FACTORS AFFECTING TIMBER SUPPLY ELASTICITY

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INTRODUCTION

The effectiveness of market mechanisms in providing adequate timber supplies has been a forestry issue for decades. Essentially this issue depends on two central components. First, and probably most important is determining what "adequate" timber supplies are. This is almost purely a normative question, one that must be resolved by public policy processes. The second question, assuming that policymakers can define or at least approximately determine adequate timber supply levels, is whether market mechanisms will provide this supply. Each of these questions is obviously difficult to answer. Nevertheless, this paper will try to examine the latter question of market effectiveness, given some reasonable assumptions about desirable supplies.

The title of this paper is "Factors Affecting Timber Supply Elasticity." Elasticity is a measure economists use to quantify the responsiveness of an output to a given input. Thus the title infers an examination of the responsiveness of timber supplies due to market or public policy factors that affect timber supplies. It will defer the question of desirable supply levels, and start instead with the responsiveness of timber supplies.

SUPPLY ELASTICITY

Economic theory dictates that in private-enterprise, free-market economies, the equilibrium prices for products will be determined by the intersection of the producer's supply curve and the consumer's demand curve. The responsiveness of markets to price signals is usually measured by price elasticities. An elasticity is a unitless measure that measures the percentage change in one (dependent) variable with respect to a percentage change in another (independent) variable. Thus, in a market equilibrium model, price elasticities may measure either the responsiveness of consumers to changes in product prices (price elasticity of demand) or the responsiveness of producers to similar changes (price elasticity of supply). The price elasticity of supply would be measured as:


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\[
E_s = \frac{\frac{\Delta Q_s}{Q_s}}{\frac{\Delta P}{P}} = \frac{\Delta Q_s}{Q_s} \cdot \frac{P}{\Delta P} = \frac{\Delta Q_s}{\frac{dQ_s}{dP}} \cdot \frac{P}{Q_s}
\]

where: \( P \) = product price
\( Q_s \) = quantity supplied

Similarly, the elasticity of demand would be measured by the percentage change in quantity demanded due to a change in price.

Elasticities can measure either the market responsiveness of producers or consumers. In the case of timber, policymakers have been most commonly concerned with the responsiveness of producers in supplying more timber as prices rise. The price elasticity of supply is the principal method for evaluating supply responses. Demand elasticities may also be relevant in evaluating market responses. For all elasticity measures, the following classifications of responsiveness are used:

<table>
<thead>
<tr>
<th>Elasticity</th>
<th>Responsiveness</th>
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<tr>
<td>(</td>
<td>E</td>
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<td>(</td>
<td>E</td>
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<td>E</td>
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Elastic supply would imply that the proportional change in output produced would be greater than the proportional change in price. Unitary elasticity would imply equal proportional changes. Inelastic supply means that proportional changes in output are less than proportional changes in prices. Elastic supply curves tend to flatter, indicating that the quantity response is greater than the price change. Inelastic supply curves are steep, indicating that quantities change little with price changes. Horizontal supply curves are perfectly elastic. In perfect (atomistic) competition, individual firms face a perfectly elastic supply curve; they cannot change the price received by varying output levels. Vertical supply curves are perfectly inelastic; the quantity produced remains constant at all price levels.

In practice, supply curves are apt to have varying elasticities depending on the point on the curve that is being measured. Small quantities of output and low prices are more likely to be more elastic than large quantities or prices. Thus, when measuring market responsiveness, the point of measurement is important. Most studies measure elasticity of supply at sample period means and draw conclusions regarding potential changes from the average conditions.

Supply elasticities may also vary depending if they are based on short-run or long-run supply curves. Short-run elasticities are generally less than long-run, as one would expect. In the short run, firm resources and supply curves are fixed, so supply responses are necessarily limited. In the long run, resources may be shifted among productive sectors and firms, allowing greater responsiveness.
The interaction of supply and demand determine market prices. Inelastic demand is apt to cause prices to increase greatly if supplies decrease (the supply curve shifts back). Similarly, inelastic supply is likely to cause large price increases if demand increases (the demand curve shifts out).

