THE PUZZLE OF INDUSTRIAL TIMBERLAND OWNERSHIP

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Abstract: Although there exist many arguments for forest products and paper companies to hold timberland, none of them examine land ownership in the context of overall business operations. After exploring the basic features of the industry, we construct a model to quantify the entry threshold and the value of an investment project. Treating the output price as a stochastic process, we find that values of an investment project and its associated option are stochastic differential functions of output price drift and volatility, the scale of the investment, the degree of the irreversibility of the investment, and other parameters. A numerical example shows that by altering the composition of fiber sources from fee land and open market, land ownership can improve a firm’s investment position in different ways.

Introduction

Of the 490 million acres of timberland in the United States, forest products and paper companies own about 70 million acres, or 14.5 percent of the country’s total (Powell et al. 1994). From this land, however, companies contribute over 32 percent of the total annual timber removals. It is estimated that about 62 percent of the total industrial holdings belongs to the 16 large companies with timberland greater than one million acres (Yin et al. 1996).

A fundamental question regarding this ownership pattern is why almost all major forest products and paper companies hold timberland rather than just relying on open market purchases? The primary reason is believed that land ownership ensures a ready timber supply for their conversion facilities at controlled costs (Hungerford 1976, Ellefson and Stone 1984). This notion has been echoed by financial analysts (Clephane and Carroll 1982) and reinforced by companies in the wake of recent federal forest land set asides in the Pacific Northwest (see, for example, Boise Cascade’s and Weyerhauser’s 1994 annual reports). Zinkhan et al. (1992) also pointed out that forest products and paper companies can rely on their own timberland to help stabilize earnings. This is because harvesting fee land timber can result in a net gain, even in a poor stumpage market, so that these receipts can serve to prop up earnings.

Tax advantages and good rates of return have also been mentioned as justifications for industrial timberland ownership (Ellefson and Stone 1984). However, following the Tax Reform Act of 1986, the tax advantage argument is no longer as valid. This is because the capital gains tax rate on appreciated values of timber is now the same as that of regular income for a corporation. As to the rates of return from timberland investments, they can be favorable in certain circumstances but also may be relatively low (Zinkhan et al. 1992, Forest Investment Associates 1996). Regardless of how

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favorable they are, however, the rates of return are insufficient to explain the near across-the-board timberland ownership by major forest products and paper companies.

Although separate justifications for companies to hold timberland have been put forth, some of which are intuitively appealing, previous analyses have failed to thoroughly examine these justifications in the context of overall forest business operations by treating timberland holdings as an integral part of these activities. Further, these analyses have not given rise to a coherent explanation of the size or degree of individual industrial timberland ownerships. As a result, we still do not have a good understanding of how land holdings can result in raw material security, whether and to what extent costs can be saved through ownership, and what the relationship between wood self-sufficiency and business performance is.

In this paper, we attempt to offer an operationalized theory for industrial timberland ownership. The next section explores the underlying features of the forest products and paper industry. These features include substantial initial investment, high degree of asset specificity, unusual market cyclical, and strict cash flow requirements. Section 3 transforms the basic ideas articulated in Section 2 into a rigorous modeling framework. Treating output price as a stochastic process, we find that the value of an investment project in the industry and the value of its associated option are stochastic differential equations of the price parameters as well as other variables. Therefore, changes in these parameters and/or variables will result in shifts in both the project and option values. We show that by altering the composition of fee land and open market fiber sources, land ownership can result in a higher project value and a lower investment threshold under given market volatility and investment requirements. These modifications make operations more attractive in terms of cash flow stability, cost containment, and alleviation of price downturn pressures, improving a firm's competitive position. Finally, some concluding remarks follow in Section 4.

**Characterizing the Wood-Based Manufacturing Industry**

Firms in the forest products and paper industries are quite diversified and offer a wide range of conditions. For the purpose of exposition and to facilitate discussion, we will concentrate our attention on the pulp and paper manufacturing sector throughout the remainder of this paper. It should be noted that even though some of the following characteristics may not fully apply to solid wood sectors, especially the lumber industry where a number of small sawmills exists, many large firms are highly integrated in the sense that both solid wood and paper products are produced. As discussed above, it is these large firms that hold most of the industrial timberland. Also, the pulp and paper sector (SIC 26) dwarfs the wood processing sector (SIC 24).

