Does Market Concentration Motivate Pulp and Paper Mills to Vertically Integrate?[*]

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Abstract

Paper mills vertically integrate into pulp production, partly because internalizing the production of their inputs allows them to avoid transaction costs. Higher market concentration, a proxy of higher asset specificity and transaction costs, should encourage vertical integration in the pulp and paper industry. However, this relationship has not been robust in previous studies or in our replication with updated FPL-UW data. Upon a deeper analysis of the data, this study should clarify the mechanism by which transaction cost can induce vertical integration in this particular industry, which does not have well-defined intermediate goods markets. In order to specify the pulp markets where paper mills are likely to trade, we construct a mill-specific concentration measure as a substitute to traditional regional concentration measures. We also narrow our sample to mills producing free sheet paper, the most profitable paper grade in this industry. With such model refinement, this research exhibits a significantly positive correlation between transaction cost and vertical integration.

JEL Classification: C23, D23, L16, L22, L69

Key Words: Market Concentration, Transaction Cost, Vertical Integration

1. Introduction

Recent empirical studies on the determinants of vertical integration have witnessed a transition from the use of industry-level data to plant-level data (e.g., Acemoglu et al., 2004). The availability of mill-level data and the natural connection of upstream and downstream production makes pulp and paper industry ideal to study vertical integration to test economic theory (Ohanian 1994 and Melendez 2002). Moreover, the pulp and paper industry has experienced an increasing degree of vertical integration in the last century. For example, in 1900, the ratio of integrated mills to non-integrated ones was 24%, and became 29% in 1940. The ratio increased to 77% in 1970 and to 84% in 2000. Transaction Cost Economics (TCE), introduced by Williamson (1975), considers vertical integration as a way of circumventing potential holdup problems. Therefore, internalizing the production of input allows mills to avoid transaction costs.

Despite the dramatic four fold increase in the proportion of vertically integrated mills, there are very few studies about vertical integration in this industry. Ohanian (1994) studies the historical pattern of vertical integration in the pulp and paper industry using data from 1900-1940. In line with TCE, Ohanian finds that the vertical integration of pulp and paper production is positively associated with regional concentration, an indicator of transaction cost. Melendez (2002) uses new data from 1970-2000 from the same data sources Ohanian used to investigates the factors that influence the decision of a paper mill to integrate into pulp production, but cannot find the same results.

In this study, we investigate vertical integration in the pulp and paper industry, using a new data set from the Forest Products Laboratory in collaboration with the University of Wisconsin (FPL-UW). The FPL-UW data record detailed capacities and other information of individual mills in the United States from 1970 to 2000.

The pulp and paper industry has experienced a rapid evolution after the World War II. Due to improved transportation and globalization, the pulp market that each paper mill can access to has greatly extended. Therefore, it is important to find the actual market for each paper mill so that transaction costs can be measured more accurately. Our approach is to define mill-specific markets, in which paper mills are more likely to trade, to replace the traditional regional markets; and then to construct a mill-specific market concentration to measure transaction costs.

On the other hand, it is possible that the economic relationship between vertical integration and transaction costs has changed, relative to other technological economies. In order to test this possibility, we also estimate models for the paper grades that are likely to be most affected by transactional costs. There are several paper grades in the industry defined by end uses and production processes. The integration patterns may differ in their production. More specifically, free sheet is used to produce printing and writing paper, and is rather expensive compared to other grades of paper. Thus, it may be economical to use market pulp in free sheet production. In this case, technological economies may not dominate transaction-cost economies as in some other paper production.

This paper is organized as follows. Section 2 introduces the standard transaction cost economics on vertical integration, and Section 3 presents a brief review of the literature that discusses vertical integration in the pulp and paper industry. Section 4 introduces our dataset. Section 5 estimates with a cross-sectional model in previous studies. Section 6 refines our model by investigating the definition of pulp market and a basic sample. Sections 7 and 8 estimate a model using panel data and check the robustness with various specifications. Section 9 concludes.

2. Data

The data are from the United States Department of Agriculture (USDA) Forest Service, Forest Products Laboratory (FPL), in collaboration with the University of Wisconsin-Madison (FPL-UW hereafter). The data contain annual production capacity for all mill locations in the United States from 1970 and 2000, including company name, the city and state located, and ZIP code. The information on capacity is very detailed and is differentiated by process type for each product category, such as using recycled fiber or woodpulp, and integrated chemical pulp or market chemical pulp.[1]

The term "integrated" in the FPL-UW data means that papermaking capacity is combined with pulping capacity at the same facility or mill location. Paper and paperboard are downstream goods ("paper and paperboard" will be referred to as "paper" in the following discussion unless otherwise specified), and pulp is upstream or intermediate goods.

Because *Lockwood's Directory* includes estimates for pulp capacity, Ohanian (1994) and Melendez (2002) define a paper mill as vertically integrated if pulp capacity is a positive value. The FPL-UW data do not have information on pulp capacity, but instead report the sources of pulp used in the paper production. We can identify integration status for each paper category based on whether the production utilizes integrated pulp. A paper mill is defined as non-integrated if it only uses market chemical pulp. For example, a free sheet mill is defined as integrated if it uses all or some integrated chemical pulp,

[1] The product in the pulp and paper industry is divided into three broad commodity groups: paper, paperboard, and market pulp. The paper group includes eight conventional categories: newsprint, four categories of printing and writing paper (uncoated free sheet, coated free sheet, uncoated groundwood, and coated groundwood), tissue and sanitary paper products, unbleached kraft paper, and other specialty packaging and industrial paper products. The paperboard group includes four conventional commodity categories: linerboard and corrugating medium, solid bleached board, and other recycled paperboard. Market pulp is produced at one location and sold to industrial users at another location or exported. It primarily includes hardwood and softwood kraft market pulp, deinked market pulp based on recycled fiber, and relatively small amounts of bleached chemithermomechanical market pulp (CTMP) and cotton linter pulp. For more details, see Ince et al. (2001).

because it will need to have chemical pulping capacity to produce integrated pulp. In our definition, vertically integrated mills include those use entirely integrated pulp or a combination of integrated pulp and market pulp. Moreover, for a paper mill, if the pulp is supplied internally by a pulp mill that belongs to the same owner, then this paper mill is also defined as integrated because it does not entirely use market pulp.[2] Therefore, our definition of VI is based on ownership and technical integration, not necessarily the integration at the same production site.

In order to compare the data, we present descriptive statistics in Table 1, in comparison with the statistics from Melendez (2002), which is based on the same data sources as Ohanian's and covers the same time period as our data. As can be seen in the table, the descriptive statistics on vertical integration are similar.[3] In this study, recycled pulping is viewed as non-integration because it is very different from wood pulping process.

3. Vertical Integration in the Pulp and Paper Industry

In general, vertical integration can help to avoid the problems caused by market imperfection, such as supply uncertainties, government intervention, or "double-marginalization". Additionally, vertical integration can be motivated by production-cost reduction and transaction-cost reduction. Production cost can be retrenched if fewer resources are used to produce the downstream output upon integration with the upstream production process. Transaction cost, on the other hand, is incurred due to the probability of "opportunistic behavior," which may arise where specific assets are needed. Based on the TCE, the fewer the number of parties in the intermediate-goods market and the more

[2] As discussed later in the paper, such a mill must be close enough to the paper mill.