EMPIRICAL TIMBER STUDIES

Early Research

Several econometric studies performed in the 1970s estimated timber supply elasticities as part of their modeling effort. Adams (1974) developed a quarterly econometric model of Douglas-fir region forest products markets to simulate the response of prices and output to various national forest timber supply policies. The stumpage sector in the model consisted of the Forest Service, Bureau of Land Management, Private (Integrated Forest Industry and Non-Integrated), and other government. The model also included log and secondary products sectors. Twenty-nine equations and identities were developed for the market model and model parameters were estimated using a modified form of two stage least squares.

In using the model to examine national forest policies, Adams found that as the Forest Service offered different volumes of timber for harvest, most price shifts were confined to the stumpage sector with successively smaller price changes at the log and secondary products levels. As Forest Service cut increased, private timber harvest fell by nearly 60 percent of the increase, so that total regional harvest was only slightly changed over the sample period. Adams notes that "In the usual equilibrium supply-demand framework, the reduction in private harvest would depend heavily on the price elasticity of private stumpage supply. In the present model, this elasticity is effectively zero, with private harvest being most strongly influenced by the rate of secondary product output and the level of log inventories."

Robinson (1974) developed an 8-equation econometric model of the markets for Douglas-fir and southern pine stumpage. For the time period examined, Robinson determined that the demand for southern pine lumber was infinitely elastic, thus allowing only two equations to satisfactorily represent the southern pine sector, one for supply of lumber and one for stumpage. He found a price elasticity of demand of -0.14 for Douglas-fir stumpage and -0.52 for southern pine stumpage. The more inelastic Douglas-fir demand implied that producers were less able to adjust their production decisions than southern pine producers in response to changes in the price of stumpage. By considering both quantity and price as endogenous variables, Robinson estimated the short-run price elasticity of southern pine stumpage supply to be 0.32; Douglas-fir was 0.11. He noted that the supply of stumpage usually depends on landowner objectives, which are in large measure insensitive to the price of stumpage.

Duerr (1974) also examined timber supply in a review article. He cited a Forest Service study (Division of Forest Economics Research 1963) of the long-run supply of West Coast Douglas-fir that found price
elasticities of 0.07 to 0.12—approaching absolute inelasticity. Elasticities to the guiding rate of return ranged from minus 0.7 to 1.1, about 10 times as great as the price elasticities in absolute terms. He also mentions an unpublished Canadian study that found price elasticities of long-run supply that were essentially zero at all guiding guiding rates of return down to about 6 percent. The largest price elasticities ran from 0.02 to 0.12. Based on these studies, Duerr concludes that perhaps the best means for increasing supply would be to "subsidize" the rate of return that guide forest management, not subsidies to raise timber values. Lastly, he states that:

"...society can beam price signals at forest owners until everyone concerned is blue in the face, and little will happen except an exchange of money from one set of pockets to another.

That is to say, all our vast consumer efforts over the decades to buy, bid, and wheedle more wood out of our timber factories by offering to pay higher and higher prices for wood and its products have served merely to keep the processing industries afloat and to leave the timber situation about as it would have been anyhow."

Timber Assessment Market Model

In 1980, Adams and Haynes (1980) published their seminal monograph on the Softwood Timber Assessment Market Model (TAMM). TAMM is an econometric "spatial model of North American softwood lumber, plywood, and stumpage markets designed to provide long-range projections of price, consumption, and production trends. Six geographic demand regions and nine supply regions (including Canada) are included in the model."