From an investment perspective, businesses in the wood-based manufacturing industry shares four important features:

1. **Substantial Capital Requirements**—It is well-known that the technology in the pulp and paper industry is characterized by economies of scale. Mills in the woodpulp and in the paper and paperboard sectors with annual production greater than 300,000 tons account for 75 percent and 58.5 percent of industry capacity, respectively (Pulp and Paper 1994). In order to achieve these economies of scale, however, a substantial initial investment is required to get a modern mill online. The current cost estimate for building a model paper or paperboard mill is about $500 million (Papermaker 1995). In the linerboard sector, a kraft mill with a capacity of 1,300 tons per day requires an initial investment of either $520 million for furnish consisting of 25 percent recycled fiber and 75 percent unbleached kraft, or $585 million for furnish consisting of 100 percent virgin fiber (Null 1995).
Assuming a 17 year mill life and a straightline depreciation schedule, the annual capital cost of such a mill is $30.6-$34.4 millions.

2. High Degree of Asset Specificity—The pulp and paper industry is also notorious for its high degree of asset specificity. The degree of specificity of an asset is defined to be the fraction of its value that would be lost if it were excluded from its major use (Milgrom and Roberts 1992). Pulp and paper mills are established for pulp and paper production. Outside of their specific uses of manufacturing pulp and paper, plant and equipment lose much of their value. Therefore, once set up, they will continue to be employed for their designed purposes. Of course, if markets for their outputs were always favorable, then investing in these specific assets might even be preferred because specialization can enhance productivity and profitability. However, since pulp and paper markets are highly cyclical, their designed manufacturing operations must be sustained even when prices are severely depressed because the likelihood of switching to other uses is very small. Further, temporary mothballing does not obviate the substantial fixed costs as well as suspension and maintenance expenses which must be incurred. As a result, mills continue their operations as long as the potential losses are less than the sum of fixed costs and other expenses associated with temporary shutdown.

High capital requirements and asset specificity underscore the lack of reversibility and flexibility in the operation of pulp and paper mills. This in turn makes the sector vulnerable and sensitive to stochastic market conditions.

3. Unusual Market Cyclical—In general, pulp, paper, and paperboard prices are highly cyclical. As shown in Figure 1, these prices, though rising at a faster pace from the late 1980s, present more volatility than does the price index for all industrial commodities. Driven by business cycles, pulp and paper prices tend to decline in economic recessions and rise during recoveries. Strong competition and the irregular pattern of capacity expansion often exacerbate price fluctuations, resulting in wide market swings (Pulp and Paper 1995). While there are few financial concerns during boom periods, other than reaping as much profit as possible, during slack periods prices can be so low as to cause either a substantial profit margin squeeze or an inability to cover even production costs. For example, Table 1 suggests that in the linerboard sector, while market upturns can lead to pretax profit margins greater than 25 percent of sales price, downturns can cause prices to drop close to the cost of manufacturing and delivery for an average southern mill. Thus, while economic recoveries give a mill’s management a lift, recessions place substantial pressures on it. Therefore, maximization of profits during boom periods and minimization of losses during recessions are two equally important concerns for management to address in the long-run.

4. Stabilized Cash Flows—Because corporations are owned by stockholders, profit maximization often takes the form of stock price maximization. The degree to which this occurs hinges on a number of factors. Chief among these factors is a stabilized cash flow, but market volatility makes this task especially difficult to accomplish. If earnings change dramatically and the management cannot avoid sharp business downturns, then this poor performance will result in: 1) risk-averse stockholders requiring a higher premium for holding the stock, 2) stockholders being less likely to receive steady dividends, and 3) inadequate retained earnings for normal maintenance and/or upgrading expenditures. High risk premiums, low expected returns, and insufficient reinvestment can discount a firm’s share price to such an extent that the management may never fulfill stockholders’ objectives (Bingham 1992). Worse, the manager’s status will be hurt under incentive contracts which link management’s rewards with the firm’s performance.
Figure 1. Price indices (1982 = 100).

