PULPWOOD MARKET DYNAMICS: THE EFFECTS OF WOOD PELLET PRODUCTION

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1. Introduction

Pulpwood consumption has been traditionally centered within Pulp and Paper Industries (PPI) and Composite Panels (OSB, MDF, etc.). However, the local stock of biomass and European policies on renewable energy have prompted wood-pellet facilities to location. The magnitude of the impact of these plants on pulpwood market is uncertain since their biomass sources range from wood residuals to pulpwood. On the supply side, forest landowners have gained one more option to sell wood and, thus they have one more incentive, in addition to the weak recovery of the sawtimber prices, to shift their forest planning to shorter rotations. These dynamics might spread across different markets over time changing their linkage process and impacting pulpwood prices behavior. Therefore, understanding how pellet markets affect geographical price transmission is essential to decision makers in public and private forestry organizations.

The US South has been among the leading wood pellets suppliers to European power plants. Between 2012 and 2016, wood pellet exports from the US to Europe went from $267 million to $607 million (US Census Bureau, 2017). At the same period, 16 new pellet mills were installed in the US South, which if added to the plants under construction, can achieve the potential to produce 7.4 million metric tons of pellets or 17.12 million tons of wood fiber (Forest2Market, 2015).

The entry of pellet mills in the US South has concerned traditional wood consumers like the PPI and Composite Panels. The demand for raw material from these industries are likely to overlap since wood pellets availability might fall within 75 miles around their mill (Forest2Market, 2015) (Figure 1). Although previous analysis on price of pulpwood and wood chips have shown no indication suggesting higher competition

(Conrad and Bolding, 2011), the sector expected an higher raw-material costs in the next years (Abt et al., 2014; Benjamin et al., 2009; Conrad et al., 2011; Galik et al., 2009).

[Insert Figure 1]

Sudden shocks on demand or supply caused by new competitors might change market linkages, generating opportunities for riskless profits and misinforming economic agents. The initial attempts to investigate timber price behavior in the US South relied on the single market hypothesis, where timber prices have some connection degree through the region (Hultkrantz, 1993; Washburn and Binkley, 1993, 1990). However, results from Prestemon and Holmes (2000) has indicated that timber market in the US South is likely formed by clusters with different sizes depending on the timber product (pulpwood or sawtimber). These features are reinforced by Nagubadi et al. (2001) in the hardwood market and by Yin et al. (2002) in the softwood market.

Hood and Dorfman (2015) adopted non-linear model studying sawlog stumpage prices across the US South. The authors combined a STAR model with an external transition variable (house starts) to evaluate the degree of cointegration across time in the sawlog market. Previous research that assumes nonlinearity have focused on the prices of Orientated Strand Boards (Goodwin et al., 2011) and Roundwood market in New Zealand (Niquidet and Manley, 2011).

This paper complements the current literature in spatial price transmission by: **(i)** the dataset is more geographically disaggregate. **(ii)** We use non-linear models; to our knowledge, **(iii)** Little attention has been given to pulpwood market. In the last decades, the timber market has passed through several changes - e.g., the housing crisis in 2008 and the rise of a strong bioenergy market, and, **(iv)** we tested where pellet mills capacity have affected the cointegration process over time in the similar fashion as Bingham et al.(2003) but used logit models instead.

We combine co-integration analysis and Smooth Transition Autoregression models (STAR). Our data set is composed of bimonthly stumpage prices for pulpwood softwood from 2005 to 2015. Results indicated that the spatial relationship between different markets is sophisticated and covers a broad spectrum of different price behaviors in the US South. Our model shows that distances have, surprisingly, positive effect on cointegration likelihood and wood pellet affects the price dynamics positively when both micromarket pairs have a robust wood pellet market.

This paper is structured as follows: First, we describe the pulpwood market briefly in the US South and its relative importance. Then the econometrics models are described. Results are covered next, followed by the discussion and, market and politicy implications.

2. Smooth Transition Autoregressive Models (STAR)

Smooth Transition Autoregressive Models (STAR) have shown a significant advantage compared to their linear counterparts since the timber market faces high transaction costs (including transportation) that lead to nonlinear adjustment to the equilibrium condition after an external shock (Serra et al., 2011). Among the regime shifting models, there is a substantial indication that timber prices have smooth changes instead of discrete. The rationality behind is the timber prices are formed by the average of many transactions from heterogeneous agents. Therefore, the effect of an external shock would be absorbed in distinguished speeds across the market, creating a smooth process.