[3] The pulp used in paper production can be classified broadly into three categories: mechanical pulp, chemical pulp, and recycled pulp. Recycled pulp is different from the other two pulping process since a paper mill can purchase recycled (deinked) pulp directly from the pulp market or purchase wasted paper for in-house recycling.

specialized the assets involved in the transaction, known as "asset specificity," the higher the transaction costs.[4]

When assets become specific to a particular transaction, the firm is vulnerable to opportunistic behavior by the supplier (Klein et al., 1978).[5] Globerman and Schwindt (1986) argue that asset specificity occurs in papermaking because the salvage value for a mill or component assets is low. The fixed-proportions and continuous-process nature of papermaking also imply a greater potential loss from the interruption of input supply compared to variable-proportion or batch-process industries (Ohanian, 1994).

While asset specificity cannot be easily measured, market concentration has been used in studies to capture situations in which holdup problems are likely to occur. High concentration indicates greater potential for exploitation in market transactions, and thus the firm has greater incentive to vertically integrate. MacDonald (1985) finds that the levels of vertical integration within the manufacturing sectors are strongly associated with high levels of concentration. Ohanian (1993, 1994) investigates vertical integration in the U.S pulp and paper industry, using mill-level data from 1900 to 1940 collected from the Lockwood's Directories.[6] She finds that vertical integration of pulp and paper production is positively associated with regional concentration, paper mill capacity, and the production of standardized grades of paper. Melendez (2002) uses data for 1975 to 1995 from the same source as Ohanian to study vertical integration in the same industry. However, unlike Ohanian, she finds that vertical integration is positively correlated to paper mill capacity, the production of standardized grades of paper and forestland dummy, but negatively associated with regional concentration. Because of the contradicting result,

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[4] For example, a desktop computer can be used in many productive activities whereas a Fourdrinier machine can be used only in papermaking.

[5] As the topic of vertical integration has been popular in the domain of new institutional economics for many years, extensive literature reviews on the determinants of vertical integration can be found in recent studies, theoretical reviews such as that in Joskow (2005) and Whinston (2003), and empirical reviews such as that in Klein (2005) and Acemoglu et al. (2004).

[6] *Lockwood's Directory of the Paper and Allied Trades*, published since the 1870's.

Melendez explains that market concentration is endogenously determined in the reduced form model, and thus the estimates are biased.

4. A Cross-Sectional Model to Replicate Previous Studies

For the first step using our new data, we try to replicate Ohanian's results. The logit model is defined as

$$P(VI_i = 1) = \Lambda(\beta_0 + \beta_1 concentration_i + \beta_2 capacity_i + \beta_3 news_i + \beta_4 kraft_i).$$

VI is a dummy variable, equal to one if a paper mill is vertically integrated with the pulping process and Λ is the logistic function.[7] The type of integration is often modeled as a discrete variable: "make", "buy", or "hybrid" (Klein, 2005). In this paper, "hybrid" is defined as integrated as it still involves the pulp making process.

In the model, *Concentration*, which refers to regional market concentration, is a measure of asset specificity. Ohanian defined it as the product of the top four mill concentration ratios (CR4) for the pulp market and for the paper markets in each region.[8] The concentration is calculated based on reported mill capacities.[9] *Capacity*, the logarithm of the paper capacity of each mill, is a proxy of mill size because data such as sales or output are not available.[10] Size is another proxy of transaction cost because the frequency and volume of transaction rises with mill size. *News* and *kraft* are two

[7] A "paper mill" is defined as "a mill with positive paper and paperboard capacity".

[8] Ohanian's division of four regions is as follows: the North includes CT, DE, ME, MA, MD, NH, RI, VT, NY, NJ, PA; the Lake and Central regions include IL, IN, MI, OH, WI, IA, KS, MN, MO; the South includes FL, GA, NC, SC, VA, WV, AL, MS, TN, AR, LA, TX; the Pacific includes CA, OR, WA. The FPL-UW data include no mills in RI, but they include mill(s) in AK, AZ, CO, DC, ID, KY, MT, NM, OK. We added the states where paper mills were not located before 1940 into the four regions according to the Census division.

[9] Ohanian argues that a regional measure is appropriate because most grades of pulp and paper were traded within the producing region during her sample period.

[10] The paper capacity in Ohanian's model is measured by thousands of pounds per 24 hours. We measure the capacity of pulp and paper by thousands of short tons per year.

dummies for positive newsprint and kraft capacity. They represent the higher degree of asset specificity that results from the specialization of pulping assets so that they conform to the requirements of the papermaker (Ohanian, 1994).

Ohanian's model is estimated with cross-sectional data at ten-year intervals between 1900 and 1940. We also estimate the model at ten-year intervals using our sample. Table 2 shows the mean values of the independent variables in our model and that from Ohanian's Table 1. It appears that the pattern of vertical integration changed significantly several decades after 1940. The total number of paper mills declined considerably during the 20th century due to increased capacity of each paper machine. Because of technology advance, the average capacity of paper mill increased dramatically during the 20^{th} century. From 1900 to 2000, the average capacity for both integrated and non-integrated paper mills increased more than 29 times.

Although the number of integrated paper mills is still lower than the number of non-integrated mills, these numbers became much closer after 1970. The ratio of the capacity of integrated paper mills to that of non-integrated paper mills is also higher in our sample period, and the proportion of newsprint and kraft mills declined in the 1900-40s period and stabilized after 1970. The last row of Table 2 shows the concentration of integrated and non-integrated mills. For both types of mills, market concentration has been increasing. Also, it appears that the relationship between market concentration and the status of vertical integration between 1970 and 2000 reversed, and non-integrated mills became more concentrated.

The estimates of Model (2) are reported in Table 3. All paper mills with positive paper and paperboard capacity are included in each regression. The integration status is shown to be positively associated with mill capacity and the two dummies of specialized papermaking over our sample period, similar to those reported in Ohanian's paper. The coefficients of mill size are statistically significant in each sample year, but the coefficients of specific paper grades are insignificant in some years after the 1980s.

However, the coefficients of concentration measure are negative and significant (for most years), which clearly contradicts Ohanian's result. With the same specification but new data between 1975 and 1995 from the same data source Ohanian used--*Lockwood's Directory*, Melendez (2002) fails to obtain same result for the concentration variables too, i.e., the coefficient of concentration is also negative and significant (see Table 3.1 in Melendez).

Based on economic theory, concentration should generally promote vertical integration. According to Perry (1992), there are three main factors causing integration: technological economies, transactional economies and market imperfections. Technological economies resulting from vertical integration help to save cost by replacing some intermediate inputs with the primary input and reducing the requirements of other intermediate inputs. An example from the paper industry is the energy savings from not having to convert the dry pulp to its slush form for the paper production. Transactional economies occur when transaction costs are reduced as integration replaces market exchange by eliminating "opportunistic behavior." Market imperfection theories attribute vertical integration to avoiding costs caused by monopoly or monopsony market power, price controls, and market uncertainty. In general, higher level of market concentration should reinforce those factors. For example, higher market concentration may increase the chance of "opportunistic behavior" and market uncertainties due to fewer alternatives. As a result, higher concentration should generally cause higher probability of vertical integration.

