outreach and extension. In addition, results from an ordinal logistic regression showed that landowners' willingness to participate in forest certification was significantly related with expected benefits and limitation associated with certification schemes, landownership motivation and management objectives, and characteristics of the forestland as well as the household. Findings will be useful to institutions and policy

makers interested in understanding and promoting market for forest certification in China and other developing countries with similar socioeconomic and forest resource characteristics.

**Keywords:** Forest certification; Ordinal logistic regression; Forest landowners



### 3.1 Introduction

Forest certification is a market-based mechanism to promote sustainable forest management through improving forest management practices and handling of forest products. Initially, it was advanced by non-governmental organization (NGO) as a response to deforestation and poor forest management in tropical forests (Leslie, 2004; Rametsteiner and Simula, 2003; Durst et al., 2006). More recently, forest certification has become a preferred strategy by forest industries across the world to promote sustainable forest management. While it has gained rising popularity among forest landowners and industry stakeholders in European and North American countries, reasonable progress has yet to be made in developing countries including China that remain a significant exporter of a wide range of forest products to the world (Campbell et al., 2008). China had a late start (late 1990s or early 2000s) in engaging in forest certification and the first certified forestland was the Changhua Tree Farm in Zhejiang Province in 2001 under the internationally recognized Forest Stewardship Council (FSC) certification scheme. Another commonly used certification scheme in China is the Programme for the Endorsement of Forest Certification schemes (PEFC). In addition to the FSC and PEFC certification schemes (Hui et al., 2008), China has also developed its own national forest certification regulations headed by the China Forest Certification Council (CFCC) which is endorsed by PEFC (China Forest Certification Scheme, 2014).

In recent years, China has made notable progress in forest certification. For instance, total area of forests certified by PEFC have increased from 439,630 hectares in 2006 (Yuan and Eastin, 2007) to over 5.8 million hectares in December, 2016 (PEFC, 2016). In addition, the afforestation rate in China is the highest in the world with forest cover increasing from 12%

(1983) to more than 21% (2013) in about 30 years (PEFC, 2014). The current goal for forest coverage is to reach 23% (or 223 million hectares) by 2020 (PEFC, 2014). Certification would be an important policy for long-term ecological and economic sustainability of these newly established (as well as existing) forests. Accordingly, China has a large forest certification market potentially available to both national and international certification schemes in the near future. Besides, with rapid growth in China's international trade of forest products and associated goods, it is important to institutionalize best management practices like certification.

In the global context, numerous studies have examined the potential constraints faced by the landowners regarding forest certification. Some have found that the relatively high cost and stringent requirements of forest management plan with forest certification are major concerns to landowners, especially amongst the small landowners (Molnar et al., 2004; Kilgore et al., 2007; Tikina et al., 2008; Leahy et al., 2008; Zhao et al., 2011; Ma et al., 2012; He et al., 2015). For example, a study of non-industrial private forest (NIPF) landowners in the U. S., Bensel (2001) identified the major barriers to forest certification in Pennsylvania and found that high cost of certification was a big barrier. A similar study by Perera *et al.* (2007) found that landowners in Louisiana and Mississippi were not averse to having their forests certified, but they were unwilling to bear the cost associated with the certification process.

In China, Zhao *et al.*, (2011) also stated that the cost of certification was a major concern among landowners. The same study also mentioned that forest certification was not widely understood by the landowners in China, which was another major factor limiting landowners' participation. However, studies in some parts of the United States have also found low level of certification knowledge among NIPF landowners (e.g., Kilgore et al., 2008; Leahy et al., 2008).

Based on a recent case study of collectively-owned forest ownership, He *et al.* (2015) found that the identification of plantation and decentralized forest tenure are the main obstacles for forest certification in China. Besides, Liu and Zhi (2012) found that multiple barriers including poor forest management level and low recognition/familiarity of forest certification hindered the uptake of forest certification in Yunnan province.

In addition to the potential factors that affect landowners' attitudes to forest certification, knowing the relative significance of the attributes of forest certification scheme to landowners is equally important. Some studies have analyzed the costs and benefits associated with forest certification. Chen *et al.* (2015) and Zheng *et al.* (2011) reported that forest certification has increased business profitability because the increased value of certified timber outweighs the increase in forest management costs after certifying. Also, Zhao *et al.* (2011) reported that the economic benefits was around US\$ 150 million while the certification cost ranged from US\$ 0.66 – 86.63 million under the assumption that if 50% of China's commercial forests were certified, which suggested that the benefits of forest certification far outweighed the cost. Moreover, Zhang *et al.* (2014) reported that the ecological and environmental protection of state-owned forest farms in the Shunchang County of Fujian province was significantly improved with forest certification.

Despite a handful of studies, a knowledge gap still exists in understanding what factors determine landowners' willingness to participate in forest certification programs. To bridge this gap, this study assessed how the landowners' interests in forest certification are related to personal characteristics (age, education, income, occupation, and gender), management objectives, ownership structure and motivations, and perceived benefits and costs associated with

certification schemes. Specifically, the objectives of this study were to: 1) assess landowners' knowledge and attitudes towards forest certification, 2) explore whether and what kinds of opportunities and constraints landowners face in participating in certification, and 3) identify the factors that influence landowners' willingness to participate in forest certification programs. Such information will be important to forest policymakers and forest certification institutions in promoting forest certification and sustainability in China in particular and other developing countries with similar circumstances. In addition, policymakers can benefit from the findings to design and launch outreach and extension programs to enhance landowners' awareness and interest in forest certification.

## **3.2 Methodology**

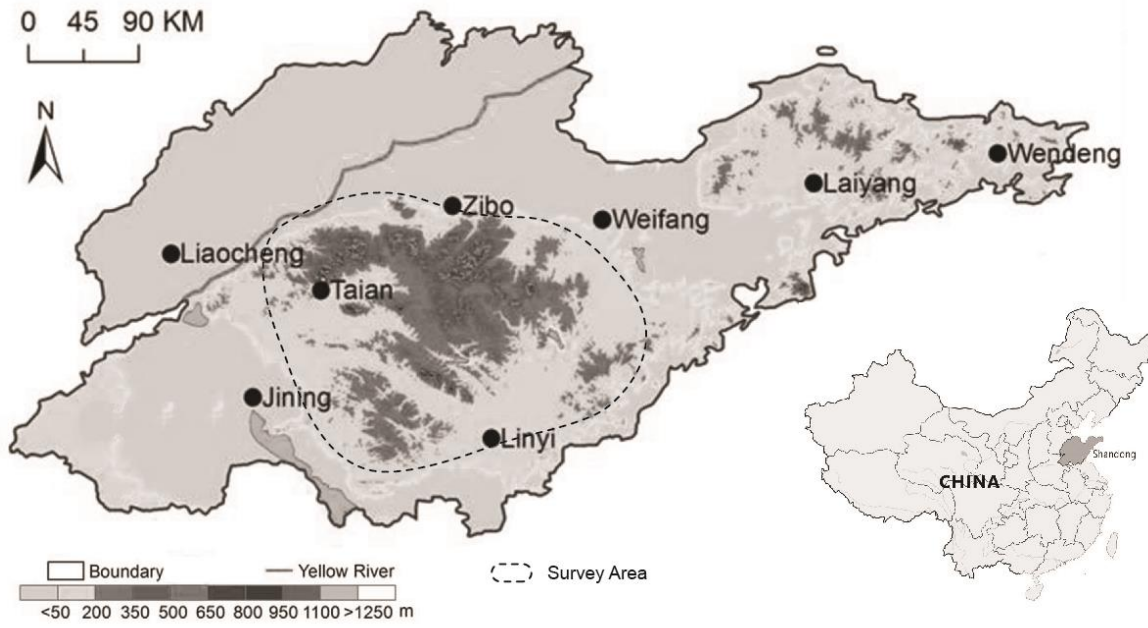
### ***3.2.1 Study area***

The geographic focus of this study was Shandong province of China, which is in the eastern coast of China and the downstream of Yellow River, with longitude of 114 ° 36'-122 ° 43' and latitude of 34 ° 25'-38 ° 23' (Figure 3.1). Total land area of Shandong province is 157,900 square kilometers and the population is 97.47 million (Shandong Statistical Yearbook, 2015). This province has a continental mild climate and resides in the warm temperate zone. On average, the annual temperature is between 11 °C and 14 °C and annual rainfall, which mostly concentrates between June and September, is from 550 mm to 950 mm. The forests area in this province is about 2.55 million hectares (38.19 million mu) by the end of 2012 according to the eighth forest inventory results and forest coverage rate is around 16.73%. The forests mainly include arbors forest and economic forest with rich tree resources which covers about 80 family, 203 genera, and 615 species. Meanwhile, the area of timber production forests is approximately

0.83 million hectares (12.49 million mu) and the most popular forest type is fast-growing-and-high-yield poplar forests. Data were collected using face-to-face survey with a representative convenient sample of forest landowners in large and heavily forested cities including Taian, Jinan, Linyi, Liaocheng, Jining, and Weifang (Figure 3.1).

### ***3.2.2 Data collection***

A survey of landowner was conducted in summer of 2016. A 15-page instrument was first developed after a thorough review of literature regarding landowners interest in forest certification. Questions regarding constraints and opportunities were adopted from similar studies conducted elsewhere (e.g., Kilgore et al., 2007) and modified to fit the context in China. The survey comprised questions regarding landowners' knowledge and perception of forest certification and their willingness to have their forest certified. A total of 27 questions classified into three segments were included in the survey. Overall, the questions included in this survey were grouped into sociodemographic, forest ownership and management objective, motivation of owning forestlands, interest in forest certification participation under various requirements, and perceived benefits and drawbacks with forest certification. The first section inquired about landowners' forest management history (e.g., tenure, forest type, ownership size, harvest history *etc.*) and motivations for owning forestland. The second section asked about landowners' familiarity with forest certification, perceptions of perceived benefits and drawbacks with forest certification, willingness to participate in forest certification under various program designs, and interests in adoption of forest certification. The third part of the survey included sociodemographic information regarding landowners. Survey questions included Likert scale items regarding respondents' interest level (1 = very unlikely, 5 = very likely) in participating in



**Figure 3.1 The survey area in Shandong, China**

forest certification program under different program requirements and their agreement level for the perceived benefits and drawbacks of forest certification (1 = strongly disagree, 5 = strongly agree).

The survey instruments were developed in both English and Chinese (given this to respondents) and approved by the Institutional Review Board (IRB) at the University of Tennessee, Knoxville. A total of 3 research assistants were involved in household visit and survey. Altogether, 557 landowners were requested to fill out survey. Only 507 of them completed and provided useable surveys, yielding a 91% response rate. The relatively high response rate is not surprising because the survey was administered by in-person visit to landowners' residences. The main reasons for using a personal approach strategy were: 1) to include all representatives in the survey population (mail and internet surveys were not viable for low income classes especially the landowners living in remote villages), 2) mail surveys need longer time period for delivery and return than personal visit and mail address contact lists are mostly unavailable, and 3) telephone contacts were unavailable and considering the complexity of survey, it probably is impractical to gather data over the phone. After arriving at each city, we firstly visited the local forestry bureau to collect the information about who owns forest lands and how many forest farms etc. and then the employees helped us reach out those landowners. On average, respondents completed the survey in approximately 40 minutes.

### ***3.2.3 Econometric modeling***

The dependent variable is respondents' level of interest in forest certification. Based on the economic theory of utility-maximization, I assume that landowners make choices to increase their utility/satisfaction and a continuous and unobservable variable representing the utility

associated with each rating is needed. As a result, the utility derived by the  $i$ th participant from the  $j$ th attributes of forest certification ( $U_{ij}$ ) is defined as:

$$U_{ij} = \beta_i B_i + \beta_j F_j + \epsilon_{ij} \quad (1)$$

where  $B_i$  is a vector of participant and forestland characteristics,  $F_j$  denotes a vector of forest certification program attributes;  $\epsilon_{ij}$  is the error component of utility with a normal distribution and  $\beta_i, \beta_j$  are unknown parameters to be estimated. Nevertheless, the participants' utility of forest certification could not be directly obtained except their discrete rating for their interest level. Therefore, a transformation function ( $f$ ) is established under the assumption that participant  $i$ 's observed rating for program  $j$  ( $Y_{ij}$ ) is related to his/her utility through  $f$  (Klosowski et al., 2001):

$$Y_{ij} = f(U_{ij}) \quad (2)$$

Following Eq. (2), each participant's rating for their interest in forest certification is dependent on the program attributes, personal and forestland characteristics. Furthermore, based on the theoretical framework typically discussed in landowners' decision-making literature (Markowski-Lindsay et al., 2011; Leitch et al., 2013; Thompson et al., 2013), an econometric model of landowner interest in forest certification participation was developed as shown in Eq. (3).

Interest Level in Participating in Forest Certification =

$$f \left( \begin{array}{c} \text{Siodemographic, Forest Ownership and Management Objectives,} \\ \text{Motivations for Owning Forestlands, Perceived Benefits} \\ \text{and Drawbacks of Forest Certification} \end{array} \right) \quad (3)$$



This study involved modeling an ordinal variable of landowner's level of interest which is measured in a 4-Point Likert scale (1 = no interest at all, 4 = high interest). When the dependent variable is not continuous and has more than two levels and the values of each level have a meaningful sequential order, an ordinal logistic regression is typically employed (Kleinbaum and Klein, 2010). Mathematically, the ordinal logistic regression has an observed ordinal variable  $Y_{ij}$  which is a function of an unmeasured continuous latent variable  $U_{ij}$ . Regarding the value of the latent variable  $U_{ij}$ , it is based on the different cut-off points to determine the meaning of the observed ordinal variable. In this study, the dependent variable has four ordinal levels and the mathematical expression is presented as:

$$\left\{ \begin{array}{l} Y_{ij} = 1 \text{ if } U_{ij} \leq k_1 \\ Y_{ij} = 2 \text{ if } k_1 \leq U_{ij} \leq k_2 \\ Y_{ij} = 3 \text{ if } k_2 \leq U_{ij} \leq k_3 \\ Y_{ij} = 4 \text{ if } k_3 \leq U_{ij} \leq k_4 \end{array} \right. \quad (4)$$

where  $k_1, k_2, k_3, k_4$  are the cut-off values. Parameter estimates in the ordered logit regression model is obtained by using maximum likelihood (Borooah, 2002) and the assumption is that the error component has a standard logistic distribution. Collinearity among explanatory variables was tested by computing variance inflation factors (VIF) index.