A manager facing these constraints has many options that he can pursue. During down cycles, he can lay off employees, reduce R&D and maintenance spending, and even liquidate assets. Though effective for temporary cost containment, these steps often entail negative strategic consequences. On the other hand, recognizing the nature of the business, the manager may become overly hesitant in undertaking long-term expansion and market positioning, even when there exist promising opportunities. Another option is the ownership of certain types of production factors, which often occurs through process integration. For example, facing ever-higher energy costs, the pulp and paper industry has turned to self and cogeneration of energy. Cogeneration and onsite power plants now meet more than 56 percent of its own needs. It has been claimed that through cogeneration, overall energy costs have been kept relatively steady over the past decade despite wide fluctuations in energy prices (Pulp and Paper 1994). Self-generation also means that direct cash outlays are reduced through lower fuel cost expenditures. This can help combat cash drain when gross revenues are weak, and increase profit margins overall.

Timberland ownership functions in a similar fashion. First, the investment in timberland comes from long-term capital accumulation. Unlike buying on the open market, the mill does not need to make cash payments for its own timber once the fee land is under its control. In an uncertain environment, this helps to maintain secure fiber flows and steady streams of earnings. Ownership also opens the opportunity for timing timber procurement and saving fiber costs. In strong stumpage markets, the firm can harvest from its fee land rather than buying from the market, obtaining high rates of return. However, because strong stumpage demand comes in the wake of strong final product demand, the
Table 1. Manufacturing cost and profitability for an average southern linerboard mill (Nominal $ per short ton).

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Average price</td>
<td>320</td>
<td>274</td>
<td>295</td>
<td>361</td>
<td>403</td>
<td>405</td>
<td>380</td>
<td>336</td>
<td>344</td>
<td>311</td>
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<tr>
<td>Fiber</td>
<td>113</td>
<td>106</td>
<td>98</td>
<td>103</td>
<td>107</td>
<td>114</td>
<td>118</td>
<td>120</td>
<td>124</td>
<td>128</td>
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<tr>
<td>Energy</td>
<td>34</td>
<td>32</td>
<td>24</td>
<td>24</td>
<td>23</td>
<td>23</td>
<td>25</td>
<td>25</td>
<td>26</td>
<td>26</td>
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<tr>
<td>Labor</td>
<td>35</td>
<td>35</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>37</td>
<td>38</td>
<td>39</td>
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<td>41</td>
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<tr>
<td>Chemicals</td>
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<td>15</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>16</td>
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<tr>
<td>Other</td>
<td>17</td>
<td>17</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>18</td>
<td>19</td>
<td>19</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Delivery</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>33</td>
<td>34</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>Interest</td>
<td>15</td>
<td>17</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Overhead</td>
<td>15</td>
<td>15</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Depreciation</td>
<td>21</td>
<td>23</td>
<td>24</td>
<td>25</td>
<td>26</td>
<td>28</td>
<td>30</td>
<td>31</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Total costs</td>
<td>299</td>
<td>292</td>
<td>278</td>
<td>283</td>
<td>292</td>
<td>306</td>
<td>319</td>
<td>323</td>
<td>329</td>
<td>334</td>
</tr>
<tr>
<td>Pretax profit</td>
<td>21</td>
<td>-18</td>
<td>17</td>
<td>78</td>
<td>111</td>
<td>99</td>
<td>61</td>
<td>13</td>
<td>15</td>
<td>-23</td>
</tr>
</tbody>
</table>

Source: Adapted from Pulp and Paper (1994).

A firm may opt to buy from the outside market when prices of final products are high. On the other hand, if a firm can harvest from its fee land during downturns, then it will be relieved from extreme cost reduction pressures. Depending on the degree of self-sufficiency, in any period, millions of dollars could be saved. Even if the firm suffers from a lower rate of return from its timberland investment in this circumstance, it could still generate a sizable return for financing its overall operations, including even expansion expenditures as well as dividend payments. As a result, stockholders may maintain sufficient confidence in the firm's performance.

In contrast, if a firm buys timber from the open market when its output market is weak, then it must take up an additional amount of cash costs for fiber consumption. This may completely erode profit margins or even result in a net loss. Worse than small or no dividends, stock prices may fall due to the fear of the firm's uncertain future. Finally, timber produced from fee land can also function as a leverage for stabilizing stumpage prices. That is, when stumpage prices are high, a firm can switch to harvest more from its fee land as a means to prevent sharp market price runs.