The question therefore becomes why the same model generate different results using data from different time periods. In order to test the robustness of the result, we estimated a few alternative specifications. The first one is to replace the current concentration measure with a lagged value. Integrating pulping capacity with paper production usually takes years to complete given the long term nature of the investment in the pulp and paper industry. Therefore, the current market concentration may not

affect current status of vertical integration. Another advantage of using lagged value is that it can mitigate the possible problem of endogeity for concentration, if some omitted variables affect both current concentration and integration status. We use a three-year-lagged CR4 to estimate the model, but the results change little from the model with current concentration.

The second alternative specification is to control for the forest resources. During the first half of the century, the paper industry in the U.S. was going through a relocation process from the North towards the South by acquiring large timber tracts and constructing high-capacity pulp mills.[11] Meanwhile, many newly built pulp mills are integrated into papermaking for sustained competitiveness (Toivanen, 2004). Thus, the number of mills in the South was small and then concentration was high, but the ratio of integrated paper mills was high, and hence a positive relationship between vertical integration and concentration revealed.

After the 1970s, however, the industry settled, and the differences in market concentration across regions narrowed. In the forest abundant south, many pulp mills have been built there, which result in a low seller-market concentration. Because of the historical pattern discussed above, those pulp mills are likely to integrate into paper production. As a result, a high level of vertical integration correlates with a low level of market concentration in this area. Therefore, omitted variables that represent the level of forest resources are correlated with both market concentration and vertical integration. To control for such an effect, we added a South dummy variable to control for forest resources. Yet, the estimates for concentration variable still do not change much, although the South dummy is positive and significant for vertical integration as expected.

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[11] Toivanen (2004) details the reason as, "Rapid diffusion of kraft pulp innovations propelled industrial relocation in the North American pulp and paper industry. The cost and availability of pulp wood in traditional industrial regions was a persistent subject of debate. ..... The kraft process was the first pulping technology that could potentially utilize on large scale the vast stands of Southern pine, often characterized as 'waste,' and thus prompted managers to consider Southern strategy."

Because the expected positive effect of market concentration on vertical integration predicted by economic theories only appeared in earlier data not in the new data, we turn to refine the models by controlling for possible structural changes during the last century. For the pulp and paper industry, major changes in last century probably include i) technology advances that result in much larger capacity of an average mill, and the larger capacity may cause the dominance of technological economies in determining vertical integration; ii) improvement in transportation, which may make regional concentration less important; iii) globalization that makes concentration in domestic market less important.

5. Refinement in Specifications

A sample based on free sheet mills

Technological economies in the pulp and paper industry lies primarily in reducing costs involved in processing market pulp versus producing pulp directly at an integrated mill.[12] The cost advantage to integrated paper mills varies, depending on the structure and sales price of the final product (Zavata, 1993). The savings from integration are approximately five to ten percent of pulp manufacturing costs (Diesen, 1998). This extend of saving is significant for low value-added paper product that mainly uses mechanical pulp or unbleached kraft pulp.[13] The relatively low prices of those products make it less attractive to buy pulp from the market. Therefore, hardly any mechanical pulp or unbleached kraft pulp is sold in the market, because the added cost in drying,

[12] Typically, market pulp must be dried and baled before being shipped to the paper mill, where it has to be diluted again. In an integrated paper mill, wet pulp is sent directly to the paper machine. The elimination of the pulp-drying stage as well as the stage of converting the dry pulp to its slush reduces both investment and operating costs because a mill no longer needs for a drying machine, and saves energy and packaging material costs (Zavata, 1993).

[13] For the pulp categories, the following common divisions are used: mechanical pulp (produced by a mechanical process), chemical pulp (produced by a chemical process), semi-chemical pulp (made by a chemical process followed by a mechanical process), and other pulp (for example, deinked pulp or recycled pulp).

transportation and re-wet makes it less attractive.[14] As a result, paper grades that use mechanical pulp or unbleached kraft pulp are mostly integrated in the production due to the dominance of technological economies. For example, many newsprint and paperboard mills are able to eliminate the use of purchased market pulp because of improvements in technology.

On the other hand, the saving from vertical integration is less significant for high value-added paper. For example, free sheet paper, which accounts for all fine writing and printing paper, is produced primarily with bleached chemical pulp, with generally less than ten percent mechanical pulp content. Although the cost of chemical pulp is much higher than that of recycled pulp and mechanical pulp, free sheet paper is much more expensive, compared to other grades of paper.[15] As a result, almost all market pulp produced and sold in North America is bleached kraft pulp, which is mainly for free sheet production. Therefore, technological economies are less important for the decision of vertical integration for freesheet mills.

The dramatically increased mill capacity after 1970 has reinforced technological economies for those low value-added grades because of the savings from the economy of scale. Since technological economies are likely to dominate other factors affecting integration decisions for those grades, including those mills in the sample will not help to identify the effects of other factors in vertical integration. This may cause the different results using data after 1970 compared to that before 1940, when the economy of scale in a mill was relatively small.

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[14] In 2000, the production of mechanical pulp in the U.S. was 1,745 thousand tons compared with that of chemical pulp of 48,199 thousand tons. Import of mechanical pulp in the U.S. was as low as 437 thousand tons. In the FPL-UW data, the capacity of U.S. market mechanical pulp was zero in the nine years between 1970 and 2000.

[15] For example, coated free sheet (No. 1 grade) currently sells for about $1,500 per ton, whereas newsprint (an uncoated paper grade made from high-yield mechanical pulp, often with a very small fraction of bleached chemical pulp) currently sells for about $500. Bleached kraft market pulp costs about $300 to $400 per ton to make, so it is economical to use market pulp in coated free sheet paper, but the price of newsprint is too low to support the use of market pulp.

Therefore, we restrict our sample in two high value-added categories of paper production: coated free sheet paper and uncoated free sheet paper.[16] Free sheet mills (referred to as mills with positive free sheet capacity) need bleached chemical pulp, so they are more likely to involve a decision of whether to purchase market pulp or to produce the pulp internally.[17] In this case, factors other than technological economies may also play an important role in firm's decision of vertical integration.

Table 4 presents some summary statistics. The size of free sheet mills grew and the number decreases between 1970 and 2000. The total capacity of free sheet mills increased 145 percent between 1970 and 2000, while the number of free sheet mills decreased after 1990s. The number of firms and single-mill firms (referred to firms with one mill only) declined even faster. The proportion of vertical integration rose from 56 to 64 percent from 1970 to 2000, and the ratio of integrated capacity to non-integrated capacity gradually increased from 60 to 75 percent during the thirty years.

Reconsiderations on the pulp market

Most grades of pulp and paper were traded within the producing regions at the beginning of the 20th century, which motivates Ohanian (1994) to use a regional concentration measure. Nowadays, market pulp can be transported by sea or by rail a very long distance at much lower costs than before. The import of chemical pulp in the U.S. is equal to thirteen percent of chemical pulp production in 2000. Hence, assuming that pulp is traded only within regions may no longer be true in the second half of the 20th

[16] Coated free sheet paper generally falls on the highest value end of the printing and writing paper spectrum and used almost entirely in commercial printing applications such as annual reports, product sales brochures, or advertising pamphlets that generally demand high image quality and color printing. Uncoated free sheet paper is primarily used for producing office reprographic paper for copiers and printers.

[17] Another grade that is likely to purchase market chemical pulp is tissue. In tissue production, recycled pulp is used extensively. It is a complicated issue with regard to whether recycled pulping should be viewed as integrated or non-integrated. Generally, recycled pulping may be carried out by either de-inking recovered paper or purchasing market recycled pulp. To avoid this complication, we do not include tissue mills in our sample. For freesheet mills, the use of recycled pulp is very limited.

century.[18] Another problem for dividing the country into regional markets is that, for some mills located close to the boundary of the region, they are more likely to trade across region as they may be closer to mills in other regions. For these reasons, regional concentration measure used for the data before 1940 may not be relevant to the data after 1970.

