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Faustmann in an uncertain policy environment ☆

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Abstract

This paper deals with optimal forest rotation age and silvicultural investment under policy or regulatory uncertainty to which wasteful deforestation and lack of reforestation and afforestation efforts in the developing countries and loss of old growth forests and biodiversity in the developed countries are attributed. Incorporating a stochastic uncertainty factor into the familiar deterministic Faustmann formula yields a result that confirms with casual observations — when policy uncertainty is present, forest stands are harvested earlier and silvicultural investment is smaller than otherwise. The policy implication is that, in order to promote forest resource conservation, encourage afforestation and reforestation, and attack other forest-related problems effectively, the pervasive nature of policy uncertainty needs to be curbed.

Keywords: Faustmann model; Policy uncertainty; Regulatory taking; Optimal rotation; Silvicultural investment

1. Introduction

This paper deals with optimal rotation age and silvicultural investment under policy or regulatory uncertainty. Uncertainty arises when not all of the many possible states of the world and outcomes are known in advance and the possibilities of these states and outcomes are unknown or may not exist (Knight, 1921). Policy uncertainty occurs when producers and consumers are uncertain about exogenous public policy events (Hirshleifer and Riley, 1979). In contrast to market uncertainty where an economic agent is fully certain about its own endowment and productivity but unsure about the supply–demand offers of other economic agents, policy uncertainty is an event uncertainty that concerns exogenous events.

In the last 30 years, forest economists have tried to incorporate various uncertainty factors into the Faustmann model (Faustmann, 1849). Norstrom (1975) incorporates price uncertainty in forestland value. Brazee and Mendelsohn (1988, 1990) and Newman et al. (1985) demonstrate the impact of price uncertainty on rotation age. Lem-

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bersky and Johnson (1975) dealt with both price uncertainty and response uncertainty of stands to management actions. Heaps (1984) considers age distribution of a forest and allows for variable harvesting costs. Lohmander (1988) shows that adaptive optimization under price and growth uncertainty increases the expected present value of forests. McConnell et al. (1983) incorporate prices and production cost variation in timber production planning, and Hardie et al. (1984) allow for changing rotation lengths over time. Reed (1984) and Routledge (1980, 1987) consider fire, potential catastrophic mortality, and change in land productivity on optimal forest rotation age.

Studies on market uncertainty (stumpage price, or product prices and logging and transportation costs) show that producers can sometimes benefit from market uncertainty as land value may increase and the rotation length may be longer. On the other hand, studies on event uncertainty or technological uncertainty such as stand response to management treatment, catastrophic mortality, and changes in land productivity generally indicate that a reduction in land value and rotation length is more likely to occur.

Although there are papers on policy implications of risk (Lohmander, 1987; Thorsen, 1999), few studies have explicitly considered public policy uncertainty, with the exception of Mendelsohn (1994) and Yin and Newman (1995). Hopefully, this is not because the issue is unimportant, since casual observations show that policy uncertainty is one of the major sources of uncertainty if not the major source of uncertainty facing timber producers, both in developing and developed countries (WRI, 1997).

This study differs from Mendelsohn (1994) by incorporating silvicultural investment. It covers forestry-related uncertainty in both developed and developing countries, and thus extends and generalizes the results of Yin and Newman (1995). Section 2 reviews literature and demonstrates the pervasive nature of policy uncertainty in forestry all over the world. Section 3 develops the results of a model that adds a stochastic factor into the familiar Faustmann formula. Section 4 provides some concluding remarks.

2. Evidence of policy uncertainty

The purposive courses of action or inaction made by governments are defined as public policy (Anderson, 1984). Governments influence management of forest resources for a variety of purposes: to compensate for the failure of markets, to account for the full social costs and benefits of resource use, and to achieve certain distributive objectives. In other words, the purpose of government involvement is to correct externality of private actions.

Although maybe rightfully motivated, many government policies have often caused uncertainty to timber producers and other resource users and negatively impacted their forest management behavior. Consider the following examples.