An Investment Modeling Framework

In the last fifteen years, much research progress has been made in explaining investment behavior and assessing investment opportunities by explicitly incorporating various investment features into the analytic framework. These features include factors such as uncertainty, irreversibility, and option which we identified above. Works by Dixit (1988), Pindyck (1991), and McDonald and Siegel (1985), are representatives of this growing body of literature in the field. This literature is well synthesized in Dixit and Pindyck's (1994) book, entitled Investment under Uncertainty, which offers us guidance in formulating our analytic structure. A limitation of Dixit and Pindyck's method is the assumption that the operation of a project can be costlessly temporarily suspended when output price $P$ falls lower than variable cost $C_v$ (or $P < C_v$), which forces the profit to zero. However, this assumption is quite restrictive since it understates the consequences of production suspension.
We know that in reality, setting up a project involves an initial investment, \( I \). Then, a stream of fixed costs, \( C_f \), which are the depreciated annual values of \( I \), must be incurred regardless of the operation of the project. Suspending the operation also entails shutdown and maintenance costs \( M \). For the pulp and paper industry, these costs—the fixed costs, the shutdown costs, and the maintenance costs—are too substantial to be ignored. As such, an appropriate expression for the profit from a mill in the pulp and paper sector is \( \pi = P - C_v - C_f \), when it operates; or \( \pi = -C_f - M \) when it is suspended. The operation will not be shut down as long as \( P - C_v - C_f > -C_f - M \), or \( P > C_v - M \).

In the following theoretical and empirical analyses, we use a linerboard mill as our example. Since the capacity for such a mill is relatively fixed once it is set up, it is reasonable to normalize the mill’s output to one unit per year, so that we can take linerboard prices over time as a stochastic variable following a geometric Brownian motion:

\[
dP = \alpha P dt + \sigma P dz
\]  

where \( \alpha \) and \( \sigma \) are constant drift (or trend) and standard deviation of the prices, and \( dz \) is a Wiener process. At any instant, the profit flow \( \pi(P) \) from the mill is given by:

\[
\pi(P) = \max[P - C_v - C_f, -C_f - M]
\]  

Then applying Ito lemma and manipulating (Dixit and Pindyck 1994), the stochastic differential equation for the (net) value of mill \( V(P) \) can be expressed as:

\[
\frac{1}{2} \sigma^2 P^2 V''(P) + \alpha PV'(P) - rV(P) + \pi(P) = 0
\]  

where \( V' \) and \( V'' \) are the first and second order derivatives of \( V(P) \) with respect to \( P \), and \( r \) is the discount rate.

Because \( \pi(P) \) is defined differently when \( P < C_v - M \) than when \( P > C_v - M \), equation (3) must be solved separately first and then the solutions be stitched together at \( P = C_v - M \) to find \( V(P) \). In the region \( P < C_v - M \), \( \pi(P) = -C_f - M \). The general solution to \( V(P) \) is just a sum of the solution of the homogeneous part, which is a linear combination of the two power functions of \( P \) corresponding to its two roots, and a particular solution of the nonhomogeneous part:

\[
V(P) = K_1 P^{\beta_1} + K_2 P^{\beta_2} - (C_f + M)/r \]  

with \( \beta_1 = \frac{1}{2} - \alpha/\sigma^2 + \sqrt{[\alpha/\sigma^2 - \frac{1}{2}]^2 + 2r/\sigma^2} > 1 \), \( \beta_2 = \frac{1}{2} - \alpha/\sigma^2 - \sqrt{[\alpha/\sigma^2 - \frac{1}{2}]^2 + 2r/\sigma^2} < 0 \), and \( K_1 \) and \( K_2 \) are constants to be determined. Note that \( r > \alpha \) for the mill’s possible operation.

Although a sum of fixed costs and expenses associated with mothballing must be incurred when production is temporarily suspended, there is a positive probability that the price process will, at some future time, move into the region \( P > C_v - M \). In that case, production will resume so that the value

\[\text{It should be noted that here, maintenance cost takes a different meaning from that related to normal operation. In the latter case, the expenses are included in material cost.}\]
$V(P)$ when $P > C_v - M$ is just the expected net present value of such future flows. We also know that as $P$ becomes very small, the possibility of its rising above $C_v - M$ becomes increasingly unlikely, except perhaps in the remote future. The expected net present value of future profit flows should approach $-(C_f + M)/r$, and so should the value of the mill, implying that $K_2 = 0$ given $\beta_2 < 0$. This leaves $V(P) = K_1 P^{\beta_1} - (C_f + M)/r$.