In order to balance the cost effectiveness of trading with mills closer-by and the extended trading range after 1970, we define a mill-specific concentration measure. In particular, according to industry sources, we define a circular market for each paper mill of a 350-mile radius, in which the paper mill can purchase market pulp at lower transportation costs.[19] We refer to this market as a "neighbor market" in contrast to a "peripheral market," which includes the U.S. as well as foreign countries outside the circular area. This distance is considered the maximum transportation distance for wet-lap pulp and an effective distance of highway transportation for dried market pulp.[20] Because for some paper mills, there is no mill located within neighbor market, we have added the five closest pulp or paper mills outside the "neighbor market" in order to define the market concentration. This setup is useful, as it reflects the relative accessibility for a paper mill in purchasing market pulp.

For each mill's neighbor market, we calculated a mill-specific market concentration measure based on the Herfindahl-Hirschman Index (HHI). i.e., HHI for the buyer market (HHI-paper) and the seller market (HHI-pulp), respectively.[21] In the calculation, HHI is based on the ownership, i.e., we only include mills belong to a

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[18] One kind of pulp called "wet-lap pulp", which is not totally dried and has lots of moisture (about fifty percent), is still traded in the pulp market, albeit in small quantities. While wet-lap pulp is more cost-effective, it tends to deteriorate rapidly if it remains wet for a long time, e.g., a few days. Paper mills often use highway transportation for wet-lap pulp for its efficiency.

[19] Melendez (2002) also used concentration measures for local market defined similarly.

[20] In order to test the sensitivity, we also used other distances in our estimation. The results are not very sensitive.

[21] Since some neighbor markets do not have four firms, we do not use CR4 to measure concentration.

different firm. Thus, it accounts for the possible interlink between sister mills that belong to the same firm. As shown in Table 6, HHI-paper is lower than HHI-pulp. The concentration in both markets has been rising since 1970, resulting from industry consolidation (Li, McCarthy, and Urmanbetova, 2005). Additionally, for HHI-pulp, the difference between integrated mills and non-integrated ones are small; while for paper, integrated mills are more concentrated than non-integrated ones.[22]

In addition, market concentration may exert different effects on integration strategy for mills that have pulp mills owned by the same company in the "neighbor market" (referred to as "sister pulp mills") than for the mills that don't have sister pulp mills. In the former case, the impact of transactional economies and market imperfection should be much smaller because of the accessibility of pulp from sister mills. In order to control for this factor, we include a dummy variable for the existence of sister pulp mills in the neighbor market.[23]

Estimates

Using the new sample on free sheet mills and with the new measures on market concentration, we re-estimate the logit model of vertical integration. In the model, we use three-year lag of the concentration measure. We also include a dummy variable indicating whether a mill is located in the South in order to capture the distribution of forest resources. As discussed above, mills in south are more likely to be integrated. Additionally, we also add a dummy variable for uncoated free sheet mills to control for technological economies.[24] As usual, free sheet capacity is included to reflect mill size, a proxy of asset specificity.

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[22] Pulp mill is referred to a mill with positive market chemical pulp capacity.

[23] Another option is to define a paper mill that has a sister mill close-by as integrated one. However, it is hard to specify such a distance. We believe that a dummy variable is less restrictive to control for the impact.

[24] Coated free sheet paper uses mainly hardwood pulp.

Table 6 and 9 show cross-sectional estimates for free sheet mills based on different specifications for concentration measures.[25] In those tables, the estimates for variables other than concentration are quite robust. More specifically, the coefficient of capacity is always significantly positive, indicating the economy of scales from vertical integration. The positive estimates of uncoated free sheet dummy show evidence that the lower the paper grade is, the more likely it is to be vertically integrated due to technological economies, as is the case for other low value-added grades. The South dummy is always positively. This is because, as discussed above, in the forest abundant area, paper mills are more likely to be integrated into pulp production.

In Table 6, the interaction of HHI-paper and HHI-pulp is included as a concentration measure. Based on Ohanian, "the product of the concentration ratios at each stage is consistent with the possibility for opportunistic behavior on the part of either party once a contract is negotiated" (page 203). The concentration measure exhibits positive effects in 1980 and 1990, albeit insignificant from zero.

Generally, inclusion of only the interaction term of two regressors in a regression model is restrictive, as it rules out the possibility that the marginal effect of each regressor does not depend on the level of the other one. In a study of vertical integration based on data for all manufacture industries, MacDonald (1985) uses the HHI for the buyer and seller markets separately and finds that the concentration of the buyer and seller markets both positively correlate with the vertical integration. He also tested for the interaction of these two concentration measures, but found no strong evidence of interaction effects between buyer and seller concentration. Therefore, we also estimated models with HHI-pulp and HHI-paper with/without their interaction. However, the results are similar, and the concentration measures are not statistically significant, although they are mostly positive.

[25] The results do not include 1970 due to the use of three-year lag of the concentration measure.

As discussed above, free sheet mills with or without sister pulp mills in the neighbor market may behave differently in vertical integration. In Table 7, we add the dummy variable to indicate the existence of sister mills in the neighbor market. As expected, with a sister pulp mill near by, the incentive for vertical integration should be lower. The estimated coefficient is negative cross years, although it is statistically insignificant. However, the sign and significance for concentration measure does not change.

two coefficients for concentration are estimated for mills with sister pulp mills and mills without sister pulp mills in the neighbor market, referred to as HHI-WS and HHI-NS[26] respectively. In addition, a dummy variable indicating whether any sister pulp mill exists in the neighbor market is included. However, for 1980 and 2000, two coefficients of concentration are both positive but insignificant, and the coefficients of the sister pulp mill dummy is negative. In the model for 1990, the coefficient of HHI-WS becomes negative, and the estimate of the sister mill dummy is positive.

Additionally, we pool the sample across year so run the model and report the results in Table 10. In the first three columns, we use similar specifications to those in the models in Table 6, 8 and 9 except we add the dummy of the sister pulp mill into the model of every column. In column I, the concentration shows an effect significantly positive at 10% level. Column III seems to indicate a result that is closer to our expectation, as the coefficient of the sister pulp mill is significantly positive, and the two coefficients of concentration show different signs. It is confusing that the coefficient of HHI-WS is significantly negative and the coefficient of HHI-NS is insignificantly positive, which may still indicate the existence of downward biases.

A new variable, import intensity, is added in the model of column IV. Although we construct a proxy of transaction cost in the neighbor market, the transaction cost in the

[26] HHI-WS denotes the HHI for the mill with sister mills in the neighbor market. HHI-NS denotes the HHI for the isolated mill without sister mills in the neighbor market. These two variables are constructed by multiplying HHI with relevant dummies.

peripheral market and world market cannot be identified easily. Import intensity is calculated as the market pulp import divided by total sales for each year in the United States. We expect that transaction costs will be higher if the import intensity is greater because high demand for imports leads to opportunistic seller behavior. The estimates of other variables being robust, the coefficient of the HHI-NS becomes significantly positive at a ten percent level compared with that in column III. Import intensity exhibits a positive relationship with vertical integration, also significant at a ten percent level.