Adams and Haynes write that private stumpage supply should react to timber prices according to economic theory, providing bases for development of long-term equilibrium models. Rational landowners would select the management regime—and hence future harvest levels—that would maximize the present net worth of stumpage returns. Owners must decide how much timber to grow (or sell) in the short run and how much inventory to accumulate for the long run. Taking this into account, TAMM includes two parts for private supply: "a short-term relation which explains the response of cut to current prices and inventory levels, and a long-term investment process which adjusts the level of management intensity and thereby growth, future inventory, and ultimately cut operating through the short-term relations. The short-term model rests on two simple assumptions, that, other things being equal: (1) private stumpage owners will vary their cut directly with stumpage price; and (2) that private cut will be greater if a greater stock is available from which to draw and less if the stock is reduced."

They calculated price and inventory elasticities of supply that were usually inelastic (Table 1). Inventory elasticities for the West
Table 1. Elasticity estimates for forest industry (FI) and other private (OP) softwood stumpage supply (computed at sample period means).

<table>
<thead>
<tr>
<th>Region</th>
<th>Owner</th>
<th>Price</th>
<th>Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Northwest West</td>
<td>FI</td>
<td>0.26</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>OP</td>
<td>0.06</td>
<td>1.00</td>
</tr>
<tr>
<td>Pacific Northwest East</td>
<td>FI</td>
<td>0.16</td>
<td>1.46</td>
</tr>
<tr>
<td></td>
<td>OP</td>
<td>0.18</td>
<td>1.00</td>
</tr>
<tr>
<td>Pacific Southwest</td>
<td>FI</td>
<td>0.26</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>OP</td>
<td>0.12</td>
<td>1.00</td>
</tr>
<tr>
<td>Rocky Mountain</td>
<td>All private</td>
<td>0.06</td>
<td>1.00</td>
</tr>
<tr>
<td>South Central</td>
<td>FI</td>
<td>0.47</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>OP</td>
<td>0.39</td>
<td>0.66</td>
</tr>
<tr>
<td>Southeast</td>
<td>FI</td>
<td>0.47</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>OP</td>
<td>0.30</td>
<td>0.72</td>
</tr>
<tr>
<td>North Central</td>
<td>FI</td>
<td>0.99</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>OP</td>
<td>0.31</td>
<td>0.35</td>
</tr>
<tr>
<td>Northeast</td>
<td>FI</td>
<td>0.32</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>OP</td>
<td>0.99</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Source: Adams and Haynes 1980.

Coast were generally unitary, implying that an increase in inventories would increase cut proportionally. Eastern regions all had inventory elasticities of less than one, reflecting that inventory increases would cause less than proportional increases in harvest. Cut on other private owners in the South was most responsive to inventory increases; northern regions were least responsive.

Price elasticities of supply were all inelastic, and all but two were less than 0.50. Elasticities for other private lands in the West were extremely low, averaging about 0.105. Forestry industry response in the West was slightly greater, at an average of 0.18, but still very inelastic. In the East, forest industry averaged a price elasticity of supply of 0.47 in the South and 0.66 in the North. Other private owners averaged 0.345 in the South and 0.66 in the North. These results confirm that private suppliers generally do not respond well to price signals, but the supply curves were not as inelastic as suggested by early studies. In addition, these are short-run stumpage supply
relations that ignore any linkages between the level of management intensity and timber harvest.

**CONTRIBUTING FACTORS**

The literature clearly indicates that timber supply responsiveness is not large. Economically, this implies that while markets may "work" in forestry—they will equilibrate supply and demand—they probably are not very effective at generating increased supplies of desirable species. Several factors may cause this lack of market responsiveness. Based on their assumptions for efficient markets, Gwartney and Stroup (1982) divide market failure into four classes: externalities; public goods; conflicts between buyers and sellers after an exchange, stemming from poor information or misrepresentation; and monopoly. Most of these factors may also contribute the unresponsiveness of timber supply to prices.

Externalities are costs or benefits that are not reflected in the market prices. They occur when the activities of one person affect the welfare of other persons who have no direct means of control over those activities, whether it be in production, consumption or exchange (Hirshleifer 1984). Externalities may occur among individuals and firms at a given point in time or over long periods of time.