Similarly, in the region $P > C_v - M$, we take another linear combination of the power solutions of the homogeneous part and add on a particular solution of the nonhomogeneous part of the equation. It can be shown that $[P/\delta - (C_v + C_f)/r]$ satisfies the equation, where $\delta = r - \alpha$. Thus, the general solution becomes: $V(P) = D_1 P^{\beta_1} + D_2 P^{\beta_2} + P/\delta - (C_v + C_f)/r$, where $D_1$ and $D_2$ are constants to be determined. Since the term $[P/\delta - (C_v + C_f)/r]$ represents the net worth of the production, the other two terms must be the additional value of the option to suspend production in the future should $P$ fall below $C_v - M$. Further, note that when $P$ becomes very large, the likelihood of suspension is very small, so its option value should be negligible. For this we set $D_1 = 0$ to rule out the positive power of $P$.

Then we are left with:

$$
V(P) = \begin{cases} 
    K_1 P^{\beta_1} - (C_f + M)/r & \text{if } P < C_v - M, \\
    D_2 P^{\beta_2} + P/\delta - (C_v + C_f)/r & \text{if } P > C_v - M.
\end{cases}
$$

To determine $K_1$ and $D_2$, let us consider the boundary $P = C_v - M$ where the two regions meet. Let $C = C_v - M$ and equate the values and derivatives of the two component solutions at $P = C$, we have $K_1 C^{\beta_1} - (C_f + M)/r = D_2 C^{\beta_2} + C/\delta - C/r \beta_1 K_1 C^{\beta_1 - 1} = \beta_2 D_2 C^{\beta_2 - 1} + 1/\delta$. Solving these two linear equations in the unknowns $K_1$ and $D_2$ we obtain:

$$
K_1 = \frac{C^{1-\beta_1}}{\beta_1 - \beta_2} \left( \frac{\beta_2}{r} - \frac{\beta_2 - 1}{\delta} \right)
$$

$$
D_2 = \frac{C^{1-\beta_2}}{\beta_1 - \beta_2} \left( \frac{\beta_1}{r} - \frac{\beta_1 - 1}{\delta} \right)
$$

Since the term in $K_1$ captures the expected profit from the option to resume production in the future, and that in $D_2$ the value of future suspension options, both constants should be positive. For that, we need $r < \beta_1 (r - \delta)$ and $r > \beta_2 (r - \delta)$.

After obtaining the value of the mill, $V(P)$, we also need to find the value of the option to invest in the mill, $P(P)$. This is because, according to the options approach (Dixit and Pindyck 1994), options to an investment (e.g., timing, scale, and location) are valuable when the decision to invest is made in an uncertain world, and it becomes irreversible once it is made. Keeping options open means flexibility. A lost option gives rise to an opportunity cost that must be included as part of the investment cost. Therefore, there exists an option value associated with any investment project.
Going through the same steps as in the previous section, we have \( F(P) = A_1 P^{\beta_1} + A_2 P^{\beta_2} \), where \( A_1 \) and \( A_2 \) are constants to be determined. At the absorbing barrier \( P = 0 \), \( F(0) = 0 \), such that \( A_2 = 0 \) and \( F(P) = A_1 P^{\beta_1} \).

At the optimal point, \( P^* \), where the investor exercises the investment option, we have the "value-matching" and "smooth-pasting" conditions. The former requires that at the investment threshold \( P^* \), the owner of the option is indifferent between making the investment to receive a net payoff \( V(P^*) \) or holding the option worth of \( F(P^*) \), and the latter requires that the two curves \( V(P^*) \) and \( F(P^*) \) to meet tangentially at \( P^* \).