6. Panel Models

So far, we have found no strong evidence that market concentration and vertical integration are positively related as indicated by standard theory. Due to unobservable factors, we can control time-invariant factors that are unobservable or unidentifiable, such as local resources, by extending our analysis to panel regression, which has become feasible due to recent development of panel model for binary choice[27] (e.g., see the summary in Green, 2003).

Fixed effect model

When we assume the individual-specific effect is non-stochastic, the fixed effect model can be applied in the following form:

$$\ln(\frac{VI_{it}}{1-VI_{it}}) == \alpha_i + \beta_1 concentration_{it} + \beta_2 capacity_{it} + X'_{it}\eta + \varepsilon_{it}. \qquad (1)$$

VI, *concentration*, and *capacity* are defined in the same way as model (2). α_i denotes an individual-specific effect, and *X* includes the dummies of the sister pulp mill and uncoated free sheet capacity.

[27] Our panel data are unbalanced because not all mills were in operation in all thirty years. Some mills entered the industry after 1970, and some exited. Unbalanced panel data still work for the fixed effect and random effect models.

Columns I to IV of Table 9 report the estimates of the fixed effect models. In column I, a three-year lagged HHI of the seller market is applied. Compared to the cross-sectional model of column I in Table 8, the positive coefficient of concentration is more significant, now at a 1% level. Furthermore, the coefficient of the dummy of the sister pulp mill becomes positive, but not statistically significant. Downward biases were adjusted to some extent, but still exist observably. We try to obtain two separate estimates for the concentration of the seller market in the model of column II and drop the sister mill dummy temporarily, and find that seller market concentration significantly affects both types of mills positively, indicating that if integration is not controlled, concentration has a delusive relationship with integration due to the positive correlation between concentration in the neighbor seller market and the local existence of sister pulp mills. When the sister mill dummy is added in the model of column III, the result is perfectly consistent with what we expected: the coefficient of HHI-WS is insignificant from zero, and the coefficient of HHI-NS is significantly positive. The dummy of the sister pulp mill also shows a significantly positive effect, with z-statistics more than 2.6. In other words, if a mill has some sister pulp mills nearby, it is more likely to be integrated than isolated mills, given that the seller concentration in a neighbor market maintains constant, and no correlation exists between seller concentration and integration strategies for mills with access to in-firm purchasing. The model of column IV is a two-way panel model with estimation of time effects for each year. The addition of time effects does not change the estimated effects of HHI-WS and HHI-NS. We find a significantly positive time trend in most years before 1990. However, in the last decade of these thirty years, the annual time effects on vertical integration for free sheet mills are insignificantly positive.

Some studies on vertical integration also use linear probability models with panel data (e.g., Acemoglu et al., 2004). The following equation is such a linear probability model with fixed effects:

$$VI_{it} == \alpha_i + \beta_1 concentration_{it} + \beta_2 capacity_{it} + X'_{it}\eta + \varepsilon_{it}. \quad (2)$$

The results are shown in column V of Table 9. The estimates of column V become more significant than those in the column III with the exception of the effect of HHI-WS, which is highly insignificant from zero. Therefore, the relationship between concentration and vertical integration is further verified.

Other models of panel regression

After controlling the idiosyncratic time-invariant factors, we find a significantly positive relationship between market concentration and vertical integration. This relationship holds for mills with sister pulp mills nearby. In order to check the robustness of the fixed effect model, the conditional fixed effect model and the random effect mode are tested.

An incidental parameters problem occurs in the fixed effect model for a binary dependent variable (e.g., Greene, 2003 and Hsiao, 2003), which means that as the time length (*T*) of panel data is typically limited, even when the number of individual (*N*) tends to infinity, the maximum likelihood estimators of all the parameters remains inconsistent. The maximum length of time period in our sample is 28,[28] considered moderately large. Chamberlain (1980) presents a conditional fixed effect model in which estimates are less efficient than they are in the fixed effect model, but consistent even if *T* does not tend to infinity. Table 10 shows estimates from two conditional fixed effect models. The results are quite similar to those in Table 9. While one common coefficient of concentration is estimated (the column I), this coefficient is significantly positive. However, the coefficient of the dummy for the sister pulp mill is insignificant. When two coefficients of concentration are estimated, the one of HHI-WS is insignificant, and the

[28] As three-year lagged concentration is used, our sample years are from 1973 to 2000.

other one of HHI-NS is significantly positive. Meanwhile, the coefficient of the dummy for the sister pulp mill becomes highly significant.

Associated with the fixed effect model, the random effect model can be used under the assumption that the idiosyncratic time-invariant factors are independent of the capacity and market concentration. Table 11 presents the estimates of the random effect models, which slightly differ from those in the fixed effect models. In the one-concentration-coefficient model (column I), the coefficient of concentration is insignificantly positive, and the coefficient of the dummy for sister pulp mill is insignificantly negative. However, with separate concentration effects applied (column II), the results are again consistent with what we expected. The coefficient of HHI-WS is insignificant from zero, and the coefficient of HHI-NS is significantly positive. The coefficient of the dummy for the sister mills is still positive, but only significant at a 30% level, which needs to be further investigated. We can add time-invariant variables in the random effect model. When the South dummy is added (column III), all coefficients are significantly positive, at least at a 10% level. The random effect models do not show as robust results as the fixed effect models, but they are still acceptable and close to our expectation.

The variables we introduce into the models may not capture all the determinants of vertical integration, but we find it difficult to locate other panel variables in the FPL-UW or outer sources. We add an import intensity variable to our panel models to capture the global effect of transaction cost. Import intensity, a time-series variable, has only one value for each year. Adding such a factor cannot bring a better fit for the two-way fixed effect model with full year dummies, but this is a good attempt to the random effect model. The estimated results are shown in Table 12 with the random effect model in column I and the fixed effect model in column II. The coefficients of import intensity are significantly positive and consistent with our expectations. Higher import intensity implies a possibility that the transaction cost for domestic product is relatively higher to

the transaction cost for foreign product, given the foreign supply does not vary and the relative price of domestic and foreign pulp does not change. The coefficient of HHI-WS becomes insignificant compared to that estimated without time factors in column III of Table 9, the same as that in the fixed effect model now.

7. Robustness Check for Integration Dynamics

In the above sections, we have focused on analyzing the relationship between integration status and market concentration. Integration dynamics is more interesting because it implies more causal interpretation for independent variables. Since the number of mills in this industry keeps declining, the size of the sample of new-entry free sheet mills is relatively small. We are considering the sample in which free sheet mills increase their free sheet capacities compared with the previous year, which also includes all the new-entry mills. The sample size is thus enlarged from 29 to 648, but the sample is notably unbalanced. Although some mills continued to increase their capacities in recent years, capacity increase occurred at some mills only one time, so these mills were dropped in the fixed effect models. Therefore, we can give the estimates only from pooled models. Some variables are redefined in the pooled models for the new sample. The binary dependent variable indicates whether the increased capacity is vertically integrated or not compared to previous year.[29] The variable of capacity measures increased capacity. The dummy variable of uncoated free sheet capacity indicates whether increased capacity included uncoated free sheet capacity or not. In addition, the concentration variable is one-year lagged since capacity increase can be a short term strategy in contrast to the change in total capacity. Obviously, the estimates for

[29] In the case of capacity increase, we know the change in integrated and non-integrated capacities. It is likely that total capacity increases while one type of capacity (integrated or non-integrated) decreases. Please see Table 13 for an illustrative explanation. We denote an integrated capacity increase if the integrated capacity increases, and the capacity increase is called a non-integrated capacity increase otherwise. The case in which both integrated and non-integrated capacity increases is viewed as an integrated capacity increase.

integration in capacity increase (Table 14) are very similar to the estimates obtained from the integration status model (Table 8) that examines vertical integration in total capacity. If a single effect of concentration is estimated, this effect is insignificantly positive regardless of whether or not the sister pulp mill dummy is added (columns I and II). If two separate effects of concentration are estimated, the estimates are similar to those estimated in the pooled logit model for integration status (column III and IV). The coefficient of HHI-WS is significantly negative while the coefficient of HHI-NS is significantly positive. Since we cannot go further to the panel models, the robustness in pooled models cannot guarantee the same results in the panel models. However, as the estimates are biased downward in the pooled models, we anticipate a more significant effect of HHI-NS in the correctly specified model, which is consistent with the TCE.