The sociodemographic group consisted of age, gender, education, income, and government-related occupation. Early studies reported that landowners of different age, income, social status have different priority and preference and face different constraints while making land management decisions (e.g., Brook et al., 2003; McDonald et al., 2006). With respect to the relationship between age and landowners' participation behavior in forestry programs, Nagubadi *et al.* (1996) found a positive effect while Langpap (2004) argued a negative influence; thus, it is

difficult to speculate in this study. By contrast, studies (Kline et al., 2000; Van Herzele and Gossum, 2009; Knoot et al., 2015) revealed that female landowners are more concerned about the environment and hence, I expected that female owners were more willing to participate in forest certification for an environmental responsible management. Research has shown that wealthier and more educated landowners appear to be more likely to be engaged in forestry conservation programs (e.g., Dennis, 1989; McDonald et al., 2006; Ma et al., 2012); therefore, a positive sign for income and education with landowners' interest in forest certification was expected. Moreover, studies (Bell et al., 1994; Nagubadi et al., 1996) believed that occupation play an important role in landowners' likelihood of participating in forestry programs. Hence, government-related employees were hypothesized to be positively related with landowner interest in forest certification considering their familiarity with forestry programs/practices.

The second category included tenure, ownership size, timber harvesting history, whether having a management plan, whether landowners received advice from neighbor/friends, and forest type. Results regarding the relationship between tenure and forest certification, Benschel (2001) found that short tenure among NIPF landowners impede the adoption of forest certification. Also, considering that long and stable tenure enables landowners to make long-term forest management plan and thus, I expected a positive association between them. For the correlation between ownership size and participation intention, Ma *et al.* (2012) reported that landowners owning more forestland are more likely to participate in forest certification and thus, a positive sign was expected. In addition, Ma *et al.* (2012) also found that landowners planning to harvest their forests are more inclined to participate in forest certification; and I expected a positive association between the harvesting history and landowners' likelihood of engaging in

forest certification. Moreover, previous forest management experience might have a positive effect in landowners' participation in forest stewardship programs (Bell et al., 1994), so a positive effect of having a management plan was anticipated. Regarding the forest type, I expected a positive association between timber production forests (i.e. a poplar forest) and landowners' intention of certifying their forests, whereas a negative sign was expected for protective forest (i.e. arborvitae forest).

Ownership motivation variables included the importance placed on timber production and financial investment. Kilgore *et al.* (2007) found that landowners who have a great interest in timber production are likely to certify their forests. Hence, I expected that those placing higher importance on timber production were more likely to certify their forests and a positive sign was anticipated. By contrast, previous studies reported a mixed result for financial investment; for example, Ma *et al.* (2012) concluded that landowners owing forestland for financial reasons are less interested in forest certification; on the contrary, studies (Chen et al. 2011; Zhao et al. 2011; Chen et al. 2013; He et al. 2015) argued that economic benefits/rewards are an important motivation for landowners to participate in forest certification and likely certifiers believe that forest certification can bring great benefits economically, so landowners owing forests for financial investment are more likely to certify. Consequently, it is difficult to speculate on the relationship between financial investment and landowner interest in forest certification here.

I also expected landowners' perceptions of pros and cons of the certification, or attitude towards benefits and costs might be an important factor in decision making. Hence, variables in the perceived benefits category composing of increased timber growth, price premium, public recognition, and environmentally friendly harvest were included. A positive relationship

between those benefits and landowners interest in forest certification was anticipated.

Landowners who believe that certifying their forest can increase the timber growth and would receive a higher price for stumpage, would be more likely to participate in forest certification. For instance, Kilgore *et al.* (2007) and Rickenbach (2002) both argued that providing price premiums for certified wood would increase the adoption of forest certification. By the same token, landowners who agree that forest certification can bring a good public recognition and environmentally friendly harvest are also likely to have their forestland certified.

On the contrary, a negative association was expected between the possible drawbacks with forest certification (increased management cost, increased record keeping, and adherence to management plan) and landowners' willingness to participate. In other words, landowners who believe that certifying forests would increase the management cost and related record/paper keeping are less interested in forest certification. For example, studies (e.g., Bensel, 2001; Rickenbach, 2002; Kilgore et al., 2007; Perera et al., 2007; Leahy et al., 2008; Zhao et al., 2011; Ma et al., 2012) stated that cost of certification and related management are important barriers in forest certification. Likewise, landowners agreed that adherence to forest management plan was an important drawback of forest certification were less willingly to participant in forest certification. Kilgore *et al.* (2007) and Leahy *et al.* (2008) both found that requirement of adherence to management plan decreased landowners' interest in forest certification.

### **3.3 Results**

Of 507 that responded, 71% were male. There was a wide range of educational attainment among the respondents, 26% were less than middle school, 24% said they were high school graduates, 25% reported to have vocational training, 16% reported to have college

education, and 9% of the respondents reported some graduate school. About half (52%) of the respondents reported their annual income between RMB 20,000 and 50,000 and 34% reported that household income was above RMB 50,000. About half (49%) reported primarily living in rural areas, and another 47% indicated county communities as general area of residence. The remainder (7.7%) reported living in metropolitan area. In terms of forest ownership size, approximately 47% of the respondents reported between 10 and 100 hectares; 25% reported more than 100 hectares, and about 27% indicated less than 10 hectares. When asked about the how long have they been owning the forest, the respondents on average indicated 22 years. Specifically, 62% of the sample managed their property less than 20 years and 22% between 20 and 50 years, as well as 16% over 50 years.

When asked about their familiarity with the concept of forest certification prior to receiving this survey, 77% of the respondents indicated to have no familiarity before receiving our survey; about 23% indicated to have at least a nominal understanding of forest certification. Even so, when given a definition and associated knowledge (e.g., the possible benefits and purpose of forest certification, etc.), 63% said they would like to consider participating.

### ***3.3.1 Desirability of certification attributes among landowners***

To assess how landowners feel about various attributes of certification programs, respondents were asked to indicate their level of interest (1 = very unlikely, 5 = very likely) to participate in forest certification under various conditions. As shown in Table 3.1, average level of interest to participate in certification was highest (4.23) if the certifying institution were a government organization, followed by an educational institution (3.35) and forest product industry association (3.07) and a forest landowner association (3.04). Respondents indicated the

lowest (2.27) interest to participate if the certifying institution were not affiliated with any particular association or group they are familiar with.

When asked to indicate the level of interest to participate in certification if they were required to be actively involved in the process, results showed that the level of interest was highest (3.72) if they were required to be involved in some stages of process and lowest (2.57) if they were not required to be involved at all. It should be noted that about as high as 47% of respondents indicated they are unlikely or very unlikely to participate if the program does not require their involvement at all.

When asked about their willingness to participate in certification in relation to the potential requirement of disclosing on-site inspection report to the public, respondents indicated highest level of interest in participating if the program required making only the summary to the public (3.56) (Table 3.1). The level of interest was lowest if the program required not making the report available to public (2.98).

As far as the requirement of forest management plan is concerned, highest level of interest to participate was indicated by respondents if the certification program required a plan (3.70) and lowest interest was reported if it is not required (2.96) (Table 3.1). For instance, 62% of the respondents inclined to have their land certified if management plan was either required (3.70) or encouraged but not required (3.56). By contrast, only 29% of them said they would likely to certify under the case of no management plan required.

For the question if they would participate if landowners were required to use a professional forester when managing their forest after certifying, level of interest to participate was higher if this was required (3.65) than if it was not (2.92). About 65% of the respondents

**Table 3.1 Interest in participating in a forest certification program under different program requirements (n = 507).**

	Mean	Percent of response (%)				
		Very unlikely	Unlikely	Neutral	Likely	Very likely
Would you participate if the certifying organize was:						
A government organization	4.23	1	4	10	42	43
a forest products industry association	3.07	5	9	38	43	5
a forest landowner association	3.04	11	14	38	32	4
an educational institution	3.35	10	14	42	27	7
an organization not affiliated with any particular association or group	2.27	37	22	23	12	6
Would you participate if you were:						
required to be involved throughout the process of certifying your forest	3.63	2	11	25	45	17
required to be involved in some part of certification process	3.72	3	4	27	50	16
not involved in the certification process	2.57	29	18	25	24	4
Would you participate if you had to pay:						
none of the costs to certify your forest	4.64	3	4	10	46	36
some of the costs to certify your forest	3.37	8	8	20	50	14
all of the costs to certify your forest	2.61	21	26	29	17	6
Would you participate if the results of on-site inspections were:						
made fully available to the public	3.48	6	10	35	28	21
made available to the public only in summary form	3.56	5	4	35	44	12
not made available to the public	2.98	16	12	39	25	8

**Table 3.1 Continued.**

	Mean	Percent of response (%)				
		Very unlikely	Unlikely	Neutral	Likely	Very likely
Would you participate if a forest management plan was:						
required	3.70	3	6	29	41	21
encouraged but not required	3.56	4	7	27	54	8
not required	2.96	14	13	45	20	9
Would you participate if you were:						
required to use a professional forester when managing your forest or harvesting timber	3.65	3	11	21	47	18
not required to use a professional forester when managing your forest or harvesting timber	2.92	12	19	35	31	2
Would you participate if you:						
were required to notify the certifying organization of your intent to harvest timber	3.31	6	17	33	29	15
were required to use only loggers who were trained in environmentally-friendly practices	3.30	16	19	26	27	12
could use any logger you choose	4.21	8	8	15	41	28
Would you participate if you:						
received a higher price for your timber	4.23	1	3	13	40	44
received the same price for your timber	2.59	17	26	42	13	2
Would you participate if forest product mills gave:						
preference to buying timber from certified forests	4.22	1	4	15	31	48
no preference to buying timber from certified forests	2.72	14	21	47	16	2

Responses based on a five-point Likert scale: 1: very unlikely to participate, 2: unlikely to participate, 3: neutral, 4: likely to participate, and 5: very likely to participate.



said they were likely to certify if this was required (Table 3.1).

In terms of potential requirement about using loggers or reporting harvesting intention to certifying institutions, higher level of interest to participate was reported (4.21) if landowners could use any logger they choose (Table 3.1). As high as 69% of respondent indicated likely or very likely to participate in certification if they could use any logger they choose. Not surprisingly, the level of interest to participate was much higher (88% likely or very likely to participate) if they were to receive higher price for timber (4.23) than if they received the same price (2.59). Similar results regarding interest to participate were observed about potential preference to certified woods. As high as 79% respondents indicated likely or very likely to participate if timber mills gave preference for certified timber. The level of interest to participate in such scenario (4.22) is higher than a scenario of no preference from buyers (2.72).

Overall, based on the mean scores of survey results (Table 3.1), the certification program designs that landowners expressed clear preferences were: if landowners do not have to pay certification cost (4.64), if landowners could use any logger they choose to harvest forests (4.21), if the timber price were higher for certified forests than not certified (4.23), and if forest product mills gave preference to buying timber from certified forests (4.22).

### ***3.3.2 Importance of benefits and drawbacks of forest certification to landowners***

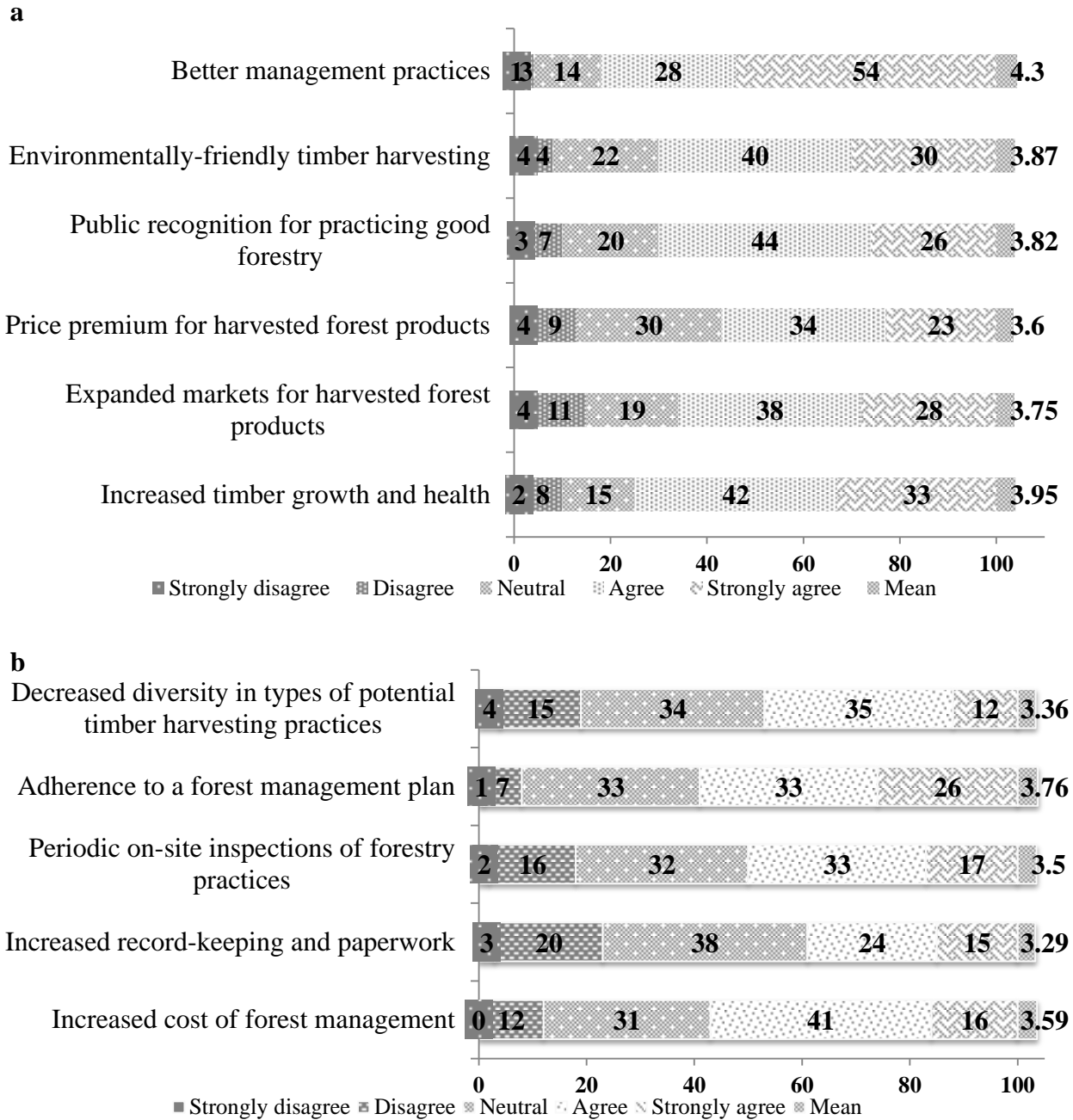
Respondents were asked to rate their level of agreement (1-strongly disagree, 5-strongly agree) with various statements about potential benefits and drawbacks of certification. The results on respondents' perception of benefits (Figure 3.2a) and drawbacks (Figure 3.2b) associated with forest certification are presented in Figure 3.2. Potential benefits they were asked about included increased timber growth and health, expanded markets for harvested forest

products, price premium for harvested forest products, public recognition for practicing responsible forestry, environmentally-friendly timber harvesting, and better management practices. Among those perceived benefits, the most important benefit to landowners was *better management practices* (mean = 4.30) followed by *increased timber growth and health* (mean = 3.95) and then *environmentally-friendly timber harvesting* (3.87). Certainly, the respondents believed that other benefits were also important as the mean score in each case exceeded the neutral.