However, these conditions only can be satisfied in the operating region where \( P > C \). Consequently, we have:

\[
A_1 [P^*]^{\beta_1} = D_2 [P^*]^{\beta_2} + P^*/\delta - (C_v + C_f)/r \tag{7}
\]

\[
\beta_1 A_1 [P^*]^{\beta_1-1} = \beta_2 D_2 [P^*]^{\beta_2-1} + 1/\delta \tag{8}
\]

Substituting \( D_2 \) from equation (6) and eliminating \( A_1 \) from equations (7) and (8) gives us the following optimal investment rule:

\[
(\beta_1 - \beta_2 D_2 [P^*]^{\beta_2} + (\beta_1 - 1)P^*/\delta - \beta_1 (C_v + C_f)/r = 0 \tag{9}
\]

Equation (9), which is easily solved numerically, gives the investment threshold \( P^* \).

Before we turn our attention to a numerical illustration, several points should be made. First, the investment characteristics for the industry discussed in the last section are incorporated in the value function of the project, \( V(P) \), of equation (4). We find that as usual, market dynamics (i.e., price trend and volatility) are represented through drift and standard deviation terms. In addition, fixed costs are included to capture the effects of possible initial investments. The effect of timberland ownership on \( V(P) \) is highlighted by altering fiber supply sources and therefore the magnitude of \( C_v \). This is because cash flow equals revenues less direct outlays and using fee land timber involves less cash outlays than buying timber from the open market. Further, in conjunction with the objective of value maximization, the two branch solutions corresponding to either operation or mothballing are formulated to reflect the asset specificity and the importance of stable cash flows. Because \( P^* \) in equation (9) is determined based on the "value-matching" and "smooth-pasting" conditions, factors influencing the value of the project affect the investment threshold as well.

Finally, analytic difficulties notwithstanding, we can show numerically that there exists a unique solution for \( P^* \) such that \( V(P^*) > 0 \). That is, the project must have a net present value that exceeds zero before it is optimal to invest.

### A Numerical Example

The detailed cost and other related information for a model linerboard mill of 465,400 tons per year was adopted from Null (1995). For the case with 100 percent kraft furnish, which is used here, the
Table 2. Estimated total manufacturing costs in the linerboard sector.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (tons per day)</td>
<td>1300</td>
</tr>
<tr>
<td>Total investment ($ million)</td>
<td>585</td>
</tr>
<tr>
<td>Number of employees</td>
<td>290</td>
</tr>
<tr>
<td>Furnish: Wood (BDT/ton)</td>
<td>1.76</td>
</tr>
<tr>
<td>Fiber cost: $/BDT</td>
<td>55</td>
</tr>
<tr>
<td>Operating costs ($/ton)</td>
<td>200</td>
</tr>
<tr>
<td>Fiber</td>
<td>97</td>
</tr>
<tr>
<td>Chemicals</td>
<td>13</td>
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<td>Energy</td>
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<td>Labor</td>
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<td>Materials</td>
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<tr>
<td>Landfill</td>
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</tr>
<tr>
<td>Out-bound freight</td>
<td>13</td>
</tr>
<tr>
<td>Property tax and insurance</td>
<td>30</td>
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<tr>
<td>Sales, general, and administration</td>
<td>15</td>
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<tr>
<td>Depreciation</td>
<td>74</td>
</tr>
<tr>
<td>Total cost</td>
<td>332</td>
</tr>
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</table>

* Bone dried tons.

Source: Based on on estimated figures from Null (1995)

initial investment is $585 million. As such, the fixed cost (C_f) is $74 per ton, which is the depreciation of the initial investment calculated by applying the 17-year, straightline procedure. The sum of all other costs is the variable cost (C_v), which includes costs for fiber, chemicals, energy, labor, materials, landfill, out-bound freight, property tax and insurance, and overhead for sales, general and administration. In our example, variable cost is $258, so that the total cost (C_v + C_f) is $332 (Table 2). Of this total cost, fiber cost and capital cost are the two primary components for our interest. The former amounts to $97, or 29.2 percent, while the latter accounts for 22.3 percent. Additionally, if the mill is shut down, the annual cost of mothballing and maintenance is set at $10 per ton. This figure was derived on the basis of the actual industry experience in recent years (Pulp and Paper 1995).