8. Summary and Conclusions

Based on the FPL-UW data, this study has produced results from cross-sectional, pooled, and panel logit models that analyze the relationship between market concentration and vertical integration in the pulp and paper industry. The transaction cost economics indicates that this relationship should be positive, which is verified in Ohanian (1994), as market concentration can be viewed as a proxy of asset specificity and transaction cost. However, the new updated data from FPL fail to repeat Ohanian's results in a duplicate model due to the existence of endogeneity, which is now revealed in that technological change tremendously changed the structure of industry.

Before extending our analysis to panel regression, due to the naturally integrated production nowadays of the low-grade paper product such as newsprint, kraft, and paperboard, we refine the model by narrowing the sample to free sheet mills and introducing a mill-specific measure for concentration. Free sheet mills are likely to purchase chemical pulp in the market because of higher profit margins even though chemical pulp is also much more expensive. With the introduction of a mill-specific

concentration measure, we hope to locate the neighbor market in which the paper mill can purchase market pulp at a lower cost. Free sheet mills are further divided into two categories, those with or without sister pulp mills in their neighbor markets, because they have a different pattern of vertical integration at the mill level caused by the different status of vertical integration at the firm level.

In the cross-sectional and pooled logit models, the buyer concentration of paper mills is positively associated with their integration status, but the estimates are sometimes insignificant. Meanwhile, the coefficient of concentration for paper mills with access to in-firm purchasing is expected to be insignificant from zero; however, it is significantly negative in pooled models. Since controlling the technological factors of integration in cross-sectional models which benefits the production is difficult, we utilize the panel feature of the thirty-year data in order to control the time-invariant factors that affect the strategy of vertical integration and correlate with market concentration, such as forestland abundance. The estimates from the panel models all confirm our expectations. For isolated mills in neighbor pulp markets, market concentration is positively correlated with vertical integration. Furthermore, the mills along with sister pulp mills nearby are likely to get pulp within their own firm; thus, their strategy of integration is affected little by market concentration. Checked by various panel models, such as fixed effect, conditional fixed effect, and random effect models, the results are robust enough to support our hypothesis derived from transaction cost economics. Integration dynamics is investigated tentatively in a pooled logit model when we look at the strategy of vertical integration when free sheet mills increase capacity relative to the previous year. No dissimilarity between the models appears whether the focus is on vertical integration in total capacity or that in increased capacity.

In conclusion, many economic factors that affect vertical integration can be attributed to the technological economy, which should be controlled in empirical models. Previous

studies did not thoroughly explore this particular industry, so they did not identify the real mechanism linking market concentration and vertical integration. We have redefined the measure for market concentration by narrowing our sample to mills that are most strongly affected by transaction cost in the paper industry. Then, using panel regression and robustness check, we successfully verify the sound relationship between transaction cost and vertical integration.

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Table 1. Vertical Integration in the Pulp and Paper Industry, 1975-1995

	1975	1980	1985	1990	1995
Statistics from the FPL-UW Data					
Number of integrated paper mills	236	233	232	233	222
Number of total paper mills	549	527	505	502	496
Percentage of integrated paper mills	43%	44%	46%	46%	45%
Percentage of integrated paper mills based on Lockwood's Directory (Melendez, 2002)	46%	53%	44%	47%	46%

Source: the FPL-UW data and Melendez (2002).

Table 2. Variable Means for the Model of Paper Mills

Integrated vs. Nonintegrated Paper Mills

	1900		1940		1970		2000	
	NITG	ITG	NITG	ITG	NITG	ITG	NITG	ITG
Number of mills	612	147	546	152	312	239	256	214
Average paper capacity per mill†	3	13	22	61	45	173	91	361
Dummy (Newsprint)	0.06	0.37	0.00	0.16	0.01	0.08	0.02	0.09
Dummy (Kraft)	—	—	0.07	0.26	0.02	0.12	0.03	0.07
Average regional concentration (CR4)	0.04	0.06	0.05	0.07	0.09	0.08	0.12	0.09

Notes: †Thousand short tons per year.

1. NITG: non-integrated; ITG: integrated.

Source: the FPL-UW data and Ohanian (1994).

Table 3. Logit Regression Model of Vertical Integration, 1970-2000

Basic model with the sample of all paper/paperboard mills

	1970	**1980**	**1990**	**2000**
Concentration (CR4 prod.)	-14.968***	-7.239**	-5.010**	-2.123
	(4.006)	(3.145)	(2.479)	(1.756)
Capacity (log)	0.748***	0.799***	0.787***	0.779***
	(0.094)	(0.103)	(0.101)	(0.098)
Dummy (Newsprint)	1.325**	1.209*	0.712	1.085*
	(0.662)	(0.653)	(0.587)	(0.583)
Dummy (Kraft)	1.177**	1.323**	0.622	0.645
	(0.531)	(0.544)	(0.543)	(0.547)
Constant	-2.029***	-3.020***	-3.196***	-3.684***
	(0.549)	(0.609)	(0.592)	(0.557)
Log likelihood	-299.82	-285.64	-281.64	-266.07
N	551	527	502	470

Note: 1. The dependent variable, vertical integration, is a dummy variable, which equals one if a paper mill is integrated with the pulping process. The concentration ratio is the product of the ratios of top-four paper mill capacity and top four market pulp capacity in the region.

2. ***, **, *: the coefficient is significant at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

Source: the FPL-UW data.

Table 4. Descriptive Statistics for Free Sheet Mills, 1970-2000

	1970	**1980**	**1990**	**2000**
Number of free sheet mills†				
Free sheet capacity only	82	87	88	80
Total free sheet mills	116	117	120	108
Integrated mills	65	69	74	69
Integration ratio	56%	59%	62%	64%
Number of free sheet firms	50	48	36	35
Single free sheet mill firms†	30	30	22	22
Integrated capacity (thou. short tons/year)	5408	7822	11703	16438
Total free sheet capacity (thou. short tons/year)	9022	12128	16808	22069

Notes: †. Free sheet mills are defined as mills with positive free sheet capacity. Single free sheet mill firms denote firms with only one free sheet mill.

Source: the FPL-UW data.