On the contrary, potential drawbacks they were asked to indicate their perception included increased cost of forest management, increased record-keeping and paperwork, periodic on-site inspections of forestry practices, adherence to a forest management plan, and decreased diversity in types of potential timber harvesting practices. Among them, the most important drawback to the respondents was *adherence to a forest management plan* (3.76) followed by *increased management cost* (3.59). The last least important one was *increased record-keeping and paperwork* (3.29).

### ***3.3.3 Factors influencing participation***

Estimates from ordinal logistic regression were presented along with the VIF index in Table 3.2. Since the VIF were far less than critical threshold of 10 (Freund and Wilson, 1998), multicollinearity was not a concern in our model. The log likelihood test of the ordinal logistic regression model for estimating participation in forest certification was significant ( $p < 0.01$ ). Gender was not statistically significant in our model. By contrast, education and forest related income were both positively and significantly ( $p < 0.05$ ) related to respondents' interests in forest certification.



**Figure 3.2 The importance of possible benefits (a) and drawbacks (b) associated with forest certification to landowners (n = 507)**

The positive coefficient on education and forest-related income implies that respondents who having at least some college education and whose income depend more on forests are more likely to participate in forest certification than their respective counterparts. Similarly, the positive and significant coefficient ( $p = 0.08$ ) on dummy variable government employee indicates that respondents who work for the government agencies are significantly more interested than their non-government counterpart to participate in forest certification program. Among the variables representing forest ownership and management objective, coefficient on tenure was significant ( $p < 0.01$ ) with a positive sign, implying that compared to those with shorter tenure, respondents owning their forelands for a longer period of time are more likely to participate in forest certification. Result also showed that landowners with poplar forests were likely to have significantly ( $p < 0.05$ ) higher level of interest in participating on forest certification, whereas those with arborvitae forests were likely to have significantly ( $p < 0.01$ ) lower interest. By contrast, ownership size, harvest history, and variables including whether landowners had a management plan or received advice from their neighbors/friends were all found to be insignificant.

Among the variables characterizing landowners' ownership motivation, the importance placed on timber production was positively and significantly ( $p = 0.07$ ) associated with respondents' interest in forest certification. This indicated landowners whose motivation for having forestlands is timber production are more likely to participate in forest certification scheme than those with other non-timber motivations. By contrast, the importance placed on land investment was found to be insignificant.

**Table 3.2 Results from ordinal logistic model explaining factors related to landowners' interest in participating forest certification.**

Variable	Description	Mean (S.E.)	Coefficients (S.E.)	VIF
<i>Sociodemographic</i>				
Gender	Dummy variable, 1 if male, 0 otherwise	0.71 (0.45)	-0.12(0.26)	1.56
Education	Dummy variable, 1 if landowner has more than college education, 0 otherwise	0.36 (0.48)	0.60(0.24)**	1.35
Forest income	Continuous variable, the percentage of income that is from forestland management (%)	37.97(28.73)	0.01(0.004)***	1.39
Government employee	Dummy variable, 1 if landowner is a government employee, 0 otherwise	0.07(0.25)	0.82(0.045)*	1.45
<i>Forest ownership and management objective</i>				
Tenure	Number of years the property has been with landowner's family	21.89(20.48)	0.03(0.007)***	1.98
Ownership size	Continuous variable, the forestland area that landowners own (hectare)	139.41(385.41)	0.0001(0.0003)	1.36
Harvest	Dummy variable, 1 if the landowner recently harvested timber or planning to harvest soon, 0 otherwise	0.66(0.47)	-0.19(0.35)	2.41
Management plan	Dummy variable, 1 if the landowner has a written management plan, 0 otherwise	0.52(0.50)	0.40(0.24)	1.69
Neighbors/Friends advice	Dummy variable, 1 if the landowner receives management advice from neighbors/friends, 0 otherwise	0.30(0.46)	0.97(0.41)	1.46

**Table 3.2 Continued.**

Variable	Description	Mean (S.E.)	Coefficients (S.E.)	VIF
Poplar forests	Dummy variable, 1 if landowners' predominant species is poplar, 0 otherwise	0.60(0.49)	0.88(0.34)**	1.83
Arborvitae forests	Dummy variable, 1 if landowners' predominant species is arborvitae, 0 otherwise	0.06(0.23)	-3.38(0.71)***	1.72
<i>Motivations of landowners to own a forestland</i>				
Timber production	Dummy variable, 1 if landowners' motivation of owning forests is for timber production, 0 otherwise	0.74(0.44)	0.61(0.34)*	2.16
Land investment	Dummy variable, 1 if landowners' motivation of owning forests is for land investment, 0 otherwise	0.69(0.46)	0.39(0.28)	1.81
<i>Perceived benefits with forest certification</i>				
Increased timber growth	Dummy variable, 1 if landowner believes certification leads to increase timber growth in forest, 0 otherwise	0.90(0.30)	0.29(0.43)	1.91
Price premium	Dummy variable, 1 if landowner believes certification will result in price premium for timber, 0 otherwise	0.86(0.35)	0.64(0.43)*	2.38
Public recognition	Dummy variable, 1 if landowner believes certification will help in public recognition for their business, 0 otherwise	0.89(0.31)	0.04(0.42)	2.01

**Table 3.2 Continued.**

Variable	Description	Mean (S.E.)	Coefficients (S.E.)	VIF
Environmentally friendly harvest	Dummy variable, 1 if landowner believes certification will enhance environmentally friendly harvesting, 0 otherwise	0.91(0.28)	0.32(0.45)	1.75
<i>Perceived drawbacks with forest certification</i>				
Increased management cost	Dummy variable, 1 if landowner believes certification will increase management cost, 0 otherwise	0.87(0.33)	-1.86(0.37)***	1.41
Increased record keeping	Dummy variable, 1 if landowner believes certification will involve increased record keeping, 0 otherwise	0.77(0.42)	-0.55(0.29)*	1.58
Adhering to management plan	Dummy variable, 1 if landowner believes certification will require adhering to a management plan, 0 otherwise	0.92(0.27)	-1.62(0.41)***	1.34

Among the category of perceived benefits with forest certification, a significant ( $p = 0.06$ ) and positive association between price premium and respondents interest in certifying their forests was found. This result suggested that expected price premium of the timber from a certified forest is the most important benefits for respondents and this benefit positively impacted respondents' interest in participating forest certification. On the contrary, other benefits such as increased timber growth, public recognition, and environmentally friendly harvest were insignificant.

Among the variables representing perceived drawbacks, increased management cost ( $p < 0.01$ ), increased record keeping and paperwork ( $p = 0.09$ ), and adhering to a management plan ( $p < 0.01$ ) were all significantly related to respondents' willingness to participate in forest certification. Moreover, the negative sign suggested that those who believed that certifying their forests would increase the corresponding management cost and paper work were less likely to participant in forest certification. Further, adhering to a forest management plan also negatively affected respondents' willingness to certify their forests.

### **3.4 Discussion**

The results of this study indicate that the level of awareness and understanding of forest certification among landowners in Shandong province is fairly low. This is not particularly surprising considering that similar results have been reported in other studies around the world. For instance, Jayasinghe *et al.* (2007) reported that landowners in Canada have low levels of knowledge and awareness regarding forest certification, Butler *et al.* (2008) showed that less than 3% of family forest landowners in the U.S. have heard forest certification surveyed in 2006; in addition, Kilgore *et al.* (2007) and Leahy *et al.* (2008) found that family forest landowners in



Minnesota generally were unfamiliar with the concept of forest certification. Similarly, Chen *et al.* (2011, 2013) reported that both wood products manufacturers and landowners in China had a low familiarity with forest certification. This result is an indicative of the need for more comprehensive education and outreach effort to enhance the general awareness and knowledge of forest certification among landowners in China.

Regarding the certification program affiliation, landowners in China showed more interest in certifying their forests if the certify organization was affiliated with government or education institutions. However, both Kilgore *et al.* (2007) and Leahy *et al.* (2008) reported that landowners in the U.S. were unlikely to certify their land if the certify organization was run by a government institution. On the contrary, as He *et al.* (2015) stated that government has an important role in all areas with no exception in forest certification and landowners would be encouraged to have their lands certified if government is involved in this process. Moreover, forest landowners also believed that university professors or forest professionals have an important role in delivering the knowledge of forest certification and educating them and landowners have a high level of trust on these institutions. This result is consistent with the finding reported by Chen *et al.* (2011), who also stated that forest farmers trust the professionals from educational institution.

The documentation requirements associated with forest management plan, landowners in China were more likely to certify their forests if management plan was required than not required. This finding is inconsistent with the results reported by Kilgore *et al.* (2007) and Leahy *et al.* (2008), who said that the family landowners in Minnesota were likely to participate in forest certification program if it did not require having a management plan. Even though

writing a detailed management plan is quite onerous for landowners in China and majority of them possibly cannot handle it by themselves (Chen et al., 2013), they believe that this requirement provides a paper proof for responsible forest management. On the contrary, if management plan was not required, landowners stated that it decreases the trustfulness of the certify program and even associated certify organization.

Besides, another big concern of landowners to forest certification is the direct/indirect certification cost and the finding of this study implied that landowners would be more willing to participate in certification program if there is no certification cost. This confirms previous studies (Hayward and Vertinsky, 1999; Bensel, 2001; Rickenbach, 2002; Kilgore et al., 2007; Perera et al., 2007; Leahy et al., 2008; Zhao et al., 2011; Ma et al., 2012; Chen et al., 2013; He et al., 2015) indicated that certification cost is a big barrier for landowners to adopt forest certification.

This study demonstrates that a landowner's decision to participate in forest certification is influenced by a wide range of ownership and land characteristics. The finding that landowners who have at least some college education exhibit a greater level of interest in forest certification corroborates the findings of Ma *et al.* (2012), who reported that landowners having higher education have a higher probability of certifying their forestland. Meanwhile, landowners who were more dependent on forest for family income were more likely to participate in forest certification implying that economic rewards were their primary concern and motivation to manage forests. Even though some demographic characteristics including age and gender were found insignificant in explaining landowners' willingness to participate in forest certification in our study, previous studies (Nagubadi et al., 1996; Langpap, 2004; Ma et al., 2012) have found age to be important factor in predicting landowners' participation behavior in conservation

programs although effects are mixed (i.e. positive and negative). By contrast, the occupation of landowners is significantly related to their interest in participating in forest certification. For instance, the results suggested that if landowners were government employees, they were more likely than others to certify their forestlands. This is probably because of their familiarity with government programs or forestry practices or forest certification. Bell *et al.* (1994) and Nagubadi *et al.* (1996) believed that landowner occupation played an important role in participation in forestry programs. Such information about basic demography of landowners who are interested in certifying forestlands would be helpful for effective communication and outreach to those segments assistance.

Landowners who owned their forest for a longer period of time were more interested in forest certification than their shorter tenure counterparts, which is in line with the finding of Bensel (2001) who found that short tenure is a major barrier to forest certification among private landowners. This observation can be explained by the fact that more stable tenure enables landowners to make long-term forest management plan and invest in forest certification. This observation is consistent with the finding of previous studies that found that secure forest land tenure plays an important role in forest certification (Chen *et al.*, 2013; Liao and Zhi, 2013; He *et al.*, 2015), especially considering the historical tenure reforms in China. Regarding forest type, landowners were more likely to certify their forests if the predominant species of forests is poplar while they were less willing to certify if it is arborvitae. The timber production forests in Shandong province mainly refer to the fast-growing and high-yield poplar forest (Tian *et al.*, 2013) and the finding in this study implies that landowners with commercial forests such as poplar forests have a higher probability to participate in forest certification. On the contrary,

landowners managing forests of less economic value such as arborvitae forest were less likely to participate.

Landowners who place higher value in timber production are likely to certify their forests, which is consistent with the finding of Kilgore *et al.* (2007) in a Minnesota study, who stated that likely certifiers were more interested in timber production. The explanation for this observation is that landowners whose major motivation of owning forestland is timber production might see the greater benefits of forest certification such as better quality of timber following certification management plan or a higher price after harvesting timber. Hence, they may believe that the economic benefits of certification surely outweigh the cost.

Among the perceived benefits with forest certification, price premium positively influenced landowners' likelihood of participating forest certification. If the timber from a certified forest has a potential of yielding price premium or preference from buyers, landowners would become more interested in forest certification program. This confirms previous studies suggesting that economic benefits/rewards are an important motivation for landowners to certify their lands (Kilgore *et al.*, 2007; Leahy *et al.*, 2008; Chen *et al.*, 2011; Zhao *et al.*, 2011; Chen *et al.*, 2013; He *et al.*, 2015). By contrast, the possible drawbacks associated with forest certification including increased management cost and record keeping as well as adherence to a management plan negatively influenced landowners' willingness to certify their forests.

### **3.5 Conclusions**

Considering the current low rate of participation in forest certification in China, it is important to explore landowners' attitudes towards certification and to understand what kind of barriers/concerns they experience. Findings from this study should help policy makers/program

leaders identify potential landowners with interest in certifying their forests and in designing outreach strategies and educational programs to encourage otherwise less interested landowners to participate in forest certification.