We estimated the annual price drift and volatility using quarterly prices for standard kraft linerboard (42 lb) from 1979.1 to 1994.4 (Pulp and Paper 1980-95). Due to the practice of price discounting in the industry, some of the observations fall in a certain range of about $10-30 difference rather than being single-valued. To overcome this difficulty, we chose the lower bounds for these observations. The calculated $alpha$ and $sigma$ are 4.2 percent and 24.4 percent respectively. Figure 2 plots the price series and offers supportive evidence to our claim that though the nominal price growth rate is relatively high, the market is highly cyclical.

With the specification of the above original parameters, intermediate parameters $beta_1$, $beta_2$, $A_1$, $D_2$, and $K_1$ can be easily computed and we can then solve for $P_*$, $V(P)$, and $F(P)$. We present our results for $P_*$ in Table 3. Our base case shows that with stochastic market and irreversible investment, the entry threshold into the linerboard sector for an investor is $485.3 (Figure 3). This price level is much
Figure 2. Quarterly linerboard prices (1979.1 to 1994.4).

Table 3. Estimated optimal entry thresholds for a linerboard mill.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Base Case</th>
<th>I</th>
<th>II</th>
<th>Alternative Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.042</td>
<td>0.022</td>
<td>0.042</td>
<td>0.022</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.242</td>
<td>0.121</td>
<td>0.121</td>
<td>0.242</td>
</tr>
<tr>
<td>$r$</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>$C_r$</td>
<td>258.0</td>
<td>258.0</td>
<td>258.0</td>
<td>258.0</td>
</tr>
<tr>
<td>$C_f$</td>
<td>74.0</td>
<td>74.0</td>
<td>74.0</td>
<td>74.0</td>
</tr>
<tr>
<td>$P^*$</td>
<td>485.3</td>
<td>408.1</td>
<td>385.7</td>
<td>515.5</td>
</tr>
</tbody>
</table>
higher than not only that of the break-even price in a static world—$332 (the sum of variable and fixed costs) but also recent market prices. This helps to explain why the industry tends to favor "minimills" with a certain percentage of recycled fiber furnish over large mills with 100 percent virgin fiber in recent capital spending plans (Null 1995). This is because the former gives rise to a generally lowered fixed cost as well as possibly lowered variable costs.

By changing various parameters ($\sigma$, $\alpha$, $r$, $C_v$, and $C_f$), we can examine alternative scenarios to gauge their impact on $V(P)$, $F(P)$, and $P^*$. We denote the resultant new curves as $V^*(P)$ and $F^*(P)$ in our figures. Because the critical entry value associated with our original price drift and volatility parameters is too large to serve as a benchmark for our comparative study, we lowered them in Case I, which indicates that if $\alpha = 0.022$ and $\sigma = 0.121$, then the entry price declines to $408$. Compared to this, Case II suggests that when the expected price growth rate increases, a rational investor will lower his/her entry threshold. Figure 4 suggests that increasing the rate of price growth leads to increased project value, which grows faster than the opportunity cost of waiting. Therefore, the optimal entry price drops.

However, as market volatility increases (Case III), investors demand for a higher entry price ($515$) to execute the investment decision. Figure 5 shows that although an increase in $\sigma$ raises the value of the project $V(P)$ due to a greater likelihood of price upturns, it results in the value of the investment option $F(P)$ (and thus the opportunity cost of investing) to shift up as well for any $P$. As a result, $V(P)$ and $F(P)$ meet at a higher $P^*$, both postponing and reducing investment. Similarly, increasing
Figure 4. Changes in $V(P)$, $F(P)$, and $P^*$ (increased price drift).

Figure 5. Changes in $V(P)$, $F(P)$, and $P^*$ (increased price volatility).
the interest rate also raises the critical price $P^*$ at which investment occurs (Case IV). This is because even though a higher $r$ implies, other things being equal, a higher opportunity cost of waiting to invest, its damping effect on the expected rate of price increase is more pronounced, shifting $V(P)$ downward. Consequently, the two value curves join at a higher price. This is illustrated in Figure 6.