Table 5. Descriptive Statistics for Free Sheet Mills

Integrated vs. Nonintegrated Free Sheet Mills

	1980		**1990**		**2000**	
	NITG	ITG	NITG	ITG	NITG	ITG
Number of mills	48	69	46	74	39	69
Paper capacity†	58	136	77	179	75	278
Dummy (uncoated free sheet capacity)	0.833	0.942	0.826	0.892	0.872	0.855
Dummy (south)	0.021	0.246	0.043	0.311	0.051	0.319
Dummy (sister pulp mills)	0.146	0.217	0.196	0.230	0.051	0.261
HHI-paper, 3-year-lagged	858	1335	1078	1341	1268	1500
HHI-pulp, 3-year-lagged	1433	1608	1784	1711	2011	2024
Number of non-freesheet mills	20	390	15	367	13	349

Notes: †. Thousand short tons per year.

1. NITG: non-integrated; ITG: integrated.

Source: The FPL-UW data.

Table 6. Logit Regression of Vertical Integration for Free Sheet Mills, 1980-2000

Cross-sectional model with HHI product as concentration measure

	1980	**1990**	**2000**
HHI (product) 3-year-lagged	0.338	0.028	-0.108
	(0.273)	(0.124)	(0.171)
Capacity (log)	1.236***	1.051***	1.560***
	(0.280)	(0.263)	(0.331)
Dummy (uncoated free sheet production)	1.498**	0.886	0.693
	(0.754)	(0.628)	(0.758)
Dummy (south)	1.874	1.659**	1.146
	(1.223)	(0.812)	(0.935)
Constant	-6.745***	-5.241***	-7.094***
	(1.446)	(1.403)	(1.842)
Log likelihood	-53.70	-62.07	-46.09
N	117	120	108

Notes: 1. The dependent variable, vertical integration, defined as a dummy variable with one indicating a free sheet mill integrated with the chemical pulping process. The HHI product is the concentration measure obtained by multiplying the HHI of the seller and buyer markets for chemical pulp.

2. ***, **, *: the coefficient is significant at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

3. Three-year lagged concentration is used since three year is an appropriate length for a mill to make decision to change integrated status.

Source: the FPL-UW data.

Table 7. Logit Regression of Vertical Integration for Free Sheet Mills, 1980-2000

Cross-sectional model with sister mill dummy

	1980	1990	2000
HHI (prod) 3-year-lagged	0.465	0.065	-0.105
	(0.343)	(0.141)	(0.171)
Capacity(log)	1.284***	1.063***	1.586***
	(0.290)	(0.264)	(0.351)
Dummy (uncoated free sheet capacity)	1.511**	0.851	0.734
	(0.744)	(0.635)	(0.780)
Dummy (south)	1.834	1.723**	1.181
	(1.270)	(0.823)	(0.941)
Dummy of sister pulp mills	-0.711	-0.441	-0.232
	(0.668)	(0.608)	(0.938)
Constant	-6.982***	-5.263***	-7.238***
	(1.474)	(1.408)	(1.948)
Log Likelihood	-53.12	-61.80	-46.06
N	117	120	108

Notes: 1. The dependent variable, vertical integration, is a dummy variable, indicating a free sheet mill is vertically integrated if it is integrated with the chemical pulping process. HHI-WS denotes the HHI for the mill with sister mills in the neighbor market. HHI-NS denotes the HHI for an isolated mill in a neighbor market. These two variables are constructed by multiplying the HHI with relevant dummies. Dummy of sister pulp mills indicates whether a free sheet mill has a sister mill within its 350-mile radius circular neighbor market.

2. ***, **, *: the coefficient is significant at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

3. Three-year lagged variables are used since three year is an appropriate period for a mill to make decision to change integrated status. One-year lagged and two-year lagged variables are also tested. The results are robust.

Source: the FPL-UW data.

Table 8. Logit Regression of Vertical Integration for Free Sheet Mills, 1973-2000

Pooled cross-sectional model with various specifications of concentration measure

	I	II	III	IV
HHI (product)†	0.034*			
	(0.023)			
HHI (seller market) †		-0.059		
		(0.095)		
HHI-WS (seller) †			-1.016***	-0.983***
			(0.237)	(0.238)
HHI-NS (seller) †			0.156	0.191*
			(0.109)	(0.112)
Import intensity†				0.017*
				(0.011)
Capacity (log)	1.265***	1.273***	1.248***	1.255***
	(0.053)	(0.053)	(0.053)	(0.054)
Dummy (sister pulp mills)	-0.309***	-0.285**	1.657***	1.662***
	(0.116)	(0.115)	(0.448)	(0.448)
Dummy (UCFS capacity)	1.089***	1.096***	1.071***	1.067***
	(0.129)	(0.129)	(0.130)	(0.130)
Dummy (south)	1.700***	1.717***	1.740***	1.746***
	(0.176)	(0.176)	(0.175)	(0.176)
Constant	-6.166***	-6.044***	-6.298***	-6.958***
	(0.279)	(0.316)	(0.324)	(0.546)
Log Likelihood	-1572.02	-1572.96	-1562.37	-1561.21
N	3,235	3,235	3,235	3,235

Notes: †. Three-year lagged variable.

1. The dependent variable, vertical integration, is a dummy variable, indicating a free sheet mill is vertically integrated if it is integrated with the chemical pulping process. The HHI product is a concentration measure by multiplying the HHI of the seller and buyer markets for chemical pulp. The HHI of the seller market is used as another concentration measure for the chemical pulp market. HHI-WS denotes the HHI for the mill with sister mills in the neighbor market. HHI-NS denotes the HHI for an isolated mill in a neighbor market. These two variables are constructed by multiplying the HHI with relevant dummies. Dummy of sister pulp mills indicates whether a free sheet mill has a sister mill within its 350-mile radius circular neighbor market.

2. ***, **, *: the coefficient is significant at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

3. In Column IV, the coefficient of HHI-WS is significantly negative and the coefficient of HHI-NS is positive. Therefore, the different between the coefficients of HHI-WS and HHI-NS is significant. In the following results, this criteria can be applied to many cases.

Table 9. Panel Logit Regression of Vertical Integration for Free Sheet Mills, 1973-2000

Fixed effect models

	I	II	III	IV	V
HHI (seller)†	1.896***				
	(0.615)				
HHI-WS (seller)†		1.889***	-1.436	-0.272	0.002
		(0.679)	(1.459)	(1.858)	(0.019)
HHI-NS (seller)†		1.824***	2.662***	4.946***	0.052***
		(0.603)	(0.730)	(1.239)	(0.009)
Capacity (log)	5.136***	5.186***	4.999***	13.297***	0.056***
	(0.919)	(0.919)	(0.928)	(2.679)	(0.009)
Dummy (sister pulp mills)	0.622		10.137***	10.436**	0.091***
	(0.688)		(3.893)	(4.987)	(0.034)
Dummy (UCFS capacity)	4.267***	4.250***	4.580***	3.880	0.148***
	(1.183)	(1.186)	(1.201)	(2.547)	(0.021)
N (Groups)	75	75	75	75	75

Notes: †. Three-year lagged variable.

1. The dependent variable, vertical integration, is a dummy variable, indicating a free sheet mill is vertically integrated if it is integrated with the chemical pulping process. The HHI of the seller market is used as a concentration measure for the chemical pulp market. HHI-WS denotes the HHI for the mill with sister mills in the neighbor market. HHI-NS denotes the HHI for an isolated mill in a neighbor market. These two variables are constructed by multiplying the HHI with relevant dummies. Dummy of sister pulp mills indicates whether a free sheet mill has a sister mill within its 350-mile radius circular neighbor market.