First, the majority of landowners in Shandong province lack knowledge and understanding of forest certification. However, they are willing to consider participating in forest certification program when provided with pertaining information (i.e. potential cost, benefits). This suggests that there may be a potential market for certification program in China with appropriate outreach and extension which may be achieved by hosting seminars/workshops and lectures and/or training programs by local forest service sector or other institutions. Meanwhile, landowners in China are relatively more comfortable with government-based certifying organizations. Hence, the involvement of government in forest certification and operation may be desirable.

Second, forest certification cost may be the most important concern/barrier for landowners to participate in certification program. Therefore, establishing incentive-based mechanisms such as providing subsidy/compensation or tax reduction to reduce or share the certification cost may be helpful, especially for those small-scale forest landowners (Chen et al., 2013). In addition, providing price premium or market preference for the timber from certified forests might play an important role in encouraging landowners to participate in forest certification. Consequently, mechanism designed to educate and assure landowners on potential premium for certified woods might be needed.

Third, landowners were found uncomfortable with some requirements related to certification programs. For instance, requirements related to using trained workers or

professionals during management and harvesting are likely to hinder the certification process. Some landowners may be uncomfortable having external parties involved in their land operation. However, program administrators may take this opportunity to clarify the need for such requirements and demonstrate that benefit of these steps outweigh cost. Finally, group certification might be needed to promote landowners interest in forest certification especially for small landowners having a small holding size. Since the landowners are most sensitive to the cost, taking a group certification approach may help achieve the economy of scale too. For example, He *et al.* (2015) presented a successful case of cooperative-based forest certification in China using Longquan Nengfu Professional Cooperative for Forestation a potential model.

It is worth noting that there are a few limitations in this study. First, this study relied on a convenient sampled landowner based on the list provided by the local forest bureau and only landowners that were at residence during our field trip were able to be interviewed or approached. Second, it should be noted that not everyone interested in participating in forest certification is eligible and the certification program might require a minimum property size and this was not considered in this study. Therefore, developing participation requirements to reflect a forest certification program goal is a future research direction. Third, forests of Shandong are not necessarily the same as other provinces, so the finding may not be the same with other places/provinces and a broader study may be needed with more data collection. However, the approach used in this study is applicable to other places for similar study. In addition, future studies could apply an economic approach to examine the landowners' interest in forest certification to estimate the minimum willingness to accept (WTA) and understand their attitudes toward more specific details (e.g., time commitment, BMP requirement).

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**Appendix B: Assessing Forest Landowners Knowledge, Attitudes, and  
Interest in Forest Certification**

**(A survey of landowners in Shandong, China)**



**Summer 2016**

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**Ph. D Student**

**Department of Forestry, Wildlife, & Fisheries**

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**USA**

Dear Landowner,

My name is Nana, Tian and I am a current Ph.D. student at the University of Tennessee, USA. As part of my research project, I would like your opinion on forest certification! You do not need any prior enrollment in forest certification programs in order to complete this survey. This survey will be used in academic research and findings will be useful to agencies interested in forest outreach and policy making. We appreciate your support and help!

You must be 18 years old to participate in this survey. If you have any questions about this study, please feel free to contact me at the address given below. If you have questions about your rights as a research participant, contact the University of Tennessee's Office of Research compliance Officer at (865)974-3466.

### **What is forest certification?**

Forest certification is a process of certifying your forests by a third party, and is used as a documentation of evidence for sustainable forest management and wood production; certification ensures the buyers of your timber that the woods are being imported from responsibly management forest. Typically, forest certification will remain in effect for five years and can be renewed.

Forest certification can promote sustainable forest management and responsible consumption, and provides an easy way to differentiate well-managed forests, and at the same time, combat illegal logging.

In order to properly certify your forestlands, the following procedure is typically involved:

- 1): Landowners must make the decision to certify their forests of their own free will;
- 2): Landowners should file a written application to the certifying organization to have their forest land certified;
- 3): The certifying organization reviews the submitted information (for example, the landowner's forest management plan) and conducts an on-site inspection of the forest to verify that the standards for forest management and timber harvesting specified by the certification organization are being met;
- 4): The certifying organization then decides whether the forest meets the standards required for the proposed forest certification;
- 5): If the forest is certified, periodic on-site inspections of the forest are conducted to verify the certification standards are being met. If the standards for certification have been violated, the forest land could lose its certification status.

**Section 1: Information about your forestland and forest management**

1. The ownership of the forests is.....
  - 1) Collectively owned
  - 2) Individually owned
2. Which of the following describe your forest type? .....
  - 1) Fast-growing and high production poplar
  - 2) Chinese walnut catalpa
  - 3) White ash
  - 4) Locust tree
  - 5) Speed grows willow
  - 6) Sawtooth oak
  - 7) Sycamore
3. How many hectares of forest lands do you own?  
.....
4. How important are each of the following reasons for owning forestland?

Reasons for owning forestland	No importance	Low importance	Neutral	Some importance	High importance
To enjoy the scenery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
To protect nature and biodiversity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
For recreation (hiking, family gatherings, fishing, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
For timber production	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
For land investment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Part of my farm	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

5. How did you acquire the majority of your forestland? .....
  - 1) Purchased it

- 2) Inherited it
  - 3) Traded for it
  - 4) Rented it (Go to Question 6)
6. How much are you paying for renting it ...../hectare/year?
7. How many years has your forestland been owned by you or your family?  
.....
8. When was your most recent harvest (*circle only one*)?
- 1) within the last year
  - 2) 1 – 5 years ago
  - 3) 5+ to 10 years ago
  - 4) more than 10 years ago
  - 5) have not harvested
9. Do you intend to harvest trees on your forestland in the next 10 years? .....
- 1) Yes
  - 2) No
  - 3) Unsure
10. Do you have a management plan for your forests? .....
- 1) Yes
  - 2) No
11. Do you receive management advice from any of these sources? (*Check all that applies*): .....
- 1) a government source
  - 2) extension foresters or university employees
  - 3) private consultants, forest industries, or loggers
  - 4) non-profit organizations
  - 5) neighbors or friends
  - 6) Other
12. What is your future plan for your forestland? .....
- 1) Continue to self-manage it
  - 2) Sell it
  - 3) Rent it to someone else
  - 4) Pass it on through the family
  - 5) Other

## Section 2: Knowledge of forest certification

13. Before receiving this survey, which of the following most accurately describes your familiarity with forest certification? (*Check only one*).

- 1) Not familiar at all
- 2) Slightly familiar
- 3) Moderately familiar
- 4) Very familiar
- 5) Extremely familiar

14. Below are possible **benefits** associated with forest certification. Indicate how much you agree with the importance of these benefits to you as a forest landowner (*please check one for each item*):

Possible Benefits	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Increased timber growth and health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Expanded markets for harvested forest products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Price premium for harvested forest products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Public recognition for practicing good forestry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Environmentally-friendly timber harvesting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Better management practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. Below are possible **drawbacks** that can be associated with forest certification. Indicate how much you agree with the importance of these possible drawbacks to you as a forest landowner (*please check one for each item*).

Possible Drawbacks	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Increased cost of forest management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increased record-keeping and paperwork	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Periodic on-site inspections of forestry practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



Adherence to a forest management plan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Decreased diversity in types of potential timber harvesting practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16. Based on your understanding of forest certification, how likely are you to participate in a forest land certification program that has the following characteristics? (*Please circle one for each item*).

a) Would you participate if the certifying organization was:

	Very unlikely	Unlikely	Neutral	Likely	Very likely
a government organization	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
a forest products industry association	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
a forest landowner association	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
an educational institution	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
an organization not affiliated with any particular association or group	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

b) Would you participate if you were:

	Very unlikely	Unlikely	Neutral	Likely	Very likely
required to be involved throughout the process of certifying your forest	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
required to be involved in some part of certification process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
not involved in the certification process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

c) Would you participate if you had to pay:

	Very unlikely	Unlikely	Neutral	Likely	Very likely
none of the costs to certify your forest	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
some of the costs to certify your forest	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
all of the costs to certify your forest	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

d) Would you participate if the results of on-site inspections were:

	Very unlikely	Unlikely	Neutral	Likely	Very likely
made fully available to the public	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
made available to the public only in summary form	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
not made available to the public	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

e) Would you participate if a forest management plan was:

	Very unlikely	Unlikely	Neutral	Likely	Very likely
required	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
encouraged but not required	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
not required	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

f) Would you participate if you were:

	Very unlikely	Unlikely	Neutral	Likely	Very likely
required to use a professional forester when managing your forest or harvesting timber	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
not required to use a professional forester when managing your forest or harvesting timber	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

g) Would you participate if you:

	Very unlikely	Unlikely	Neutral	Likely	Very likely
were required to notify the certifying organization of your intent to harvest timber	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
were required to use only loggers who were trained in environmentally-friendly practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
could use any logger you choose	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

h) Would you participate if you:

	Very unlikely	Unlikely	Neutral	Likely	Very likely
received a higher price for your timber	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
received the same price for your timber	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

i) Would you participate if forest product mills gave:

	Very unlikely	Unlikely	Neutral	Likely	Very likely
preference to buying timber from certified forests	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
no preference to buying timber from certified forests	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. If the cost of certifying your forests ranges between 10 yuan/hectare to 20 yuan/ hectare, what is your current level of interest to have your forest certified? (*Circle only one*).....

- 1) No interest
- 2) Slight interest
- 3) Some interest
- 4) High interest
- 5) Not sure

18. By how much the price of timber will have to increase for you to certainly consider certification? ..... (%) increase from current price.

### Section 3: Information about yourself

19. Which of the following best describes the community where you live? .....

- Rural area
- Small town
- County
- Suburb of a metropolitan area
- Metropolitan area

20. Number of working individuals in your household: .....

21. Is there anyone in your household working outside? .....

- 1) Yes
- 2) No

22. What is your age?

.....

23. What is your gender? .....

1) Male

2) Female

24. What is the highest grade of school you completed? .....

1) Less than middle school

2) High school graduate

3) Vocational training

4) College graduate

5) Some graduate school

6) Graduate school

25. What is your annual income generally? .....

1) Less than ¥20,000

2) ¥20,000 - ¥50,000

3) ¥50,000 - ¥75,000

4) ¥75,000 - ¥100,000

5) More than ¥100,000

26. What is percentage of your household income come from forestry?

.....

27. What is your employment situation/current occupation? .....

1) Forester/logger/miner

2) Professional manager

3) Government employee

4) Retired

5) Farmer

6) Businessman

7) Other

Please use the space below to write your additional comments.

**Comments:**

Again, thank you for your help!

**CHAPTER IV**  
**META-ANALYSIS OF PRICE RESPONSIVENESS OF TIMBER SUPPLY**

A version of this chapter was originally published by Tian N., Poudyal, N. C., Augé, R. M., Hodges, D. G., and Young, T. M.:

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Nana Tian, Neelam Poudyal, Robert M. Augé, Donald Hodges, and Timothy Young prepared the manuscript. Nana Tian and Robert M. Augé conducted data analysis and interpretation of results.

### **Abstract**

Modeling and projecting timber supply requires a good understanding of how supply responds to price. The price elasticity of supply (PELS) reported in literature vary greatly indicating that conclusions regarding the price signaling in timber market are mixed. Therefore, we conducted a meta-analysis to determine the key factors associated with the heterogeneity of PELS of primary timber product supply by examining data from numerous studies conducted around the world. Twelve ‘moderator’ variables were examined to explore differences in PELS. ‘Moderators’ with significant impacts on variation of PELS included forest products, geographic regions, econometric models, and data type. Furthermore, two-level categorical variables contained within the econometric models including owner age and standing stock was found to have significant influence on the heterogeneity of PELS. Variation in PELS also depended on whether or not the supply models accounted for price inflation, and the time period when the study was conducted. These findings may improve the understanding of the dynamics of price signaling in timber markets, and further improve the efficiency of timber supply and forecasting models for market participants and policymakers.



**Keywords:** Price elasticity of supply (PELS), meta-analysis, moderators

## 4.1 Introduction

Wood remains the primary good in the forest product market. Therefore, timber supply is essential to sustain these industries. Annual timber harvests in the U.S. currently totals approximately 1.9 billion cubic meters, which represents 20 percent of global timber harvests (Sedjo and Sohngen, 2015). Demand for timber products is often driven by low price for building materials and paper, relative to other materials. It is also popular for other products such as furniture, biofuels, etc. In the U. S. alone, annual timber demand per capita is estimated at 816.47 kg (1,800 lbs) (Haynes, 2003). This suggests that total timber demand is likely to increase as a function of population growth. Therefore, understanding the market dynamics of timber supply with respect to price and other factors is an important issue. Timber supply refers to the volume of harvested timber within a region made available to the market (Prestemon and Wear, 1999). It has been found to be influenced by several market and non-market factors, including net prices, merchantable stock of standing timber, and the interest rate etc.

Specifically, timber supply is affected by landowner interest in non-timber goods and services (e.g., recreation, wildlife and environmental protection) (Favada et al., 2009), forest ownership (Newman and Wear, 1993), market mechanisms (e.g., price uncertainty) (Newman and Wear, 1993), and government policies (e.g., the tenure reform of forestland in China) (Zhang and Buongiorno, 2012; Young et al., 2015). Timber price as a market indicator is also considered to have an important role in determining timber supply (Kuuluvainen et al., 1996; Kuuluvainen and Tahvonen, 1999; Prestemon and Wear, 2000; Bolkesjø and Baardsen, 2002; Bolkesjø and Solberg, 2003). For example, many studies conducted in various parts of North America and Europe revealed that timber supply is positively related to price (Binkley, 1981; Kuuluvainen

and Tahvonen, 1999; Bolkesjø and Baardsen, 2002). However, investigators such as Cabbage (1986), Skog and Haynes (1987), and Prestemon and Wear (2000) concluded that timber supply is fairly unresponsive to price. Therefore, considerable variation exists in literature as to whether and to what extent timber supply responds to market price. In other words, the studies have mixed conclusions regarding the price elasticity of supply (PELS), which is a measure of relative responsiveness of timber supply to market price. Thus, what contributes to the variation in PELS of timber supply is an interesting research question.