An issue high on the global environmental agenda for many years, deforestation remains a serious problem today (WRI, 1997). Between 1980 and 1990, global forest and other wooded land area declined by 2%, or 40 million ha (FAO, 1995). Nearly all this deforestation occurred in the tropics. Since 1960, some 450 million ha of tropical forest have disappeared. Asia has lost nearly one-third of its tropical forest cover while Africa and Latin America each lost 18%. More importantly, much deforestation is wasteful, and only 10% of these cutover lands are reforested (FAO, 1995).

Most studies on the causes of deforestation point to government policy failure, in particular land tenure policy failure (Hyde, et al., 1991; WRI, 1997; Roper and Roberts, 1999). Hyde et al. (1991) point out that poorly designed and enforced tenure is a major factor in wasteful deforestation. Mendelsohn (1994) shows that insecure property rights cause tropical deforestation. Hyde and Newman (1991) suggest that lack of tenure

[1] Scott (1991) defines security of tenure or the quality of title as the extent to which a person's ownership of a property right is socially acknowledged and enforceable.

security encourages over-exploitation and disinvestment.[1] WRI (1997) asserts that in most countries, both temperate and tropical, polices governing how forest tenure are awarded, taxed, and enforced encourage highly destructive logging practices. WRI (1997) recommends that governments clarify and lengthen tenure to encourage responsible logging, secure land tenure, and create a favorable environment for timber production. Yin and Newman (1995) suggest that land tenure insecurity in general cause farmers to cut their timber earlier and offer lower lever of inputs. Zhang (1999) argues that, in spite of having all other factors of production — labor, land and capital — lack of favorable land tenure policies has hindered China's 'green' efforts as 57 million ha of land (or 6% of the total national land base) suitable for growing trees remain idle.

Timber producers in developed countries are not immune from policy uncertainty. Zhang and Pearse (1996, 1997) document that, due to lack of tenure security, forest tenure holders in British Columbia invest much less and have a longer reforestation period on public land than on private land. Zhang (2000) shows that, due to lack of compensation and the restrictive nature of the Endangered Species Act (ESA), landowners in the US South whose forests are close to a known Red-Cockaded Woodpecker (RCW, a federally listed endangered species) habitat have a high propensity to cut timber earlier and use a clear-cut method.[2] These behaviors may be to achieve one apparent objective: destruction or foreclosure of potential RCW habitat quickly and before the ESA comes into force. This means that ESA gives landowners perverse economic incentives and induced actions that they would otherwise not have and that are detrimental to the full recovery of endangered species and protection of forest ecosystems and biodiversity.

Insecure land tenure and various land use restrictions are symptoms of policy or regulatory uncertainty. Policy uncertainty can be characterized as land appropriation or reallocation or restriction (partial taking) of timber harvesting and other management activities. In all cases, no compensation will be made to the producers, and the direct result of policy uncertainty is insecure future returns. Characterizing policy uncertainty this way leads to a generalized Faustmann model under policy uncertainty that applies to both developed and developing countries.

In most cases, timber producers are sure about what they will get if a particular policy applies to them but unsure about the probability of policy event. For example, tenure holders are sure about what they can get from forests under their control, but the government may seek to evict them and allocate all or a portion of the forests for other uses through either physical confiscation or regulations. In the US, forest landowners know what will happen when an endangered species is discovered on their property, but they are not sure about the probability of the endangered species coming. The following model will show that land value will be lower, rotation age will be shorter and silvicultural investment will be less under policy uncertainty than under no policy uncertainty.[3] Although the conclusions may seem to be simple and obvious, they have far-reaching policy implications.

3. Faustmann model under policy uncertainty

To illustrate the main point of the analysis, we

[2] The significance of RCW is that it needs medium-to-large size tracts of mature southern pine forests for its habitat. Southern pines are the most important commercial species in the US South. Since the South accounts for nearly half of the timber harvests in the country (Powell et al., 1993) and more than 90% of southern forests are privately owned, protecting RCW affect many private landowners' forest management activities. The government guideline on RCW management (US Fish and Wildlife Service, 1992) requires that, within a 200-foot radius (1.2 ha) surrounding a cavity tree, no trees greater than 10 inch in dbh should be cut, no pesticide should be used, and no road should be built without permission. In addition, a minimum of 24 ha of foraging habitat within a half mile of the cavity tree, and a minimum of 3000 square feet of pine basal area in trees 10 inches dbh or larger should be maintained.