In the case of timber supply externalities, those that occur over time are most relevant. Since the independent decisions that generate prices are made by individuals whose life spans are brief, prices may not provide an adequate incentive for decisions with long-lived consequences (Randall 1981). This implies that the discount rate for individuals may be greater than that for society; i.e. they will produce less timber and other long-term products than society may deem desirable. Timber rotations usually exceed 20 years, even in the South, and are at least 50 or more years in the West. Expecting private forest landowners to make investments from which they will never see returns is optimistic, no matter how financially or socially desirable such investments may be. In addition, many private forest landowners lack the personal capital or ability to borrow for needed regeneration.

Based on the economic assumption that productive activity and personal reward be closely linked, timber production may be considered a collective good—goods that once produced, would be available to anyone to use, whether or not they paid for production. Waiting for years or even decades to receive investment rewards is not a close linkage. Thus, markets may not entice as much timber production as may be desirable. Or at the least, they may not lead to production of enough desirable species of appropriate age classes. Instead, default forest management will occur, yielding only noncommercial fiber.

Imperfect knowledge may also contribute to underproduction of timber, particularly on the part of nonindustrial private forest (NIPF) landowners. NIPF timber producers are apt to be largely unaware of the value of the goods they are producing. First, they may not realize that returns to forestry investments could be quite attractive, so fail to grow timber. Second, some producers (nonindustrial private landowners)
are likely to know very little about the quantities or the prices of the timber they grow. In fact, many probably don't even know what a board foot is, let alone how many they have "standing on the stump," or what the going per unit price of "stumpage" is. On the other hand, timber buyers make purchases regularly, and are usually either foresters or loggers who can estimate stumpage (standing timber) volumes and values with reasonable accuracy.

Corporate forest landowners may also underproduce timber because of imperfect knowledge of financial returns compared with investments in plant and equipment or because of high discount rates. Long-term timber investments often must compete with short-term equipment investments that appear to have greater rates of return, or are at least more pressing. In addition, timberlands may be looked upon as a profit center that must contribute their share to accounting-based measures of corporate returns. Thus forest products companies may liquidate inventories prematurely to satisfy corporate profit goals, or even to maximize the net present value as dictated by harvest scheduling models.

The assumption of perfect competition in timber markets is also moot. The price mechanism works best when buyers and sellers are so small that they cannot affect prices, which is commonly referred to as atomistic or perfect competition. However, modern production processes are generally rather large and firms have obvious opportunities to influence purchase or sales prices (Randall 1981). Public and private timber sellers face a related problem of imperfect competition termed oligopsony. Some markets, particularly hardwoods and southern pine sawtimber, are very competitive. But in a given market area, there are thousands of private forest landowners (producers), but probably only a few to a dozen buyers. Few buyers certainly reduces competition, and could lead to collusion (Mead 1966). Thus, timber owners could receive less for stumpage, perceive growing timber as undesirable, and invest elsewhere. Socially desirable timber supplies would be underproduced.

**IMPLICATIONS**

The empirical studies of timber supply elasticity generally do indicate that timber production is not very responsive to price changes. Data indicate that price elasticities for timber supply calculated from data for the 1960s to 1970s were generally small—0.4 or less. Elasticities for private producers in the West were much less, usually below 0.15, indicating an almost completely inelastic supply curve. Prices generated somewhat greater, but by no means spectacular, supply responses in the South. Overall, the contention that markets alone are inadequate to induce increased supplies seems reasonable. Short run responsiveness is very inelastic, which helps contribute to the volatility in the stumpage (and lumber) price markets. Most studies also indicated that demand was inelastic, which would exacerbate market volatility. Lastly, while supply price elasticities were small, they were at least significant in recent decades. One would suspect that they were virtually nonexistent in the first half of the century when prices were exceedingly low in nominal and real terms.
Neoclassical economic theory suggests that free markets should automatically produce an adequate amount of timber, or other products, assuming the underlying assumptions are met. However, few of the assumptions are met well in the case of timber. Externalities between generations, and perhaps even among present producers, are apt to reduce production by individuals. The productive activity of growing timber and the financial reward of growing timber are simply not closely linked, which probably reduce supply elasticity of price for industrial and nonindustrial owners. Nonindustrial private owners fall far short of the perfect knowledge about timber growing and competition in many areas of the country is weak. All of these factors probably help explain the inelastic price response of timber producers.