Human dimension studies of nonindustrial private forest (NIPF) landowners behavior have demonstrated significant effects of owner characteristics such as age, education and income, as well as management objectives on the volume of timber supply or intention to supply timber (e.g., Kuuluvainen et al., 1996; Favada et al., 2009; Kittredge and Thompson, 2016). Forest ownership objectives are also considered to have a substantial effect on timber supply (Kuuluvainen et al., 1996; Favada et al., 2009; Kittredge and Thompson, 2016). Moreover, a number of other variables characterizing forest (*e. g.*, standing stock) or landowner-specific circumstances (*e.g.*, interest rate option) are considered to affect timber supply. Forest standing stock has been found to have a positive effect on timber supply (Brännlund et al., 1985; Kuuluvainen et al., 1996; Toppinen and Kuuluvainen, 1997; Bolkesjø et al., 2010). However, a lack of landowner-specific data often limits researchers' ability to evaluate the effect of personal (*e.g.*, demographics) and financial (*e.g.*, interest rate) variables on timber supply. Arguably, if panel data were to be used, the effects of forest owner specific variables (say interest rate s/he faces in a particular decision time) may be implicitly taken into account by the estimated

individual (fixed or random) effects (e.g., Bolkesjø and Solberg, 2003; Sun et al., 2015), but conducting this type of study requires data from the same landowners at multiple time periods.

Other studies attempted to identify the determinants of timber supply by modeling it as a function of a range of factors. Prestemon and Wear (1999) used aggregate supply models to analyze the aggregate effects of price changes on timber supply in North Carolina. Toppinen and Kuuluvainen (1997) conducted a similar study on sawlog and pulpwood markets in Finland. In addition, Bolkesjø et al. (2010) summarized the earlier timber supply studies and classified them with micro and macro-level analyses according to the data types used. Several studies (Binkley, 1981; Dennis, 1989; Hyberg and Holthausen, 1989; Carién, 1990; Kuuluvainen and Salo, 1991) focused on NIPF owners using cross-section or time series data, whereas others utilized data over a larger region or country using panel data (e.g., Bolkesjø et al., 2010; Solberg, 2011). In general, while these studies suggest that different factors influence the volume of timber supply to varying extents, not all factors are as clear as “market price” to provide any signal to potential suppliers and buyers in the market. Considering that econometric studies have shown mixed results in terms of whether and to what extent market price affects timber supply, it is important to explore the role of various possible factors that contribute to observed variation in PELS.

The PELS as reported in studies is typically computed as the percentage change in timber volume supplied in response to a percentage change in price (Lowenstein, 1954). This unit-less measure explains the magnitude of impact of price on supply, and is therefore comparable across multiple studies. Among the studies that found a significant effect of price on timber supply, some report that supply is inelastic whereas others report that it is highly elastic. For example, Toppinen and Kuuluvainen (1997) reported 2.18 as the PELS of pulpwood in Finland whereas

Solberg (2011) calculated a PELS of 0.01 for pulpwood in France. Likewise, Prestemon and Wear (1999) indicated that the PELS of sawlogs in the United States was 4.57 while Nilsson (2002) estimated that for sawlogs in Sweden, it was as low as 0.08. Consequently, the large variability in reported PELS estimates motivated this study to explore the determinants of this variation.

It is important for market participants and policymakers to recognize the primary factors that affect PELS to better understand and predict future timber markets. It is difficult to refine timber supply models and accurately forecast future market conditions without understanding the exact sources of variation in the PELS of timber supply. To fill this knowledge gap, we conducted a meta-analysis of studies involving PELS of timber supply to investigate whether and to what extent various factors (price, market circumstances, statistical modeling etc.) contribute to observed variation in PELS. Meta-analyses and systematic reviews were used to synthesize evidence from a number of studies for a given question or objective, taking into account variation in replication and precision among studies to arrive at a global weighted average (Borenstein et al., 2009). This tool analysis allows us to examine mean consistency in PELS across the literature, and consequently test which factors influence the magnitude of the variation. Specific objectives are: 1) to quantify how much PELS varies among studies, and 2) to characterize how specific explanatory variables affect PELS: forest products, geographic regions, econometric model form, ownership characteristics (owner of supplier, non-forest income, age), data type, price observations frequency, interest rate, standing stock, price deflation, and time period.

## 4.2 Materials and Methods

### 4.2.1 Data collection

Studies appropriate for meta-analysis (to be discussed in detail later) were identified by using the ISI Web of Science (Thomson Reuters Corp., Toronto) search tool on 11 electronic databases for both refereed and non-refereed articles including theses and dissertations. On August 24<sup>th</sup>, 2015, we conducted a search of these databases with the search terms: timber market and price\* elasticity of supply. A total of 76 unique articles were extracted from 3 databases: 49 from Web of Science<sup>TM</sup> Core Collection, 26 from CABI, and 1 from BIOSIS Citation Index<sup>SM</sup>. Through examining the 76 eligible articles, 55 were excluded because they did not meet our criteria: price elasticity of supply was not reported (18); standard error was not provided and it was not calculable from data provided (19); full articles could not be located (18). The Google Scholar search tool was also used to search using these search terms, which provided about 34,800 results. The first 20 pages were examined, which resulted in 4 additional journal articles for the analysis. A total of 25 articles met the criteria and from which 51 studies were extracted, spanning 35 years (1980 – 2015).

Price elasticity and standard error were collected from each study. The majority of the studies included in our data set violated the assumption of study independence described by Mengerson *et al.* (2013). In other words, studies from the same article may not be completely independent; their effect size values may be more related to one another than to study effect sizes reported in other articles (Mengersen *et al.*, 2013). It is common to treat multiple studies reported in a single paper as if they were independent. Meta-analysis acknowledges the likely non-independence among multiple studies but it is typical practice to proceed this way because

excluding data reduces statistical power (e.g., Veresoglou et al., 2012; Slattery et al., 2013; Omondi et al., 2016; Zuber and Villamil, 2016). As in the Lehmann and Rillig (2015) work, studies were not combined in instances in which they differed in categories assigned to moderator effects, to maintain the ability to conduct moderator analysis. Therefore, following Lehmann and Rillig (2015), we addressed the non-independence for articles presenting multiple PELS means (often termed subgroups, observations, trials, or studies in the meta-analysis literature) by combining subgroups to a single effect size value using a random-effects meta-analytical approach. Subgroups were not combined where they differed in factors assigned to moderator effects and hence needed to remain independent to maximize moderator analysis. For example, subgroups were not combined when they addressed different forest product types or econometric models. Following this process, we extracted a total of 339 PELS observations from above-mentioned 51 studies from 25 different articles.

#### ***4.2.2 Effect size and moderator variables***

PELS was the single-group effect size<sup>1</sup> evaluated across studies in the meta-analysis.

PELS, a measure of the sensitivity of timber supply to price, was computed as:

$$PELS = \frac{\% \text{ change in quantity supplied}}{\% \text{ change in price}} \quad (1)$$

Generally, PELS can be classified into three categories: elastic (PELS > 1), unit elastic (PELS = 1), and inelastic (PELS < 1) (Lowenstein, 1954). In addition to price elasticity and

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<sup>1</sup> While the effect size for most meta-analyses defines the relationship between two groups, commonly mean difference or ratio of means, some meta-analyses are focused on means of a single group or population. This is the case for PELS; it is a single group effect size or simply single group summary (since effect implies a relationship). Whether the index is a two-group effect size or single group summary has no bearing on the meta-analysis computations (Borenstein et al., 2009).

standard error, we recorded information for 12 moderator variables for each study (Table 4.1), the main factors that are believed to affect the PELS.

*Forest Product:* The PELS could differ among different types of forest products due to different harvesting requirements and market situations for respective products (Toppinen and Kuuluvainen, 1997). Three primary timber products -- pulpwood, sawlogs, and roundwood-- were included in the analysis (as classified in the articles reporting their data). It should be noted that we include only the primary timber products for analysis and exclude the secondary products (e.g., plywood, sawn wood) which are different market goods.

*Region:* The response of supply to price could also depend on the geographical scope and nature of the regional timber market (Bolkesjø et al., 2010). A unit change in timber price in the U.S. market may not necessarily have the same impact on timber supply in the Malaysian market. Therefore, geographical region was used as another moderator with three categories: North America, Europe, and Asia. We believe that these three geographical regions represent a broader market of timber on a global scale.

*Econometric Model Form:* Econometric models (especially the functional form) used in modeling the relationship between timber supply and the contributing factors could have an impact on the PELS estimate (Bolkesjø and Solberg, 2003). Three categories of econometric model specifications were evaluated: linear, log-linear, and log-log. These three model forms were classified depending on whether one or both the volume of timber and price were transformed with logarithm form.

*Data Type:* Timber supply studies have mainly utilized data from one or more places or suppliers at various points in time (Bolkesjø et al., 2010). The kind of econometric model



**Table 4.1 Description of moderators used to characterize heterogeneity in PELS**

Moderators	Description
Forest Product	Materials derived from forests for direct consumption or commercial use
Region	Areas that have generally similar timber markets (classified as Asia, Europe, and North America)
Econometric Model Form	Function from used to build the relationship between timber supply and associated factors including: linear, log-linear, and log-log;
Data Type	Types of data include: 1- Cross section: data from units observed at the same time or in the same time period; 2- Time series: data from a unit (or a group of units) observed in several successive periods; 3- Panel data: multi-dimensional data involving observations of multiple units over multiple time periods
Price Observations Frequency	Types of data sample: 1- Monthly data: data used in the studies were observed monthly; 2- Quarterly data: data used in the studies were observed quarterly; 3- Annually data: data used in the studies were observed annually;
Ownership	Owners of the forestlands which mainly include industrial, government, NIPF, and aggregate
Owner's Age	Dummy variable, 1 if included in the econometric model, 0 otherwise
Non-forest Income	Dummy variable, 1 if included in the econometric model, 0 otherwise
Standing Stock	Dummy variable, 1 if included in the econometric model, 0 otherwise
Interest Rate	Dummy variable, 1 if included in the econometric model, 0 otherwise
Price Deflation	Dummy variable, 1 if price is deflated using consumer index, 0 otherwise
Time	Categorical variable, 1 if the article was published between 1980-1990, 2 if between 1991-2000, 3 if between 2001-2010, and 4 if after 2011

researchers can use partly depends on whether data are available from multiple markets (or sub-markets) and time periods. By summarizing the corresponding empirical timber supply articles, three categories of data type including cross-section, time series, and panel data were obtained. Compared to cross-section and time series data, panel data (i.e. combination of cross-section and time series) may yield more reasonable and stable PELS estimates because they cover multiple markets and time periods.

*Price Observations Frequency:* In addition to the data type, it is reasonable to expect that the number of price data points observed (for a given market) for the estimation of PELS may have some effect on PELS estimates. Studies that utilize more price observation points may offer a more rigorous analysis and perhaps therefore yield more unbiased and precise estimation of PELS than other studies with fewer price observations. Unfortunately, not all articles we reviewed mentioned the price observation frequency, which is different from the sample size. However, we took a proxy approach in creating a categorical moderator that controls for differences in studies with various price observation frequency. The basic assumption in using this proxy is that studies utilizing more frequent data observations (i.e. monthly) are likely to have more price data points than those using less frequent data observation (i.e. annual). Therefore, we included the price observations frequency moderator in meta-analysis with three levels: monthly, quarterly, and annually.

*Ownership, Owner Age, Non-forest Income:* Numerous studies, especially those focusing on the NIPF owners, have demonstrated that various characteristics of ownership (e.g., owner's objective/motivation, non-forest income, age, and education) are related to timber supply (Kuuluvainen et al., 1996; Pattanayak et al., 2002; Beach et al., 2005; Favada et al., 2009). Thus,

three moderators associated with ownership characteristics were examined, ownership type, owner age, and non-forest income. Ownership type included four categories: NIPF, industry, government, and aggregate (i.e. more than one ownership type involved). Studies classified in the aggregate category combined those that did not report specific forest ownership and instead analyzed timber supply at the market level. Owner age and non-forest income were treated as two-level categorical variables (Yes/No): whether or not they were included in econometric models of timber supply studies.

*Standing Stock:* Standing stock is believed to affect timber supply significantly (Kuuluvainen et al., 1996; Pattanayak et al., 2002; Beach et al., 2005). Theoretically, standing stock positively affects harvesting which implies that the higher the level of standing stock, the higher the harvest/supply. To examine whether and how the standing stock of timber influences PELS, we included it in meta-analysis as a two-level variable (Yes/No): whether or not it was included in models that estimated the PELS.

*Interest Rate, Price Deflation:* Interest rate and price deflation based on inclusion in econometric models were also considered as two-level moderators in meta-analysis. PELS estimation may vary among studies depending upon whether the model accounts for interest rate in the market. This is because with higher interest rates, the cost of holding standing stock increases for those forest landowners who act in perfect capital market and do not place a lot of value on non-timber amenities (e.g., Amacher et al., 2009; Bolkesjø et al., 2010). Several previous studies (Duerr, 1960; Binkley, 1987; Amacher et al., 2009; Bolkesjø et al., 2010) found a positive effect of interest rate on timber supply, whereas a study in China by Zhang and Buongiorno (2012) reported that interest rate had no effect on timber supply. Hence, it is

necessary to consider the interest rate variable in meta-analysis to test the sensitivity of PELS estimates with respect to interest rate. In addition, some articles (Brännlund et al., 1985; Bolkesjø and Baardsen, 2002; Polyakov et al., 2005; Favada et al., 2009; Bolkesjø et al., 2010; Solberg, 2011; Zhang and Buongiorno, 2012) deflated price data using consumer price index whereas other articles did not (Raj, 1985; Newman and Wear, 1993; Prestemon and Wear, 1999; Nilsson, 2002). Thus, the price deflation moderator was included as a two-level variable to test if studies that took inflation into account showed different estimates of the PELS than others.

*Time:* Change in market circumstances over time can affect price responsiveness of timber supply. The PELS has been found to vary over time (Dennis 1989; 1990). To quantify how time period has been related to PELS variation, we classified articles into four categories as 10-year intervals by year of publication (1980-1990, 1991-2000, 2001-2010, and 2011 and after) and included them in the meta-analysis.