Our model uses essential components from the previous literature on price transmission. Let $y_t = \ln(p_{it}/p_{jt})$ be the natural log of the ratio between the stumpage price of pulpwood in micromarkets *i* and *j* at time *t.* For a pair price, a linear autoregressive model of order *p*th representation is

$$\Delta y_t = \varphi_0 + \varphi' x_t + \theta_1 y_{t-1} + \varepsilon_t \tag{2}$$

where $\varphi = (\varphi_p, \dots, \varphi_{p-1}), x_t = (\Delta y_{t-1}, \dots, \Delta y_{t-p})$ and ε_t is a white noise. The STAR model (Terasvirta, 1994) for a univariate time series adds a transition function in Equation (2) as follows:

$$\Delta y_t = \widetilde{\phi_1}\widetilde{x_t}\big(1 - G(s_t;\gamma,c)\big) + \widetilde{\phi_2}\widetilde{x_t}\big(G(s_t;\gamma,c)\big) + \varepsilon_t \tag{3}$$

where $\widetilde{x_t} = (1, x_t, y_{t-1})$, $\widetilde{\phi_1} = (0, \phi_1, 0)'$, $\widetilde{\phi_2} = (\phi_{2,0}, \phi_2, \theta_2)'$, and $\theta_2 < 0$ is required. $G(s_t;\gamma,c)$ is called *transition function*, which changes from 0 to 1 as the transition variable s_t increases. Micromarkets *i* and *j* are considered completely integrated when $G(s_t; \gamma, c) = 1$ and completely unlinked when $G(s_t; \gamma, c) = 0$. This interpretation is possible because the first regime $\widetilde{\phi_1}\widetilde{x_t}\left(1 - G(s_t; \gamma, c)\right)$ is a unit root process without drift (the intercept and the coefficient on y_{t-1} are constraints to zero) (Hood and Dorfman, 2015). The parameter *c* is interpreted as the threshold between the two regimes. And, γ determinates the smoothness of the *transition function* and thus the regime shifting.

2.1 Transition Variable

There are many candidates to represent the transition variables. In the finance literature, a typical candidate is the lag of the dependent variable (Δy_{t-1}). Goodwin et al. (2011) proposed that s_t should be represented by a moving average of the lags in y_t defined as:

$$s_t = \left(\frac{1}{D_{max}}\right) \sum_{d=1}^{D_{max}} y_{t-d} \tag{4}$$

where D_{max} is the pre-specified lag limit. This specification agrees with the economic concept which in the profit opportunities occur when there is a large discrepancy in relative prices compared to a given average. After a cautious analysis on the different model criteria (Loglikelihood, AIC and, BIC), we choose D_{max} equals to 6 because in many cases timber market information (volume harvested and stock of wood) is available annualy or longer frequencies.

2.2 Transition Function

The transition function, $G(s_t; \gamma, c)$, might assume various forms as well. We use two setups of the STAR models: (i) Logistic (LSTAR) (Equation (5)) and, (ii) Exponential (ESTAR) (Equation (6)).

$$G(s_t; \gamma, c) = (1 + \exp(-\gamma(s_t - c))^{-1} \tag{5}$$

$$G(s_t; \gamma, c) = 1 - \exp(-\gamma(s_t - c)^2) \tag{6}$$

where $\gamma > 0$ is required. To facilitate the optimization process, we modified Equation (5) and (6) by: (i) substituting γ by $\exp(-\eta)$, which assures a positive value of γ without imposing any constraint, and (ii) dividing $\exp(-\eta)$ by the standard deviation of the transition variable s_t, thus $\exp(-\eta)$ is transformed into a scale-free parameter.

The LSTAR models embed linear and threshold regime shifting model in one function. When $\gamma \to \infty$, Equation (5) has a rapid change between 0 and 1, as in threshold model, while when $\gamma \to 0$, the LSTAR model reduces to a linear model. The ESTAR model, equation (6), on the other hands, become linear as $\gamma \to \infty$ or $\gamma \to 0$. We compared and selected Equation (5) and (6) for every pair prices using statistical criteria (AIC and Loglikelihood).

3. Model Estimation

Equation (3) was estimated using the Nonlinear Least Square (NLS) method. A critical step to reach the best solution is to select the initial values as close as possible to the global optimum. To assure optimality, we adopted an approached proposed initially by Terasvirta (1994) and applied by Hood and Dorfman (2015) in the sawtimber stumpage prices. We ran the sum of square function conditioned on η multiple times (ranging from -6 to 6) and selected the coefficients with the minimal Residual Sum of Squares (RSS).