2. ***, **, *: the coefficient is significant at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

3. Column I : fixed effect model
   Column II : fixed effect model
   Column III : fixed effect model
   Column IV : two way fixed effect model with time effects
   Column IV : fixed effect model (linear probability model)

Source: the FPL-UW data.

Table 10. Panel Logit Regression of Vertical Integration for Free Sheet Mills, 1973-2000

Conditional Fixed effect models

	I	**II**
HHI (seller) †	2.081***	
	(0.577)	
HHI-WS (seller) †		-1.344
		(1.404)
HHI-NS (seller) †		2.808***
		(0.691)
Capacity (log)	4.858***	4.722***
	(0.869)	(0.874)
Dummy (sister pulp mills)	0.648	10.311***
	(0.679)	(3.749)
Dummy (UCFS capacity)	4.225***	4.528***
	(1.157)	(1.171)
N (Groups)	139	139

Notes: †. Three-year lagged variable.

1. The dependent variable, vertical integration, is a dummy variable, indicating a free sheet mill is vertically integrated if it is integrated with the chemical pulping process. The HHI of the seller market is used as a concentration measure for the chemical pulp market. HHI-WS denotes the HHI for the mill with sister mills in the neighbor market. HHI-NS denotes the HHI for an isolated mill in a neighbor market. These two variables are constructed by multiplying the HHI with relevant dummies. Dummy of sister pulp mills indicates whether a free sheet mill has sister mills within its 350-mile circular neighbor market.

2. ***, **, *: the coefficient is significant at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

Source: the FPL-UW data.

Table 11. Panel Logit Regression of Vertical Integration for Free Sheet Mills, 1973-2000

Random effect models

	I	II	III
HHI (seller) †	0.037		
	(0.082)		
HHI-WS (seller) †		-0.749	1.975**
		(1.016)	(0.945)
HHI-NS (seller) †		0.274***	3.124***
		(0.086)	(0.186)
Capacity (log)	2.304***	3.101***	3.258***
	(0.105)	(0.133)	(0.200)
Dummy (sister pulp mills)	-0.095	2.271	3.752*
	(0.197)	(2.235)	(2.108)
Dummy (UCFS capacity)	0.431	0.966**	4.874***
	(0.357)	(0.484)	(0.915)
Dummy (south)			4.281***
			(1.462)
Constant	-7.698***	-12.527***	-21.836***
	(0.668)	(0.855)	(1.656)
Random Effect	7.070***	6.917***	7.341***
	(0.293)	(0.289)	(0.518)
Rho	0.938***	0.936***	0.942***
	(0.006)	(0.006)	(0.009)
N (Groups)	139	139	139

Notes: †. Three-year lagged variable.

1. The dependent variable, vertical integration, is a dummy variable, indicating a free sheet mill is vertically integrated if it is integrated with the chemical pulping process. The HHI of the seller market is used as a concentration measure for the chemical pulp market. HHI-WS denotes the HHI for the mill with sister mills in the neighbor market. HHI-NS denotes the HHI for an isolated mill in a neighbor market. These two variables are constructed by multiplying the HHI with relevant dummies. Dummy of sister pulp mills indicates whether a free sheet mill has sister mills within its 350-mile radius circular neighbor market.

2. ***, **, *: the coefficient is significant at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

Source: the FPL-UW data.

Table 12. Panel Logit Regression of Vertical integration for Free Sheet Mills, 1973-2000

Import intensity added

	Random effect model	**Fixed effect model**
HHI-WS (seller)†	-0.380	-1.163
	(1.019)	(1.522)
HHI-NS (seller)†	1.991***	2.368***
	(0.222)	(0.741)
Capacity (log)	5.537***	6.027***
	(0.267)	(1.099)
Dummy (sister pulp mills)	7.025***	8.781**
	(2.151)	(4.012)
Dummy (UCFS capacity)	3.195***	4.356***
	(0.661)	(1.271)
Dummy (south)	11.127***	
	(1.227)	
Import intensity†	0.070***	0.134***
	(0.019)	(0.048)
Constant	-34.084***	
	(2.001)	
Random Effect	6.392***	
	(0.324)	
Rho	0.925***	
	(0.007)	
N (Groups)	139	139

Notes: †. Three-year lagged variable.

1. The dependent variable, vertical integration, is a dummy variable, indicating a free sheet mill is vertically integrated if it is integrated with the chemical pulping process. The HHI of the seller market is used as a concentration measure for the chemical pulp market. HHI-WS denotes the HHI for the mill with sister mills in the neighbor market. HHI-NS denotes the HHI for an isolated mill in a neighbor market. These two variables are constructed by multiplying the HHI with relevant dummies. Dummy of sister pulp mills indicates whether a free sheet mill has sister mills within its 350-mile radius circular neighbor market. Import Intensity is calculated as the market pulp import divided by total sales for each year in the United States.

2. ***, **, *: the coefficient is significant at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

Source: the FPL-UW data.

Table 13. Definition of Vertically Integrated Capacity Increase

	1	**2**	**3**	**4**	**5**
	Integrated Capacity Increase			Non-integrated Increase	
Integrated capacity	↑	↑	↑		↓
Non-integrated capacity	↓		↑	↑	↑

Notes: In the case of capacity increase, we know the change in integrated and non-integrated capacities. It is likely that total capacity increases while one type of capacity (integrated or non-integrated) decreases. We denote an integrated capacity increase if the integrated capacity increases, and the capacity increase is called a non-integrated capacity increase otherwise. The case in which both integrated and non-integrated capacity increases is viewed as an integrated capacity increase (column 3).

Table 14. Logit Regression of Vertical Integration for Free Sheet Mills, 1973-2000

Pooled cross-sectional model for vertical integration in capacity increase

	I	**II**	**III**	**IV**
HHI (seller)†	0.073	0.116		
	(0.171)	(0.172)		
HHI-WS (seller)†			0.199	-0.977**
			(0.219)	(0.445)
HHI-NS (seller)†			0.073	0.327*
			(0.171)	(0.190)
Capacity (log)	0.359***	0.351***	0.357***	0.337***
	(0.078)	(0.078)	(0.078)	(0.078)
Dummy (sister pulp mills)		0.423*		2.566***
		(0.237)		(0.836)
Dummy (UCFS capacity)	-0.533**	-0.555**	-0.541**	-0.582***
	(0.216)	(0.217)	(0.216)	(0.218)
Dummy (south)	2.636***	2.558***	2.585***	2.686***
	(0.313)	(0.316)	(0.318)	(0.324)
Constant	-0.912**	-1.021**	-0.933**	-1.364***
	(0.427)	(0.432)	(0.427)	(0.451)
Log Likelihood	-366.54	-364.94	-366.12	-361.22
N	648	648	648	648

Notes: †. Three-year lagged variable.

1. The dependent variable, vertical integration in capacity increase, is a dummy variable, indicating whether the increased capacity is vertically integrated or not compared to last year. The HHI of the seller market is used as a concentration measure for the chemical pulp market. HHI-WS denotes the HHI for the mill with sister mills in the neighbor market. HHI-NS denotes the HHI for an isolated mill in a neighbor market. These two variables are constructed by multiplying the HHI with relevant dummies. Dummy of sister pulp mills indicates whether a free sheet mill has a sister mill within its 350-mile radius circular neighbor market.

2. ***, **, *: the coefficient is significant at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

Source: the FPL-UW data.