[3] Of course, government subsidies can make optimal rotation longer and landowners' silvicultural investment increase. See Zhang and Flick (2001) for evidence on the influence of subsidies on landowner reforestation investment behavior.

take the perspective of stand-level optimization. We assume that:

1. Capital market are perfect so that timber producers can borrow and lend at a known real interest, r.
2. Stumpage prices, P, are constant.
3. Timber yield, $Q(t,c)$ is a function of age, t, and silvicultural investment c, where $Q_i = \partial Q/\partial_i > 0$; $Q_{ii} < 0$. Following Hyde (1980) and Chang (1983), total silvicultural cost is the unit factor cost w times the volume of effort E, i.e. $c = wE$. The decision variables are t and E.
4. Under certain policy environment, the producers have a secure tenure to their forests, and the probability of losing a portion of the property right is zero. There is a non-zero (δ) probability of losing a portion (α, $0 < \alpha < 1$) of their forests if the government changes its policy (or regulation applies as endangered species is discovered in the forests).[4]
5. The probability of losing a portion of their forests (δ) is an increasing function of time. This reflects that the longer the producers wait before harvesting, the more likely that they will lose a portion of the forests either because simply the probability of eviction increases over time or because the older the forests, the more likely they attract or trigger governmental actions. For example, endangered species may move to old growths and public recreation demands for old growth forests are likely to increase. Both may trigger government regulations.

The analysis is considerably clearer and more intuitive if we begin by considering a model in which the planning horizon runs through one rotation. As we shall see later, adding infinite periods of rotation will not change the basic results.

In the case of simply focusing on one rotation and its related silvicultural investment, the objective is to maximize the expected present value of future cash flow considering policy uncertainty. If the producers do not lose any portion of their forests ($\alpha = 0$), the expected value of the forests can be expressed as:

$$V_1 = PQ(t,E)e^{-rt} - wE \tag{1}$$

If the producers do lose a portion (α) of their forests (when $\delta = 1$), the expected value of the forests can be expressed as:

$$V_2 = (1-\alpha)PQ(t,E)e^{-rt} - wE \tag{2}$$

The objective is then to maximize:

$$V(t,E) = [1-\delta(t)][PQ(t,E)e^{-rt} - wE] + \delta(t)[(1-\alpha)PQ(t,E)e^{-rt} - wE] \tag{3}$$

The model contains the weakness that it assumes timber producers are risk neutral, not risk averse. However, if the result shows that risk-neutral timber producers respond negatively to policy uncertainty, risk-averse timber producers will respond negatively to policy uncertainty as well.

Eq. (3) can be simplified as

$$V(t,E) = [1-\alpha\delta(t)]PQ(t,E)e^{-rt} - wE \tag{4}$$

First order conditions for a maximum require that

$$\partial V/\partial t = \{[1-\alpha\delta(t)](PQ_t - rPQ) - \alpha\delta_t PQ\}e^{-rt} = 0 \tag{5}$$

$$\partial V/\partial E = [1-\alpha\delta(t)]PQ_E e^{-rt} - w = 0 \tag{6}$$

These two equations can be simplified as:

$$Q_t - \alpha\delta_t Q/[1-\alpha\delta(t)] = rQ \tag{7}$$

[4] This is similar to the 'partial regulatory taking' case in US legal system, where property owners do not get any compensation if regulations only partially reduce the value of their property. They are entitled to compensation if regulations make their property worthless.

or

$$Q_t/Q = r + \alpha\delta_t/[1 - \alpha\delta(t)] \tag{8}$$

and

$$[1 - \alpha\delta(t)]PQ_E e^{-rt} = w \tag{9}$$

The optimal condition (7) can be interpreted easily. On the right is the interest foregone by postponing harvesting the forest for one period. On the left is the gain from postponing the harvest one period; consisting of the value of timber growth over the period minus the portion of timber that might be taken away by government actions during the period. Obviously, for optimality the marginal gain from postponing the harvest one period must equal the marginal loss of postponement.