4. Meta-Analysis

To analyze the effects of the pellet mills on the cointegration of pulpwood markets over time, we estimate a non-linear regression using the results of $G(.)_{ijt}$ as the dependent variable because it indicates the transition between cointegrated ($G(.)_{ijt} = 1$) and random walk ($G(.)_{ijt} = 0$) process for each pair. We define the binary function $Z(.)$ following the indicator function $Z(.) = 1$ if $\widehat{G(.)} >= 0.9$ and $Z(.) = 0$ if $\widehat{G(.)} < 0.9$.

For every micromarket pair, the independent variables tested are distance, the number of Pulp and Paper Industries and Composite Panel, and pellet mills capacity in both pairs. Distance should have negative effect on cointegration since market shocks are not transmitted in distant markets.However, distance has also shown no specific trend in previous literature (Prestemon and Holmes, 2000; Yin et al., 2002). The pulpwood market appears to be characterized by the oligopsony structure; and market power of Pulp and Paper, and composite mills might define the market extension conditioned on the market structure in their neighbors. The effects on cointegration can be mixed; the entry of more competitors might have a negative impact on price transmission since local market will become stronger. However, a stronger market might not be affect but it will affect other surrounded locations. Mathematically, the binary regression is defined as:

$$\Pr\left[Z(.)_{ijt} = 1 \middle| \mathbf{X}\right] = F(Distance_{ij}, Pellet\ Wood_{ijt}, Industry_{ijt}, Both_t, Both\ Ind._t\ , Logistic) + \eta_{ijt} \quad (8)$$

where: • $\Pr[Z(.)_{ijt} = 1|\mathbf{X}]$ is the probability $Z(.)_{ijt}$ equals one, • $F(.)$ is the cdf of the logit distribution, • $Distance_{ij}$ is the distance between centroids of micromarkets i and j, • $Pellet\ Wood_{ijt}$ is the sum of the pellet capacity in green tons in region i and j during time t, • $Industry_{ijt}$ is the number of PPI and Composite Panel mills in region i and j at time t. • $Both_t$ is a dummy variable which assumes value one if both price pairs have a pellet mill installed and zero otherwise, • $Both\ Ind._t$ is a dummy variable for the presence of PPI and Panel mills in i and j, and $\eta_{ijt}$is the error term. The variable $Both_{ijt}$ and $Both\ Ind._t$ also interact with $Pellet\ Wood_{ijt}$ and $Industry_{ij}$ respectively to capture their response when pellet mills or PPI and Composite Panel is present in market i and j. $Logistic$ equals one if the Smooth Transition Model used the Logistic transition function and zero if it adopted an exponential function.

8. Results

This paper analyzes how the wood pellet production has affected Pulpwood Price Dynamics in the US South. The dataset is composed of a bimonthly of softwood prices from 2005 to 2015 of 39 microregions in the US South provided by Forest2Market. Pellet mills capacity and location were collected from the Biomass Magazine (http://biomassmagazine.com/) and the Southern Environmental Law Center (2018); we also called or emailed wood pellet plants with incomplete information. Data containing location and status of Pulp and Paper Industry, and Composited Panel are from Forest2Market (2015).

Based on the data and methods, we compare the differences in pulpwood prices between regions with and without pellet mills, followed by the results and discussion on the STAR models.

8.1 Price Dynamics

We examined the pulpwood price ratio between 39 microregions. For every 507 pairwise combinations, we run a Logistic STAR (LSTAR) model and the Exponential STAR (ESTAR) models. After comparing their performance by the AIC statistic, 157 pair were better represented by LSTAR and 584 by ESTAR. Our results rejected the single market hypothesis in the US South as in previous studies; they reinforce not only the US South is composed by different market clusters, but also that the composition of these clusters varies across time.

8.2 Market Linkages

Here, we presented a pairwise cointegration map using micromarket (4) and (13) as a reference for the softwood pulpwood market. Market (4) and (13) have the most significant share of wood pellet capacity and are considered part of the “fuelsheds” that supply wood-based pellets to Europe (Dale et al., 2017). Further results are avaliable at the supplementary material. We show their cointegration map in four specific periods: (i) the initial period analyzed (04/2005), (ii) the period when a pellet mill started operating in the region, (iii) the period when the market reached the maximum historical production capacity of wood pellets and (iv) the final period of our data (12/2015).