Nevertheless, even if the supply (or demand) curve is inelastic, markets will still equilibrate supply and demand through the price mechanism. Inelasticity may cause real prices to rise significantly if the demand curve shifts out or the supply curve shifts back. Similarly, it may cause rapid price drops if the reverse were to occur. In general, timber markets have been extremely volatile, as would be suggested by the findings of an inelastic supply. In addition, timber prices have historically increased in real terms for at least a century (Manthy 1978a, Skog and Risbrudt 1982).

CONCLUSIONS

So far, this paper has avoided the discussing what "adequate" timber supplies are. But this is the crux of the question regarding timber supply and public policy. Some people believe that adequate timber supplies are simply the amount of wood provided by the market at equilibrium prices. Others are inclined to believe that market processes simply do not produce enough wood at reasonable prices, particularly of the most desirable commercial species. Considerable debate has occurred regarding which of these value beliefs should dictate policy.

Skok and Gregersen (1975) discuss four assumptions that underlie public expenditures for private forestry. Three of these apply equally well as goals for any public involvement. First, public programs assume more wood should be produced than is currently and that wood prices should not rise as rapidly as in the past. Second, nonindustrial private forests should produce more forest outputs than they do, and could do so at costs less than the benefits. Third, divergent public (social) and private costs and benefits justify social involvement. Fourth, spending funds to assist private forests is more efficient than spending funds on public forests.

Each of these assumptions is a mix of values and economic efficiency. Free market advocates might question the wisdom of wood for wood's sake and of preventing rising real prices. In addition, they could likely care less if private (or public) forests could economically grow more wood. Eventually, markets would equilibrate available supply and demand by substituting other resources for scarce, expensive wood. However, the public and the forestry profession have generally accepted the values implicit in the goals of ensuring adequate timber supplies.
and preventing rising real prices. Duerr (1981) suggests that all we need to support public programs is the belief that wood has value and will prove useful in the future. In practice, such beliefs are important in public policy, but not sufficient.

Divergent private and public costs suggest market failures such as public goods (unpriced values), or externalities (inter-temporal or present-day). Such problems seem likely in forestry, and public assistance programs or regulation are compensating responses that have been used. In fact, even establishment of the national forests was based largely on the perception that timber cutters were needlessly destroying timber that would be needed by future generations.

The last assumption, that of investments in nonindustrial private forestry being more efficient than those in industrial or public forests is debatable, but academic. If the first two assumptions hold, the only realistic political alternative for increasing wood output is guidance and assistance to private forest landowners. National forest timber supplies are constrained by sustained yield, multiple use legislation that will prohibit large incremental additions to supply. Additional public support for industrial forestry is unlikely. If additional timber (or other forest) resources are to be forthcoming, nonindustrial private forests must be the source.

The degree of public policy involvement deemed desirable in timber production probably depends on one's beliefs about the severity of the supply problem. Economic theory and empirical forestry studies indicate that inelastic timber supplies are likely to create volatile markets and probably contribute to rising real prices, particularly if significant declines occur in the resource inventory.

As Manthy (1978b) concluded years ago, if rising real prices and price volatility are not considered pernicious, there is no problem. If they are, there is. Who is receiving the benefit of rising prices and who is paying the costs may influence one's viewpoint. Rising prices may reduce the comparative advantage of forest products, thus causing the loss of firms, jobs, and value added from the forestry sector. On the other hand, forest landowners are apt to reap greater profits from timber growing if prices rise in real terms. In any case, empirical studies have shown that market prices do not induce much incremental timber supply. It will continue to be up to public policymakers to decide if public programs are necessary to improve market outcomes, and if so, the nature and extent of those programs.
LITERATURE CITED