#### **4.2.3 Meta-analysis**

Meta-analysis is a method of systematically reviewing and analyzing results from numerous studies to develop a new single conclusion. Following Beach *et al.* (2005), we began the analysis with a simple method of vote counting to explore the commonality among studies in terms of independent variables considered. This method summarized the percentage of each independent variable used in these studies. We estimated the summary size (weighted average effect size across studies) with Comprehensive Meta-Analysis (CMA) software (Version 3, Biostat, Englewood, NJ, USA; 2014). We employed a random-effects model, considering that true effects probably varied across studies (rather than a fixed-model, which assumes the same value or true effect for all studies). Individual studies within the meta-analysis were weighted by

the reciprocal of variance, computed from standard errors obtained directly from each study. Heterogeneity was assessed with the  $Q$  statistic, a measure of weighted squared deviations. Total variation ( $Q_t$ ) is composed of expected or within-study variation ( $Q_w$ ) and excess or between-study variation (heterogeneity;  $Q_b$ ). Heterogeneity was quantified using  $I^2$ , a descriptive index that estimates the ratio of true variation (heterogeneity) to total variation across studies:

$$I^2 = (Q_t - df) / Q_t * 100 \quad (2)$$

where  $df$  denotes the expected variation  $Q_w$  and  $Q_t - df$  represents the excess variation ( $Q_b$ ).  $I^2$  is set to 0 when  $df$  exceeds  $Q_t$ . A value of 0% indicates no heterogeneity, and positive values indicate presence of heterogeneity in the dataset with larger values reflecting a larger proportion of the observed variation due to true variation among studies. Assumptions of homogeneity were considered invalid when  $p$  values for the  $Q$  test ( $p_{hetero}$ ) for heterogeneity were less than 0.1 (e.g., Bristow et al., 2013; Iacovelli et al., 2014). For each moderator, we assumed a common among-study variance.

Meta-regression analysis was conducted using CMA (restricted maximum likelihood, Knapp-Hartung model; Inthout et al., 2014) to quantify the correlations between PELS change and the 12 moderators. Categorical moderators are described by discrete categories or levels. Meta-regression produces both intercept and slope estimates, where the intercept is the summary effect size when the moderator is zero, and the slope is the change in effect size in the corresponding level of moderator compared to the reference category/level. The meta-regression  $p$  value tests if this slope is equal to zero compared to the reference level.

Sensitivity analysis was performed for the overall summary effect by removing one study and re-running the meta-analysis for every study remaining in the analysis. The one-study-

removed process was repeated for each of the 51 studies. Change in summary effect in response to removing a study shows the contribution of that particular study. The analysis characterizes summary effect consistency and tests for extreme values.

In meta-analysis of effect sizes, where the summaries of interest involve comparison of two groups (often treatment and control) via a mean response ratio or mean difference, it is important to test for publication bias. The idea regards the possibility that non-significant treatment effects may be less likely to be published than significant ones (Rothstein et al., 2005). If this were true, studies based on smaller sample size would tend to have larger effect sizes – statistical power declines as sample size declines – raising a concern about missing data from smaller, unpublished studies. The issue of treatment significance is absent from single group meta-analyses, and the conventional tests related to publication bias (Borenstein et al., 2009) do not apply. Still, it is important to test for the possibility for missing data in meta-analyses of single group means (such as PELS). There is no reason to suspect that papers reporting proportionately larger or smaller mean PELS would be more or less likely to be rejected for publication. We did examine the funnel plot, to note if there was any tendency for smaller, less precise studies (those with larger SE) to vary more from the overall summary value than larger studies. In particular, we noted whether smaller studies whose mean PELS was close to zero were conspicuously absent. Visually, the funnel plot for PELS showed no pattern that would reflect bias toward not reporting small absolute values or negative values. Studies based on large and small sample size across the range of standard errors had the expected variability around the common effect size. Applying the Begg and Mazumbar rank correlation test across all study

means in our analysis resulted in an absolute Kendall tau value below 0.07, indicating no tendency for PELS values to either increase or decrease as study size decreased.

## 4.3 Results

### 4.3.1 Overall summary effects

Based on 25 articles summarized (see Appendix A), we found that with regard to data type, 16 studies used time series data, 6 used cross-section data and the remaining 8 employed panel data. In addition, two studies (Bolkesjø et al., 2010 and Sun et al., 2015) included all three data types. For econometric models, 13 studies employed linear models to estimate PELS, 8 used log-linear models, 8 applied log-log models, while 2 employed all 3 models to estimate PELS. In reference to the ownership type moderator, 9 studies focused on NIPF and 3 on industry and NIPF ownership. In addition, 10 articles analyzed the total timber supply without considering specific ownership. Among these studies, 76% incorporated the standing stock variable in econometric models to examine its relationship with timber supply. By contrast, approximately 48% included the interest rate in timber supply modeling. As for studies focusing on NIPF owners characteristics, 33% incorporated the owner's age into econometric models whereas 67% had non-forestry income.

The stability of the overall summary size and relative contribution of individual studies was assessed with sensitivity analysis. There were no extreme studies; each one-study-removed summary size in the series from low to high values differed from its neighboring value by no more than 0.002. The most that the overall summary size was changed by the removal of one study was 0.025; with the removal of PELS of 1.242 reported in Kuuluvainen *et al.* (2014), the overall summary size was reduced from 0.291 to 0.267. Removal of the study by Bolkesjø *et al.*

(2010) that reported low PELS of -0.185 caused a shift of 0.014 in the summary size. The summary PELS was stable and, due to the clear heterogeneity in the dataset, resolved to values between -0.02 (highly inelastic) and 1.24 (elastic) across moderators and their respective levels.

#### **4.3.2 Moderator variable analysis**

In interpreting the summary PELS, we followed Cooper (2009), who stressed that the size of the summary values and their likely scientific significance is of greater importance than their statistical significance. Similarly, Borenstein *et al.* (2009) pointed out that while a significant heterogeneity  $p$  value provides evidence that subgroups differ among trials (true effects vary), the converse does not hold. A  $p$  value above 0.05 does not provide evidence that subgroups are consistent among trials; lack of significance may be due to low statistical power. Even substantial dispersion of true effects might yield  $p > 0.05$  with a small number of studies or large within-study variance. Several of the moderator subgroups for which the analyses found no evidence of statistical difference may in reality differ, but insufficient research (low number of studies) precludes ability to resolve the difference. Summary effect precision is denoted by confidence intervals (CIs) which can be used to assess distinctness of moderator levels and degree to which summary effects overlap zero. However, many meta-analysts still use statistical significance to guide their interpretations of results. Hence, we have attempted to note both scientific significance (magnitude of PELS differences) and statistical significance ( $p < 0.10$ ) in summarizing our findings.

There was substantial heterogeneity in the summary size of PELS across studies. Eight of the 12 moderators explained heterogeneity of PELS to a statistically significant level based on

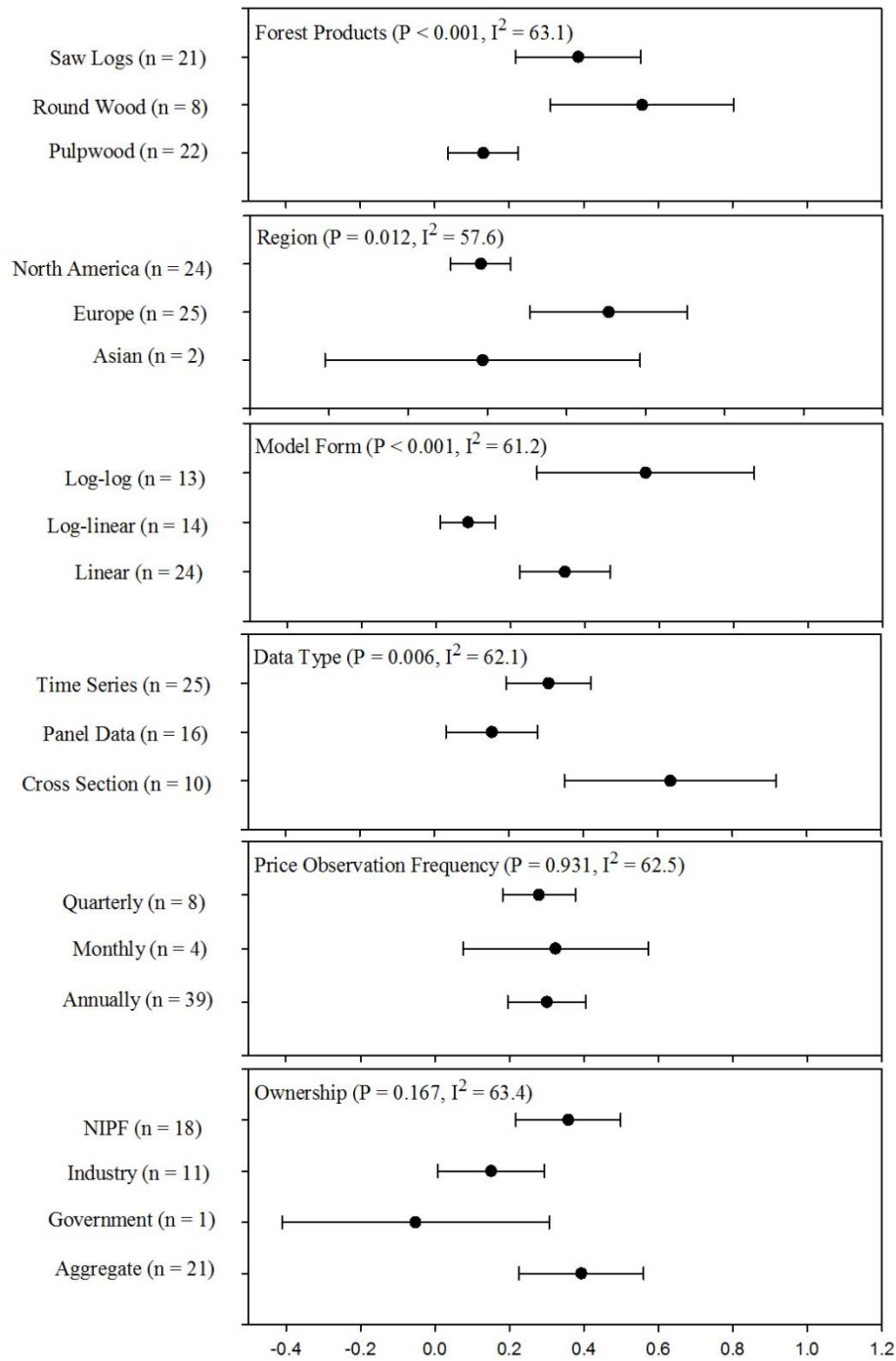


the overall  $p$  value ( $< 0.10$ ) (Figure 4.1 and Figure 4.2). Moreover, the  $I^2$  ( $\approx 60\%$ ) of these various moderators also indicated that the heterogeneity was high.

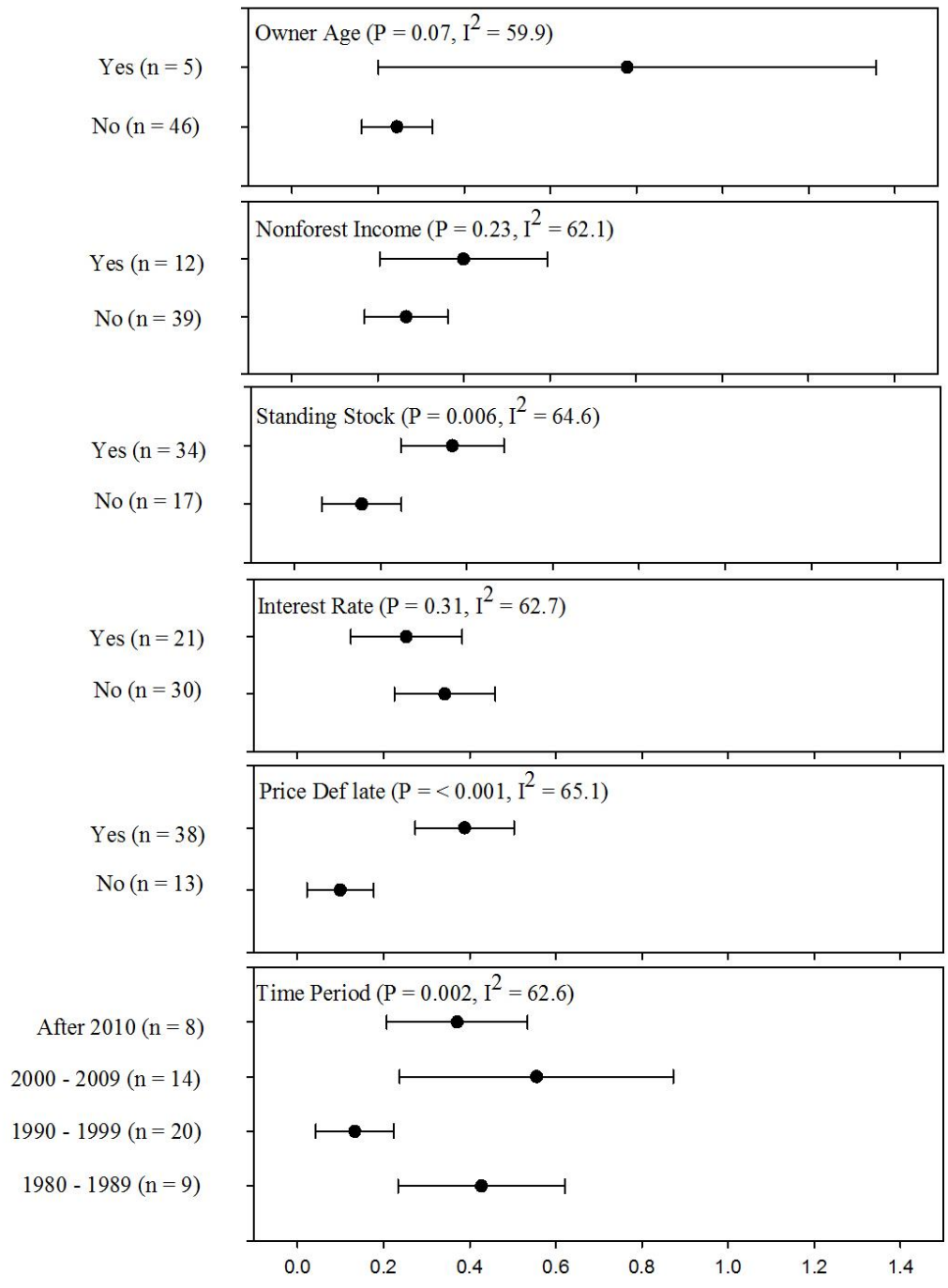
*Forest Product:* Across studies, a significant variation of PELS within the forest products moderator was observed ( $P_{hetero} < 0.10$ ,  $I^2 = 63\%$ ). PELS of roundwood (CI = 0.31, 0.80) and pulpwood (CI = 0.04, 0.22) subcategories appear different as CIs do not overlap. The summary size of PELS for pulpwood was 0.13 whereas it was 0.56 for roundwood, suggesting that roundwood was slightly more sensitive to price than pulpwood. Likewise, a true variation in PELS between pulpwood (0.13) and sawlogs (0.39) was also found and sawlogs supply was more elastic to price. On the contrary, no significant difference was seen based on the overlapped CIs and summary size of PELS between sawlogs and roundwood (Figure 4.1).