8.4.1 Micromarket (13)

There is a substantial variation in composition and number of markets cointegrated with (13) over time (Figure 2). On average, 27 were cointegrated with (13) between 2005 and 2015 respectively, 30 at the highest peaks (10/2006), and 22 at the lowest trough (6/2012). For comparison, the other micromarkets studied are linked to 19 regions on average.

The location of market (13) justifies its number of cointegration markets. Southeast Georgia is known as the “wood basket”, where the stock of wood, removals, and growth are higher than any other place in the Southeast US. Even though its share of pulpwood removals is equivalent to 1% of 79 million green tons when aggregated to micromarkets (12) and (15), they are responsible for 9% of the pulpwood removals in the US South (TPO, 2015). There are 13 Pulp and Paper, and composite mills operating in the region, the highest number in our sample. This concentration of consumers makes the local market dynamic and competitive. Also, these regions are dominant players in the long-run equilibrium in the sawtimber market (Mei et al., 2010). Therefore, it might not be an exaggeration to claim Southeast Georgia dominates or, at least, has a strong influence on the pulpwood market in the US South as well.

[Insert Figure 2]

The linkage of the market (13) seems to overcome geographical barriers since they are integrated to distant regions in the western states. This outcome corroborates with previous studies; Prestemon and Holmes (2000) showed the coastal plain of South Carolina (Region 9 and 7) is cointegrated with distant markets as well. According to their results, this area is cointegrated with pulpwood markets in Texas (Regions 36 and 37), Louisiana (Regions 29) and Mississippi (Regions 20 (partially), 23, 24, 26). Yin et al., (2002) found similar evidence in Southeast Georgia, which was linked with all the 11 regions in the US South studied by them, except, ironically, by its nearest neighbor North Georgia.

The geographical discontinuity of pulpwood market seems to relate to the market power exercised by the PPI. Market (13) is often linked to regions with traditional pulpwood markets (15, 30, 29 and 38) or their closest neighbors. Also, there are few opportunities to reduce costs in a Pulp and Paper mill due to the substantial capital invested. Since the raw material account for 30% of the total costs (FisherSolve, 2018), it is expected that mill managers use information in different regions to negotiate the final price, thereby creating links with other pulpwood markets.

On the other hand, when the pellet production at microregion (13) reached the highest capacity was the period with the lowest number of market cointegrated. One explanation is that pellet mills might create stronger internal demand which protects local market against shocks from the market (13). Alternatively, the increase in price expectation was too low to impact their surrounding regions. Also, the most recent pellet mills are installed in regions where there is less competition, where PP or composite panels closed their operations (Forest2Market, 2015). These regions probably have few transactions, and pulpwood market were stagnating.

8.3 Cointegration drivers

To reinforce determinants of the spatial cointegration between pulpwood markets, we ran a series of regression analysis and evaluated the role of distance, pellet mills, and PPI and Composite Panels. We tested many specifications of Equation (8) to account for spatial and time heterogeneity like (i) no fixed effects, (ii) individual, (iii) time and micromarkets fixed effect individually, and (iv) the combination of micromarket and time fixed effect (Table 2). The results from individual fixed effects are not demonstrated becaused it suffered from lack of convergence and perfect collinearity. The $Pseudo\ R^2$ indicated a substantial gain in the model quality after considering spatial heterogeneity (from 0.07 to 0.15 in the Softwood model), while time fixed effect has showned little contribution.

[Insert Table 1]

After accounting for spatial heterogeneity, $Distance$ had positive effect on likelihood of cointegration among softwood markets. The probability of cointegration between two micromarket prices rises by 3% with each additional 500 miles airplane distances ($Average\ Marginal\ Effect\ (AME)$ – Table 1). The counterintuitive effect of $Distance$ can be explained by transportation costs and the industry characteristics. The high transportation costs on timber products does not justify carrying pulpwood for long distances, which would imply negative effect on cointegration as in Bingham et al., 2003. However, three features of the PPI and Composite Panels favors similar movement in prices among different regions: (i) they have strong market power when negociating pulpwood prices, (ii) they are capital intensive and (iii) fiber is a large share of their total operation costs. Managers have more opportunity on reducing fiber costs than any other place on the mill, therefore, price references might come from other similar mills located in different markets.

Unfortunately, our thesis about fiber competition within PPI and Composite Panel is not supported by the results in the regression. On contrary, $Both\ Ind$. coefficients had opposite sighs and $Industry$ had positive effect on cointegration but not statistically significant. The variable number of PPI and Composite Panel might not be as representative as its real timber consumption, though the latter is not accessible bimonthly. $Wood\ pellet$, on the other hand, presented a negative relation but had no economic significance; for every additional five expansion of wood pellet capacity in five thousand, the likelihood of cointegration decreases only 0.9%. When interacting with $Both$, its sign inverted to positive, showing that if the increase in competition for fiber in both regions might strength the market relation.