Case V shows that when the cash fiber cost reduces from $97 to $68 due to partial provision of timber from fee land, then the entry threshold declines to $374. This occurs because $V(P)$ is impacted to a greater degree than is $F(P)$, resulting in a lowered $P^*$ (Figure 7). Assuming that 1.77 bone dried tons (BDT) of wood chips is needed to produce one ton of linerboard, we estimate that a cash fiber cost of about $29 per ton could be saved if 50 percent of fiber consumption is met by fee land timber and the stumpage price accounts for 50 percent of the fiber cost. Considering that the average rate of fiber self-sufficiency exhibited by pulp and paper companies falls in the range of 30-40 percent (Yin et al. 1996), it is feasible for a firm to provide 60 percent of its total fiber requirement from fee land for a limited period of time. The assumption that the stumpage price accounts for one-half of the fiber cost is based on stumpage and delivered wood prices reported in Timber-Mart South (1994). This means that the other half consists of harvesting and hauling costs. Consequently, an additional annual cash savings of more than $13.5 million is generated. To a company under market pressure and debt obligation, this cash savings flow would be substantial and welcome.

Finally, Case VI suggests that if the capital intensity could be lowered from $74 to $59.3 per ton, then the entry threshold declines to $387.2. Reduced capital intensity means lower fixed costs, whereas reduced cash fiber outlay means lower variable costs. Thus, they cause the investment threshold to be reduced in different ways. This is because fixed cost are sunk and thus must be incurred regardless of operation, but variable costs only occur when the mill is operating.

**Discussion and Conclusions**

The characteristics of the wood-based manufacturing industry influence firms' investment and operation decisions. In the pulp and paper sector, markets are cyclical, capital expenditures are intensive, and assets are specific. These factors lead to higher entry thresholds and lower project values. Further, they make it difficult to maintain sound business performance and stable cash flows. Therefore, investors must give these factors and their effects adequate consideration when they decide whether, when, where, and how to enter the industry. Similarly, managers must be sophisticated in the ways they assess risky operations when deciding how to run a project. Otherwise, as the history of the forest products and paper industry tells, poorly calculated decisions can result in severe financial consequences (Miller Freeman Inc. 1995).

The choice of timberland ownership and related fiber supply strategy can increase project values and lower investment thresholds under various market and investment settings. To sum up, fee land facilitates maintaining a secure fiber supply on the physical side and a steady cash flow on the monetary side. It also allows the possibility of fiber portfolio management, timing procurement, and cost saving, and controlling prices of various fiber components. Surely, these opportunities associated with timberland ownership can improve a mill or company's business performance. These findings are consistent with the evidence in Binkley and Washburn (1993).

All these considerations imply that it is invalid to solely evaluate an industrial timber asset based on its rate of return. Its contribution to the overall performance should be acknowledged, and its management should be viewed as an integral part of the overall business operation. However, this does not mean that a low rate of return from the timber asset is necessarily justifiable. Further, this does not imply that the current holding and management patterns are necessarily efficient. Because
Figure 6: Changes in $V(P)$, $F(P)$, and $P^*$ (increased interest rate).

Figure 7. Changes in $V(P)$, $F(P)$, and $P^*$ (reduced fiber cost).
cheap timber resources were largely available in the past, some firms may not have taken a very
careful look at the choice of timberland ownership (Pulp and Paper 1994). But those days appear to
be in the past. Recent price dynamics have indicated that fiber markets are tightening up so that the
management of industrial timberland warrants serious attention and effective effort.

It should be pointed out that fee land is only one part of the fiber supply portfolio, and the effect of
timberland holding alone is limited. Given technological and market changes, corporations now
substitute more recycled fiber for virgin fiber, more hardwood fiber for softwood fiber, and more chips
and other residuals for raw wood. They also attempt to turn out more outputs with less fiber inputs.
In addition, industrial plantation management is becoming more intensive and expanding to a larger
scale. As these developments go further, it becomes more important for companies to adopt the idea
of portfolio management in their fiber supply—when, where, and how to acquire what fiber? What is
the composition of different fiber components? And how this portfolio construction can be altered
based on market and production conditions to achieve efficient supply?

Among timber land management, land size, quality, location, management regime, harvest timing, and
control of non-fee land are some of the major factors to consider. Of course, the issue here is not
whether companies have practiced portfolio management in their fiber supply (as well as overall
business activities). Rather, it is whether they have been doing so effectively. An inevitable question
of portfolio management of fiber supply is how much timberland should be owned? Since the specific
answer to this question relies on the industry segment, market conditions, company strategy, and
manufacturing, delivery and capital cost structure, among other things, we decided to deal with it in a
separate paper.

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