*Region:* Regarding the geographical region moderator, a large heterogeneity of PELS was found ( $P_{hetero} < 0.10$ ,  $I^2 = 58\%$ ). PELS was estimated to be between 0.31 and 0.71 in Europe, but the same was 0.11 to 0.26 in North America yielding a statistically significant difference. By contrast, we found that neither the North American region (0.18) nor the European region (0.51) PELS significantly differed compared to studies from Asia (0.19) based on the overlapped CIs of PELS (Figure 4.1).

*Econometric Model Form:* Analysis of the PELS variation with respect to the econometric model form moderator showed that the PELS varied greatly among the studies that used different model forms ( $P_{hetero} < 0.10$ ,  $I^2 = 61\%$ ). A statistically significant difference in PELS was found between log-log model (0.56, CI = 0.27, 0.86) and log-linear model (0.09, CI = 0.01, 0.16). Likewise, a noteworthy difference was found between log-linear model (0.09, CI = 0.01, 0.16) and linear model (0.35, CI = 0.23, 0.47).



**Figure 4.1** Weighted summary sizes for multi-level moderators explaining the variance of PEELS. n = number of studies; heterogeneity P denotes the probability that all studies share a common PEELS; I2 denotes the proportion of observed variance that reflects real differences in PEELS among moderator levels.



**Figure 4.2 Forest plots for two-level (Yes/No) moderators and time period variable for explaining variance of PELS**

By contrast, no difference was found between the log-log and linear models according to the overlapped CIs.

*Data Type, Price Observations Frequency:* The results of the meta-analysis showed that great heterogeneity of PELS within the data type moderator was found ( $P_{hetero} < 0.10$ ,  $I^2 = 62\%$ ). However, the estimated summary size of PELS for time series data (0.31, CI = 0.19, 0.42) and cross-section data (0.63, CI = 0.35, 0.92) did not show heterogeneity based on the overlapped CIs. Similarly, regarding the studies using panel data, the PELS was estimated to be 0.15 and the CI was between 0.03 and 0.28, which overlapped the CIs of studies using time series data type; thus, no true variation in PELS was found between them. On the contrary, distinct variation of summary size of PELS was observed between the studies using cross-section data type (0.63) and those using panel data (0.15). No significant variation of the PELS was found among the levels of the price observations frequency moderator ( $P_{hetero} > 0.10$ ,  $I^2 = 63\%$ ). Also, the overlap of the CIs among monthly (0.07, 0.57), quarterly (0.18, 0.38), and annually (0.19, 0.41) data indicated that no great heterogeneity of PELS was seen among them.

*Ownership, Owner Age, Non-forest Income:* Results indicated that heterogeneity of PELS was not statistically significant in the ownership moderator ( $P_{hetero} > 0.10$ ,  $I^2 = 63\%$ ). Specifically, no significant PELS difference was seen between NIPF (0.36) and aggregate ownership (0.39). A similar result in PELS was found between government (-0.05) and industry ownership (0.15). Likewise, no PELS difference between NIPF and industry, and between NIPF and government ownership was found based on the summary size of PELS. Those results were also indicated by the overlapped CIs in the forest plot (Figure 4.1). The PELS estimated from supply models with and without taking owner age into account were 0.78 (CI = 0.20, 0.36) and

0.24 (CI = 0.16, 0.33), respectively, a statistically significant ( $P_{hetero} < 0.10$ ,  $I^2 = 63\%$ ) difference. However, the overlapped CIs suggested that no significant heterogeneity of PELS estimation was found between studies that did and did not control for the owner's age in timber supply modeling. No true variation in PELS was found between studies with and without non-forest income in the timber supply models ( $P_{hetero} > 0.10$ ,  $I^2 = 62\%$ ). The summary size of PELS was 0.40 (CI = 0.20, 0.59) and 0.27 (CI = 0.17, 0.36), respectively with and without taking the non-forest income into account in timber supply modeling.

*Standing Stock:* Forest characteristics represented by standing stock showed that variation in PELS estimates was found while considering it in timber supply models ( $P_{hetero} < 0.10$ ,  $I^2 = 65\%$ ); the summary size of PELS was 0.37 (CI = 0.25, 0.49) and 0.16 (CI = 0.06, 0.25), respectively with and without taking standing stock into account in timber supply modeling. In other words, the heterogeneity of PELS could be explained by whether researchers accounted for the size of standing stock in the models estimating PELS.

*Interest Rate, Price Deflation:* In addition, meta-analysis results of the two-level categorical moderator of interest rate showed no significant heterogeneity of PELS between the studies with and without it in timber supply modeling ( $P_{hetero} > 0.10$ ,  $I^2 = 63\%$ ). Specifically, summary size of PELS was estimated 0.25 (CI = 0.12, 0.38) and 0.34 (CI = 0.23, 0.46) respectively for supply models with and without considering interest rate. Regarding the price deflation moderator, the estimation of PELS varied greatly between the two categories ( $P_{hetero} < 0.10$ ,  $I^2 = 65\%$ ). The summary size of PELS was estimated to be 0.39 (CI = 0.27, 0.50) for studies that did deflate price and 0.10 (CI = 0.02, 0.18) for the studies that did not.

*Time:* The results showed that the variance of PELS varied significantly in the time period moderator ( $P_{hetero} < 0.10$ ,  $I^2 = 63\%$ ). No significant PELS difference was seen among 1980-90, 2001-2010, and 2011-2015, but a slight difference was found in time period 1991-2000. Specifically, the PELS was between 0.21 and 0.87 in periods 1980-90, 2001-2010, and 2011-2015. By contrast, the estimated PELS was between 0.04 and 0.22 in period 1991-2000.

### **4.3.3 Meta-regression**

Meta-regression results (Table 4.2) indicated that PELS changed significantly within the subgroups of the moderators including forest products, region, econometric model form, and data type. We used roundwood as the reference category for forest products and the results suggested that compared to roundwood, the variation in PELS was significantly lower in case of pulpwood. This result indicated that the estimated PELS of pulpwood was 0.48 times lower than that of roundwood, which was consistent with the summary effect of meta-analysis. Moreover, meta-regression result for forest products suggested that a significant difference of PELS was found between pulpwood and roundwood, but no big difference of PELS between roundwood and sawlogs. Using Asia as a reference category, dummy variable to capture the study involving timber market in Europe was positively related to the change of PELS and the coefficient 0.39 indicated that PELS reported in European studies was 0.39 times greater than those reported in the Asian studies. By contrast, a similar dummy variable to capture studies involving timber market in North America showed an insignificant effect on the variation in PELS, suggesting that the PELS in North American markets were not significantly different from that in the Asian markets.

For econometric model form, we used linear model as the reference level and the result indicated that the PELS estimated from log-log model had a significantly positive effect on the change of PELS compared to the linear model. The coefficient 0.41 represents that the estimated PELS by using log-log model was 0.41 times greater than that of linear model. This result was in line with the meta-analysis, which also suggested that there was a great heterogeneity of PELS between linear and log-log model. Regarding the data type, a positive relationship between cross-section data type and variation in PELS was found. Specifically, the PELS estimated with cross-section data was 0.77 times greater than that estimated with panel data. It was consistent with meta-analysis result in which a big difference of PELS was found between studies utilizing cross-section data and panel data. No significant effect of price observations frequency was found on the variation in PELS. Similarly, no significant association was found between the ownerships and the variation in PELS. Inclusion of owners' age, and non-forest income in the model also were not significantly associated with the variation in PELS.

In addition, a significant variation of PELS was seen in the two-level category moderators including standing stock and price deflation, suggesting that variation in estimated PELS was significantly influenced by the inclusion or exclusion of these factors in the supply model. Standing stock was also found to have significant and positive effect on the variation in PELS. Specifically, PELS was 0.42 times greater in studies that included standing stock in the supply model than those not including this variable. On the other hand, the interest rate variable was statistically insignificant, suggesting that the variation in PELS was not significantly different between studies that incorporated interest rate in supply models and studies that did not.

**Table 4.2 Significant moderators of meta-regression to explain the variation of PELS R2 = 0.33, Qexplain = 42.5%, n = 339)**

Moderator	Subcategories within moderator	Coefficient	Standard Error
Forest Product	Roundwood	-	-
	Pulpwood	-0.48	0.09**
	Sawlogs	-0.08	0.11
Region	Asia	-	-
	Europe	0.39	0.23*
	North America	-0.07	0.23
Econometric Model Form	Linear	-	-
	Log-linear	-0.23	0.11
	Log-log	0.41	0.11**
Data Type	Panel Data		
	Cross-Section	0.77	0.11**
	Time Series	0.10	0.11
Price Observations Frequency	Annually	-	-
	Monthly	-0.05	0.13
	Quarterly	-0.09	0.18
Ownership	Aggregate	-	-
	Government	-0.36	0.30
	NIPF	0.14	0.11
	Industry	-0.27	0.12
Owner Age	Yes	0.83	0.11
Nonforest Income	Yes	0.38	0.09
Standing Stock	Yes	0.42	0.08**
Interest Rate	Yes	-0.10	0.09
Price Deflation	Yes	0.49	0.10**
Time	Period 1	-	-
	Period 2	-0.48	0.17**
	Period 3	0.29	0.18
	Period 4	-0.05	0.18

Note: The first category within each group was the reference category in meta-regression model. \*\* $p = 0.05$ ; \*  $p = 0.10$ .



However, PELS in studies that deflated price to the consumer price index were found to be 0.49 times larger than those that did not account for inflation. Lastly, study time period had a significant influence on the estimation of PELS indicated by the meta-regression results using 1980-90 as the reference level. The negative coefficients suggested that the studies conducted in more recent years were more likely to find significantly higher variation in PELS than their older counterparts.

#### **4.4 Discussion**

Meta-analysis results demonstrated that PELS varied with different forest products, which is consistent with Dennis (1990), who also found that price elasticity varies substantially between different forest products. Summarized mean PELS was significantly larger in roundwood and sawlogs compared to pulpwood. Relatively less sensitivity of pulpwood supply with respect to price may be attributable to the fact that it is often considered an outcome of “joint production” with roundwood. Therefore, when the roundwood price increases in the market, it will raise the probability of both final harvests and thinning which both produce pulpwood, but not roundwood. Pulpwood supply being less sensitive to price (compared to sawlogs) may be explained by the fact that pulpwood markets are often less competitive than sawlogs markets due to their low value and residual nature of the product and the fact that there are fewer buyers. Moreover, pulpwood is supplied to paper mills and Oriented Strand Board (OSB) mills that are larger corporations with more contractual relationships developed with suppliers.

Variation in PELS was found among different geographical regions. The difference in PELS between North America and Europe is particularly interesting and is partly attributable to

differences in forest harvest-related policies, ownership structure, and market demand (Sohngen et al., 1999; Sohngen and Sedjo, 2000). However, no distinct variation of PELS in North America or Europe from Asia is probably due to the relatively small sample size of studies from Asia. This does not suggest that there is no PELS difference between Asia and the other two regions, but instead warrants more research to statistically test this potential difference.

Econometric model form also explained PELS variation among different studies. Consistent with the results reported by Bolkesjø and Solberg (2003), econometric theories and statistical methods used in timber supply analysis had a marked effect on the PELS. Likewise, Prestemon and Wear (2000) described that the variance of econometric models (e.g., linear and logit) applied in the previous studies indicate different sensitivities of timber supply to market price.

Furthermore, while no evidence of statistical difference in PELS was found among the price observations frequency in meta-analysis, it does not necessarily mean in reality there is no difference among them. This could be due to the insufficient statistical power to resolve the difference (e.g., only 4 studies for monthly data). For the three data types, variation of PELS existed between cross-section and panel data based on their summary estimation of PELS, which was consistent with the previous studies. Kuuluvainen *et al.* (2014) reported that the PELS was around 2.5 by using cross-section data, which was not in line with the results reported by Bolkesjø *et al.* (2010) using panel data. Moreover, Bolkesjø *et al.* (2010) analyzed the PELS of sawlogs and pulpwood by using all three different data types and concluded that the PELS varied among them. The explanation for the variation of PELS among different data types is that

regional timber prices are highly correlated with omitted region-specific variables. Nonetheless, it is infeasible to consider the price dynamics with so few observations over time.

Meta-analysis results indicated that no true variation of PELS was found between NIPF and aggregate ownership, which is possibly because NIPFs dominated the number of owners in aggregate studies. Moreover, no heterogeneity of PELS was found by meta-analysis and meta-regression in this study among ownerships of NIPF, industry, and government -- suggesting that further research is needed for all these ownerships to statistically test their potential differences. An intuitive explanation is that different ownerships have different forest management objectives and they might react in a different way to change in market price. For example, timber production is the main purpose of industry-owned forests; by contrast, management objectives of NIPF owners ranging from amenity to timber to heritage are affected by various non-market factors (Salmon et al., 2006; Kittredge and Thompson, 2016). Moreover, Cabbage (1986) argued that NIPF owners' relative lack of knowledge about timber price partly contributes to their unresponsiveness to timber price, resulting in a less than socially desirable quantity of timber supply. Many studies (Robinson, 1974; Kuuluvainen et al., 1996; Karppinen, 2000; Pattanayak et al., 2002; Wiersum et al., 2005; Ní Dhubháin et al., 2007; Favada et al., 2009; Kittredge and Thompson, 2016) also suggested that NIPF-owned forests had great heterogeneity of PELS due to multiple management objectives which are influenced by various non-price factors. On the contrary, industry ownership is profit-oriented and may respond quickly to supply (or lack thereof) of more timber when price increases (or decreases). Regarding government ownership, lack of heterogeneity in PELS may relate to the fact that government-owned production forests

are primarily used to supply timber to meet a wide range of societal needs rather than profit maximization even during the periods of high prices.