Regarding market structure, the wood Pellet is similar to PPI and Composite Panels. Only seven companies dominate wood pellet market. They have in total 70% of US wood pellet production capacity. Enviva has eight mills and 40% of southern wood pellet capacity (Forisk, 2018). Pellet mills also have some market power which would lead to similar movements in pulpwood prices in facilities located in different regions.

9 Summary and Conclusion

Our results suggest that there are no specific market clusters in the US South, but every micromarket has its particular relationship with each other. Any market grouping based on the bivariate cointegration analyzed was likely arbitrary for the pulpwood market. Markets are connected in many configurations; practitioners should consider not only spatial aspects but also similar market structure.

Finally, the answer to our initial question is “Yes” that the wood pellet mills have impacted pulpwood prices dynamics. Wood pellet mills have shown a mixed impact depending on the market structure of surrounding markets. Further studies could evaluate how these mills have affected price directly by evaluating its elasticities.

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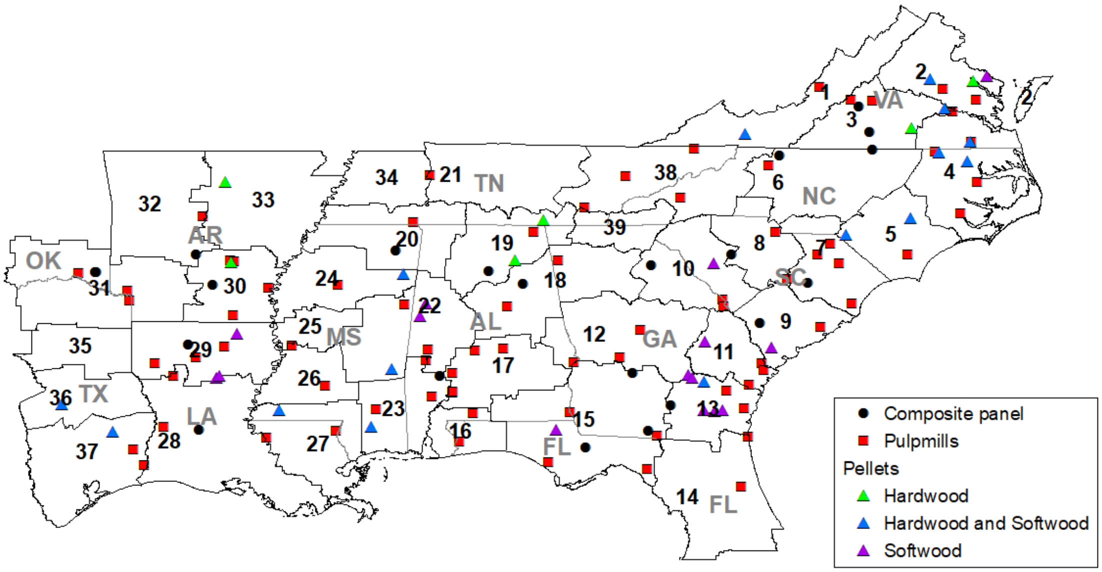

Figure 1: Distribution of the Pulpwood consumers. The numbers represent the micromarkets for timber defined by Forest2Market.**Sources:** (i) Pellets Mills: Southern Environmental Law Center and Biomass Magazine (ii) Composite panel and Pulpmills: USDA Forest Service.