Since δ_t and $[1 - \alpha\delta(t)]$ are greater than zero, the second term in Eq. (8) is positive. In the absence of policy uncertainty, $\delta(t) = 0$, Eq. (8) simply reduces to the well-known result that a forest should be harvested when its rate of growth equals the discount rate. With policy uncertainty, the forest should be harvested when the rate of growth is more than the discount rate. Naturally, this is achieved by conducting harvesting earlier than otherwise. In other words, the effect of policy uncertainty has the same impact as the increasing discount rate in the Faustmann formula.[5] A review of literature shows that, in general, an increase in discount rates leads to earlier harvesting (Hyde, 1980; Chang, 1983; Hyde and Newman, 1991).

Similarly, Eq. (9) shows the optimal condition for silvicultural effort, which should be increased until the marginal product of the last unit of effort equals its factor cost. When $\delta(t) > 0$, it means the marginal product of effort is decreased, as compared to $\delta(t) = 0$. Therefore, the silvicultural efforts will be less than otherwise.

Up to this point, we have assumed that there is only one rotation. We now drop this assumption and consider a model with an infinite number of rotations. The objective now is to maximize:

$$\begin{aligned} U(t,E) &= \{[1 - \alpha\delta(t)]PQ(t,E)e^{-rt} - wE\} \\ &\quad \times (1 + e^{-rt} + \mathrm{e}^{-2rt} + e^{-3rt} + \ldots) \\ &= \{[1 - \alpha\delta(t)]PQ(t,E)e^{-rt} - wE\} \\ &\quad /(1 - e^{-rt}) \end{aligned} \tag{10}$$

This is obviously a simple generalization of land expectation value with a policy uncertainty factor. Comparing Eq. (10) with the deterministic Faustmann land expectation value shows the land value will be lower under policy uncertainty. Therefore, producers may convert the land into other uses such as agriculture, as it has been documented in many cases (e.g. Mendelsohn, 1994; Roper and Roberts, 1999).

The first order conditions for maximization of U are

$$\begin{aligned} &[1 - \alpha\delta(t)]PQ_t(1 - e^{-rt}) \\ &\quad = [1 - \alpha\delta(t)]rPQ + \alpha\delta_t PQ(1 - e^{-rt}) \\ &\qquad - rwE \end{aligned} \tag{11}$$

or

$$\begin{aligned} Qt/Q &= r/(1 - e^{-rt}) + \alpha\delta_t/[1 - \alpha\delta(t)] \\ &\quad - rwE/[1 - \alpha\delta(t)]PQ(1 - e^{-rt}) \end{aligned} \tag{12}$$

and

$$[1 - \alpha\delta(t)]PQ_E e^{-rt} = w \tag{13}$$

Eq. (13) is the same as Eq. (9), meaning that policy uncertainty leads to lower returns to investment and that producers will invest less than under no policy uncertainty. Eq. (11) is slightly more complicated. On the left-hand side is the marginal revenue for postponing harvesting one period under policy uncertainty. On the right-hand side is the marginal cost of postponing harvesting for that period. It consists of three terms: the marginal cost of delaying harvesting revenue, the marginal cost of losing a portion of the stand, and the gain of postponing planting cost. This condition means that, when deciding optimal

[5]This result is similar to that of Reed (1984) on the consequences of catastrophic risk for forest management.

rotation age, producers have to worry that part of their stand may be taken by government actions if they wait for another period. In general, this makes them cut their timber earlier than under no policy uncertainty, similar to the result of Reed (1984) on fire damage.