Referring to the ownership characteristics, no heterogeneity of PELS was found by meta-analysis and meta-regression in this study for owner age which could be due to the insufficient statistical power. However, the findings of Favada *et al.* (2009), Kuuluvainen *et al.* (1996), and Kuuluvainen and Tahvonen (1999) reported that PELS variation was correlated with the owner age. And the possible reason for this heterogeneity is that the owners' preference possibly varies with age. For instance, older forest owners might be less willing to harvest timber, but instead more interested in non-timber benefits such as ecosystem services (e.g., Mackerron *et al.*, 2009; Knoot *et al.*, 2015; Tian *et al.*, 2015) than younger ones and thus, supply less timber to the market. Non-forest income variable was found to have no impact on PELS in our analysis. This contradicts the conclusion of Hyberg and Holthausen (1989) that reported income negatively relates to timber supply, an observation consistent with Uusivuori and Kuuluvainen (2005).

With regard to the two-level moderators in meta-analysis, inclusion of standing stock and price deflation in the supply models were significantly related to variation in PELS estimates. For standing stock, Favada *et al.* (2009) and Bolkesjø and Solberg (2003) found that this variable positively affected timber supply, which is consistent with the meta-analysis results in our study. No previous study considered the variable of price deflation with consumer price index in timber supply modeling research. Meta-analysis and regression results demonstrated that the price deflation moderator was considerably correlated with PELS heterogeneity. However, meta-analysis and meta-regression results both indicated that interest rate variable in econometric models was not significantly related to the change of PELS. While the interest rate can affect the

opportunity cost of delaying forest harvest, but it is unclear how it affects timber supply if the net savings is less than or equal to zero. On the contrary, it has a positive effect if the net savings is greater than zero (Bolkesjø and Solberg, 2003).

In line with Dennis (1990), time period had a marked effect on PELS variation and the four levels of time periods influenced PELS differently. The reason is probably due to the difference in technological advancement and market situation.

## **4.5 Conclusions**

This study identified factors that affect the heterogeneity of PELS. These findings may provide a theoretical as well as empirical basis to assist practitioners and policymakers to develop a deeper understanding of market dynamics. Policymakers are concerned with the responsiveness of producers in supplying timber as price changes. Our meta-analysis results suggest that PELS variation depends on forest products and geographic regions. Specifically, a large difference in PELS was found between sawlogs and pulpwood, indicating that the responsiveness of timber suppliers to price change differs with different categories of forest products. Moreover, pulpwood is less elastic to price than sawlogs, suggesting that pulpwood supply would not change as much as sawlogs supply with price change. Regarding the geographic regions, a large heterogeneity of PELS was found within North America and Europe, implying that dividing a large geographic region into more homogeneous sub-regions may be beneficial in understanding the market dynamics of timber supply. The other important implications from our findings is that future efforts to forecast timber supply should pay attention to the fact that PELS varies by product type, geographic region and other factors identified in this study. Hence, econometric models should take those differences into account for accurate forecasting. Additionally, forest

market planners and policy makers interested in regulating timber market through price-related instruments (e.g., price subsidy, tariffs) may also benefit from our findings in understanding the relative efficacy of such tools in influencing market supply.

A few limitations of this study should be noted. First, the meta-analysis of PELS in this study does not consider the interaction effect of multiple moderators to explore the combined or conditional effect on the PELS. Therefore, evaluating the interaction effects of price and other variables on heterogeneity of PELS may be an interesting area of future research on this topic. The second limitation is that our study did not consider the PELS variation estimated from mixed dataset. In other words, there might be a varying number of observations for different variables within studies used cross-sectional time series data. For instance, forest owner income and age vary over each cross section but not over time, so using regional price observations might result in less cross-section observations on prices than cross-section observations on the quantities traded. This could arguably influence the heterogeneity of PELS but it was not included in meta-analysis. Third, although the number of actual price observations might have a potential effect on the variation of PELS, it could not be included in the analysis as many of the reviewed studies did not provide this information.

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## Appendix C: Studies included in Meta-analysis

Study	Variables									
	Wood Product	Regions	Econometric Model	Data Type	Price Observations Frequency	Ownership	Standing Stock	Interest Rate	Age	Income
Brännlund et al. (1985)	Pulpwood Sawlogs	Sweden	Linear	Time series	Annual	Aggregate	No	No	No	No
Kumar Raj (1985)	Sawlogs	Malaysia	Log-Linear	Time series	Annual	Government	No	No	No	No
Daniels et al. (1986)	Sawlogs Pulpwood	USA	Log-Linear	Time series	Annual	Aggregate	Yes	No	No	No
Newman (1987)	Pulpwood Sawlogs	USA	Linear	Time series	Annual	Aggregate	Yes	Yes	No	No
Kuuluvaine et al. (1988)	Sawlogs Pulpwood	Finnish	Linear	Time series	Quarterly	NIPF	Yes	No	No	No
Hultkrantz et al. (1989)	Roundwood	Sweden	Linear	Time series	Annual	NIPF	Yes	Yes	No	No
Newman (1990)	Pulpwood Sawlogs	USA	Linear	Time series	Annual	Aggregate	Yes	No	No	No
Carter (1992)	Sawlogs Pulpwood	USA	Linear	Time series	Annual	Industry	Yes	Yes	No	No
Hetemäki et al. (1992)	Pulpwood	Finnish	Linear	Time series	Quarterly	NIPF	Yes	Yes	No	Yes
Newman, et al. (1993)	Sawlogs Pulpwood	USA	Linear	Cross section	Quarterly	Industry NIPF	No	No	No	No
Toppinen et al. (1997)	Pulpwood Sawlogs	Finland	Linear	Time series	Annual	NIPF	Yes	Yes	No	Yes
Prestemon et al. (1999)	Pulpwood Sawlogs	USA	Log-Linear	Panel Data	Annual	Industry NIPF	No	No	No	No

Prestemon et al. (2000)	Pulpwood Sawlogs	USA	Log-Linear	Panel data	Annual	Industry NIPF	No	No	No	No
Bolkesjø et al. (2002)	Roundwood	Norwegian	Linear	Panel data	Annual	NIPF	Yes	Yes	Yes	Yes
Nilsson (2002)	Pulpwood	Sweden	Log-log	Time series	Annual	Aggregate	Yes	No	No	No
Polyakov et al. (2005)	Pulpwood	USA	Linear	Time series	Annual	Aggregate	No	No	No	No
Mutanen and Toppinen (2005)	Sawlogs	Finnish	Log-Linear	Time series	Quarterly	NIPF	Yes	Yes	No	No
Favada et al. (2007)	Sawlogs	Finland	Log-log	Cross section	Annual	NIPF	Yes	Yes	Yes	Yes
Favada et al. (2009)	Sawlogs	Finland	Log-log	Cross section	Annual	NIPF	Yes	No	Yes	Yes
Bolkesjø et al. (2010)	Sawlogs Pulpwood	Eastern Norway	Log-log	Cross section Time series Panel data	Annual	Aggregate	Yes	Yes	No	No
Solberg et al. (2011)	Roundwood	Europe (Different countries)	All three models	Panel data	Annual	Aggregate	Yes	Yes	No	No
Zhang et al. (2012)	Roundwood	China	Log-log	Panel data	Annual	Aggregate	Yes	Yes	No	Yes
Fooks et al. (2013)	Roundwood	British	Log-Linear	Time series	Monthly	Aggregate	Yes	No	No	No
Kuuluvainen et al. (2014)	Roundwood	Finland	Log-log	Cross section	Annual	NIPF	Yes	No	Yes	Yes
Sun et al. (2015)	Sawlogs Pulpwood	USA	All three models	Cross section Time series Panel data	Monthly	Industry	Yes	Yes	No	Yes



## Appendix D: Copyright Permission Form



April 12, 2017

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Nana –

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Respectfully,

A handwritten signature in black ink, appearing to read "Scott R. Springmier". The signature is fluid and cursive, with a long horizontal stroke extending to the right.

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## CHAPTER V CONCLUSIONS

Developing fundamental understandings of landowners' behavior associated with forest resource management is becoming very important in rapidly changing social, political, and economic environments. Despite substantial research in understanding how landowners manage their forests, several gaps in literature still exist regarding how landowners' behavior/activities associate with sustaining the supply of timber and non-timber services and forest management. In this context, the studies presented in this dissertation shed some light on some of the previously unanswered questions. Findings presented in each essay are derived by employing theoretically grounded methods into rich empirical data, and therefore add significantly to human dimensions and economics literature in forestry.

The first essay mainly draws attention to the decision-making process of NIPF landowners regarding their interests in managing forests for ecosystem services by combining human dimension and economic theories (e.g., utility-maximization). Degrading conditions of natural ecosystems have raised public's concern about the decrease of ecosystem services whereas society's demand for ecosystem services continues to increase. Sustaining its supply by understanding landowners' behavior/activities becomes an important issue. Therefore, one area of potential use of the findings from this study is in designing and implementing outreach and education programs to elevate the interests of less interested landowners. For example, the results suggested that older, female landowners, and higher income landowners are generally more likely to manage their forests for ecosystem services; meanwhile, landowners whose primary motivation of owning their forests is enjoying tranquility are generally interested in

supplying ecosystem services, whereas landowners motivated by financial returns are less likely to manage their forestland for ecosystem service. Such information would be helpful in communicating and developing outreach to those landowners' segments.

The second important implication is that incentive-based mechanism may have to be established to encourage private landowners interest in ecosystem services supply. This is because integrating those ecosystem services in forest management would possibly impose significant cost on NIPF landowners. For example, providing some ecosystem services may require modifying management practice such as extending timber harvest beyond the economic rotation age to improve/enhance the ecosystem services (e.g., carbon sequestration). This may decrease profitability if timber is the only source of income. On the other hand, ecosystem services such as carbon sequestration, recreation, water quality, as well as the wildlife habitat protection etc. are largely public goods. Thus, operating practices to maintain ecosystem services is mainly benefiting the society, but NIPF landowners have to bear the cost. From this perspective, the NIPF landowners might not likely to incorporate the ecosystem services in their management decision without incentive-based programs.

The other notable implication is that studies in this dissertation shed some light about what kind of incentive-based programs that landowners are comfortable with. For example, a payment from government for landowners to internalize the costs associated with the adoption of management practices will motivate them to manage their forests for providing ecosystem services. Payment from private individuals or company could also be expected to have similar effect. Nonetheless, some landowners may be less certain about the commitment from private individuals or companies as compared to government entities (Hodges and Poudyal, 2008).

Hence, if payment on incentive-based programs were coming from government, it would be more appealing to landowners compared to those coming from private individuals or companies. In particular, property tax incentive may be a desirable government payment mechanism considering that property tax is one of the largest financial burdens that NIPF landowners face (Aarano et al., 2002).

The second essay focused on understanding the opportunities and constraints that landowners experience in adopting forest certification program in China. The results indicated that majority of landowners in Shandong province are not currently familiar with forest certification programs but are willing to consider it when provided with pertaining information (i.e. potential cost, benefits). The implication of this result is that there may be a potential market for certification program in China with appropriate outreach and extension. Moreover, results demonstrated that landowners in China are comfortable with certain programs that are administered by government organizations. Hence, the involvement of government in forest certification and operation might be a desirable policy approach.

In addition, results of this study indicated that incentive-based programs are required to promote landowners interest in forest certification schemes. For instance, payment/subsidy from government /companies to reduce or share the costs associated with forest certification and adoption of management practices may be needed. In addition, investing on outreach and extension to make landowner aware of the price premium opportunity or the preference from buyers for certified wood products may help encourage participation. Findings suggest a great deal of interest in participation among informed landowners. Those findings are useful to institutions and policy makers interested in understanding and promoting market for forest

certification in China. Information should help policy makers/program leaders identify potential landowners interested in certifying forests and design outreach strategies and educational programs to encourage otherwise less interested landowners.

The third essay highlighted how timber supply responded to market price and identified the contributing factors for the heterogeneity of this responsiveness. Total timber demand is likely to increase with the continual growth of population and sustainably and stably supply timber to the society is a big challenge. Findings from this study provide a theoretical as well as empirical basis to market participants and policymakers in understanding the dynamics of price signaling in timber market. Specifically, the results indicated that different categories of forest products and regions respond to price differently.

Forest market planners and policymakers interested in regulating timber market through price-related instruments (e.g. price subsidy, tariffs) may also benefit from a deep understanding of the relative efficacy of such instruments in influencing market supply. For example, pulpwood was less elastic to price than saw logs, suggesting that pulpwood supply would not change much with price change. The policy implication is that adjusting the market price through subsidy/tariffs may not necessarily help impact the supply of certain kinds of wood products (i.e. pulpwood). Another important implication for this study is that the econometric models should be improved by taking the factors resulting in different response of supply to price into account to accurately forecast future market conditions.

The essays presented in this dissertation mainly centered on understanding how forest resource are managed by landowners and how timber supply responds to market price. In addition to providing policy implications, techniques adopted in some of these essays have

extended or improved the existing models and methodological frameworks in forest management literature. Hypothesis testing with empirical analyses boost the arguments that forest resource management is a combination of social, political, and economic values. Given the increasing importance of sustainable management of forests for both timber supply and non-timber ecosystem services, the essays in this dissertation provide some insights in understanding the decision-making process of landowners for providing those services.

Moreover, topics addressed in this dissertation have applied unique methods for research in forest resource economics and management. For example, the third essay employed both meta-analysis and meta-regression to examine the factors behind the changeable response of timber supply to price. Meta-analysis is a relatively new method for quantitative literature review and future research in this field might consider studying the interactive effects of moderators in market dynamics.

Future studies could apply an economic approach to predict landowners' interests in both ecosystem services supply and forest certification participation in relation to a number of other aspects such as minimum compensation required, time commitment, BMP compliance etc.

## VITA

Nana Tian was born in Binzhou city of China. She graduated with an undergraduate degree in forestry in 2009 and earned a Master's Degree in 2012 from the Shandong Agricultural University, China. She later got a second master's degree in Forestry in 2014 from the Mississippi State University, Starkville, USA. In August 2014, she started doctor's degree in Natural Resources at the University of Tennessee, Knoxville (UTK) and graduated in the May of 2017. She also completed her Master's degree in Statistics from the Department of Business Analytics & Statistics at the UTK. After graduation, she plans to continue working as a natural resource professional using her quantitative skills to contribute in natural resource decision science.