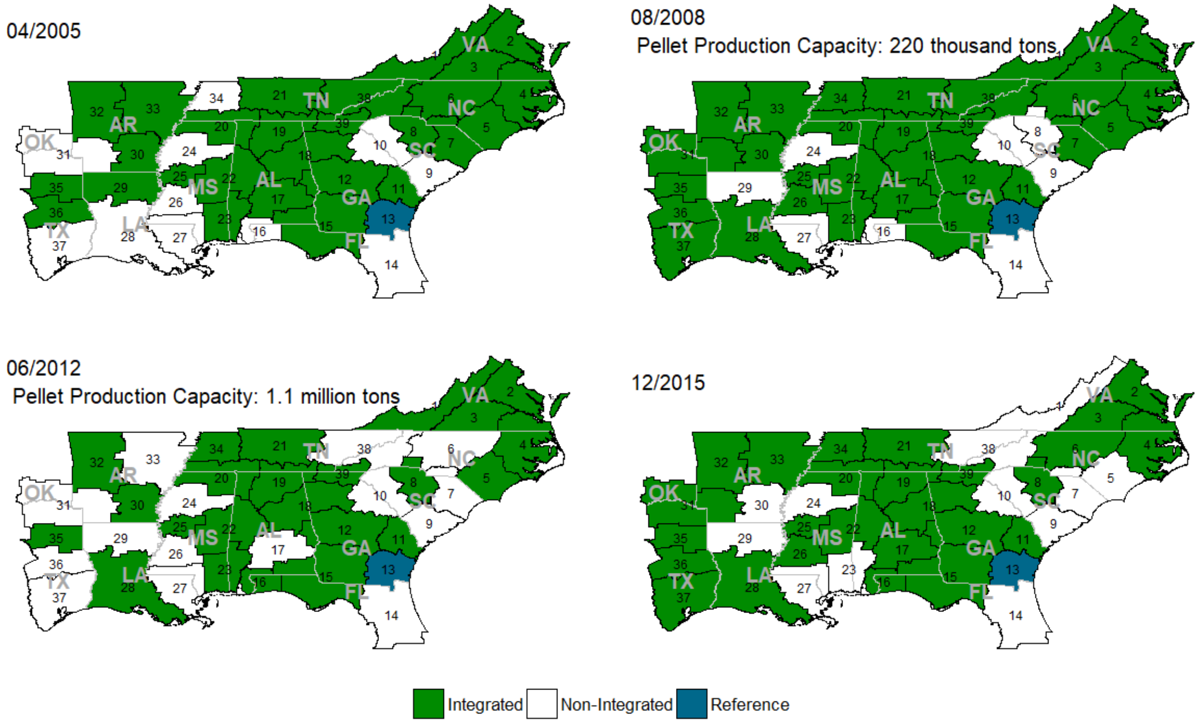

Figure 2: Spatial distribution of 38 micromarkets of softwood pulpwood. **Reference:** Microregion (13).

Table 1: Meta-Analysis Regression Results: Softwood Pulpwood

			Fixed Effect		*j - Fixed Effect*		*APE*[1]
	OLS	*Time*	*i*	*j*	$Z = I(G(.) > 0.95)$	$Z = I(G(.) > 0.99)$	*j - Fixed Effect*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Distance	−0.175***	−0.174***	−0.151***	−0.153***	−0.141***	−0.113***	−0.039***
	(0.013)	(0.013)	(0.016)	(0.015)	(0.015)	(0.015)	(0.002)
Wood Pellet[2]	−0.005	−0.012	0.001	−0.032	−0.031	−0.062***	−0.006
	(0.021)	(0.022)	(0.025)	(0.023)	(0.023)	(0.023)	(0.004)
Both[3]	−0.497***	−0.507***	−0.464***	−0.187***	−0.231***	−0.370***	−0.020**
	(0.057)	(0.058)	(0.060)	(0.065)	(0.065)	(0.065)	(0.011)
Industry[4]	−1.245	−1.199	3.360**	−1.583	−1.544	−0.900	−0.333
	(1.115)	(1.116)	(1.491)	(1.166)	(1.159)	(1.152)	(0.246)
Both Ind.[5]	0.328***	0.329***	0.146**	0.573***	0.547***	0.513***	0.017***
	(0.051)	(0.051)	(0.057)	(0.093)	(0.092)	(0.091)	(0.0076)
Logistic	−1.697***	−1.699***	−1.856***	−1.963***	−1.865***	−1.727***	−0.410***
	(0.027)	(0.027)	(0.029)	(0.029)	(0.029)	(0.030)	(0.005)
Wood Pellet x Both	0.313***	0.317***	0.269***	0.220***	0.227***	0.286***	0.03***
	(0.041)	(0.042)	(0.043)	(0.044)	(0.044)	(0.043)	0.008
Industry x Both Ind.	−3.795***	−3.803***	−2.269	−9.489***	−9.693***	−10.009***	−2.312***
	(1.242)	(1.243)	(1.385)	(1.383)	(1.375)	(1.367)	(0.163)
Pseudo R^2	0.07	0.08	0.10	0.12	0.11	0.09	

Note:[1] *Average Partial Effect,* [2] *Wood Pellet Production Capacity,* [3] *Pellet Wood Production capacity in i and j,* [4] *PPI and Composite Panel,* [5] *PPI and Composite Panel in i and j.*

*p<0.1; **p<0.05; ***p<0.01