If $\delta(t) = 0$, Eq. (12) becomes the familiar Faustmann solution:

$$Q_t/Q = r/(1 - e^{-rt}) - rwE/PQ(1 - e^{-rt}) \quad (14)$$

Comparing Eq. (12) and Eq. (14) reveals that the right-hand side of Eq. (12) is not always greater than the right-hand side of Eq. (14). Thus, the optimal rotation age under policy uncertainty can theoretically be longer than that under no policy uncertainty. The sufficient condition for the optimal rotation age under policy uncertainty longer than that under no policy uncertainty is

$$\delta_t/\delta(t) > rwE/PQ(1 - e^{-rt}) \quad (15)$$

In order to find out if Eq. (15) is satisfied, we need to know the function form of $\delta(t)$ and the values of other variables. Since the right-hand side is a very small number — a small fraction [to be exactly, $wE/PQ(1 - e^{-rt})$] of the discount rate (r), this condition is easily met in practice unless $\delta_t/\delta(t)$ is very small.[6] Thus, the rotation age will generally (but not universally) be shorter under policy uncertainty than that under no policy uncertainty.

4. Conclusion

This paper shows that when policy uncertainty exists and impacts negatively on the security of future returns, the land value will be lower, and timber producers will respond by shortening rotation age and reducing silvicultural investment. The following quote from an investor and timber producer in the US South may help get the point across:

> Public concern in recent years over protection of the environment and natural resources has brought increased regulation and control of the US timber industry by federal and state governments. In the (US) south-east, environmental groups have made efforts to restrict the harvesting of timber on either private or public lands that would reduce the habitat of the Red-Cockaded Woodpecker, a federally-listed endangered species. Restrictions on harvesting of old-growth timber are being considered at both the federal and various state levels. PPIC (pine plantation investment contracts) will concentrate its efforts on cutover land, open fields, and young plantations that neither provide habitat for the Red-Cockaded Woodpecker nor fit the description of old growth timber.

This above quote is from the web page (http://ppmc.vardaman.com/prudential/) of James Vardaman & Co. Based in Jackson, Mississippi. This company provides timber sale services to landowners and invests in timber production through pine plantation investment contracts (PPIC). It is obvious that the company is worried about regulatory uncertainty and has taken action against this uncertainty by not investing in old growth timber that may attract Red-Cockaded Woodpecker and by cutting its timber earlier so that the bird would not come to its land. This type of behavior is generated under the current, uncertain regulatory environment — when there is a probability that they are going to lose some of their future crop (old growth timber), timber producers invest less and cut earlier to avoid potential loss.

What's needed for timber producers, whether they are landowners or tenure holders, is stable and favorable policy environment, especially secure property rights and institutions that promote efficient resource use and encourage investment and conservation. North (1981, p. 23) points out that one fundamental aspect of economic history is the widespread tendency of states to produce inefficient property rights and hence fail to achieve sustained growth. He notes, "the fact that growth has been more exceptional than stagnation or decline suggests that 'efficient' property

[6] Consider the following parameters in the US South as an example. In the US South, wE is approximately US\$750/ha, and a relatively well stocked timber stand is worth approximately US\$10 000/ha (all in net present value) with a rotation age of 35 years. If interest rate is 8%, then the right-hand-side of Eq. (15) is equal to 0.0064.

rights are unusual in history".[7] Despite the significant economic growth that has been made in the world today, inefficient property rights are still widespread in many countries and hinder resources conservation, encourage over-exploitation, and discourage investment. The implication is that, by reducing policy uncertainty, government can encourage longer rotation and investment and, therefore, promote sustainable development of forest resources. Otherwise, we will continue to see large-scale wasteful deforestation, loss of biodiversity, and massive idle forestlands occurring for quite some time.

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[7]North (1981) defines efficient property rights as property rights that reduce transaction costs in order to foster maximum output of the society. Transaction costs are the costs of creating and maintaining property rights (Allen, 1991). If timber producers could not maintain their property rights over time, the property rights will not be secure, and the transaction costs will be high, as defined. Thus, efficient property rights, secure property rights, and low transaction costs are often used synonymously.

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