"A Nonlinear Asymmetric Model of Lumber Price Dynamics"

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Background

- In May 2021, lumber futures peaked at over $1400 per thousand board feet (MBF), an almost 300% increase from the year prior.
- Meanwhile, stumpage prices (price on standing timber, usually valued per stump) increased by only 17% over that same time frame.
- In addition, about 69% of the softwood lumber consumed since 2017 was used for housing, with 30% for the construction of new units and 39% of consumption for the upkeep and improvement of existing units.

Research Questions & Objectives

Questions: Does the expansive lumber inventory, spurred into existence by federal policy and market conditions, insulate the owner of timberland from price shocks to housing and finished lumber markets?

Objectives:

- Detail the history of the fundamental changes in US forestry policy since the 1950s
- Collect price data for the entire stumpage-lumber-housing supply chain.
- Review the various time series approaches to modeling stumpage and lumber price dynamics
- Estimate a nonlinear auto-regressive distributed lad (NARDL) model of stumpage-lumber-housing price dynamics
- Calculate the long-run relationships between stumpage, lumber, and housing.

Importance: Prior work has only considered the supply chain in subsets and utilized less efficient estimators of the asymmetric relationship between markets.

Major Findings:

- A 1% increase in the price of new permitted housing units raises the price of softwood lumber by 0.34% (95% CI– 0.10%, 0.53%).
- Meanwhile, A 1% increase in the price of new permitted housing units has no significant effect on stumpage prices (95% CI– -0.011%, 0.0041%)

US Forest Policy Trends

- Beginning in the 1970s, the US Forest Service began to scale down timber harvests in the West, where most of the timberland is federally owned. The primary goal was conservation of endangered species.
- Simultaneously government programs and university-led research in pine plantation production enabled the south to supplant the West as the leading timber producer (see Figure 1).
- The lumber market during this time period remained competitive, especially in the south, with firms holding more and more inventories.
- As Figure 2 illustrates, most timberland ownership in the South is private, allowing owners to manage their lands to maximize production output (i.e. shorter rotations, use of chemical fertilizers, intense site preparation, and pesticides).

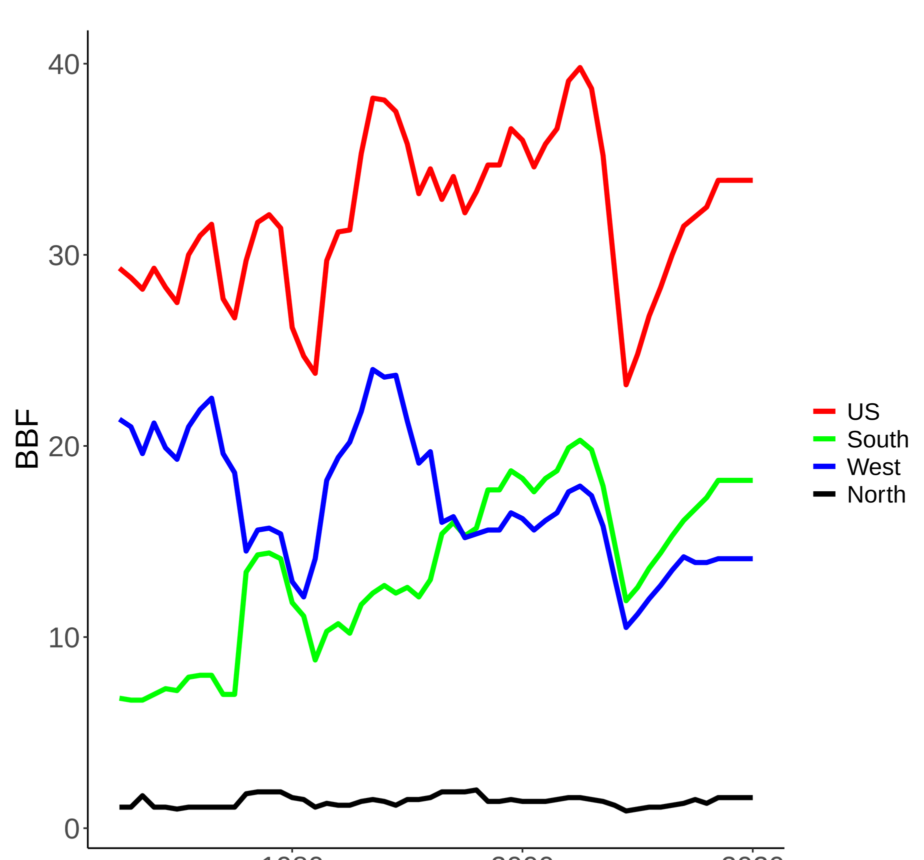

Figure 1. US Total Softwood lumber production by region 1965-2019

Source: USDA 2019

Timberland Ownership & Lumber Market Competition

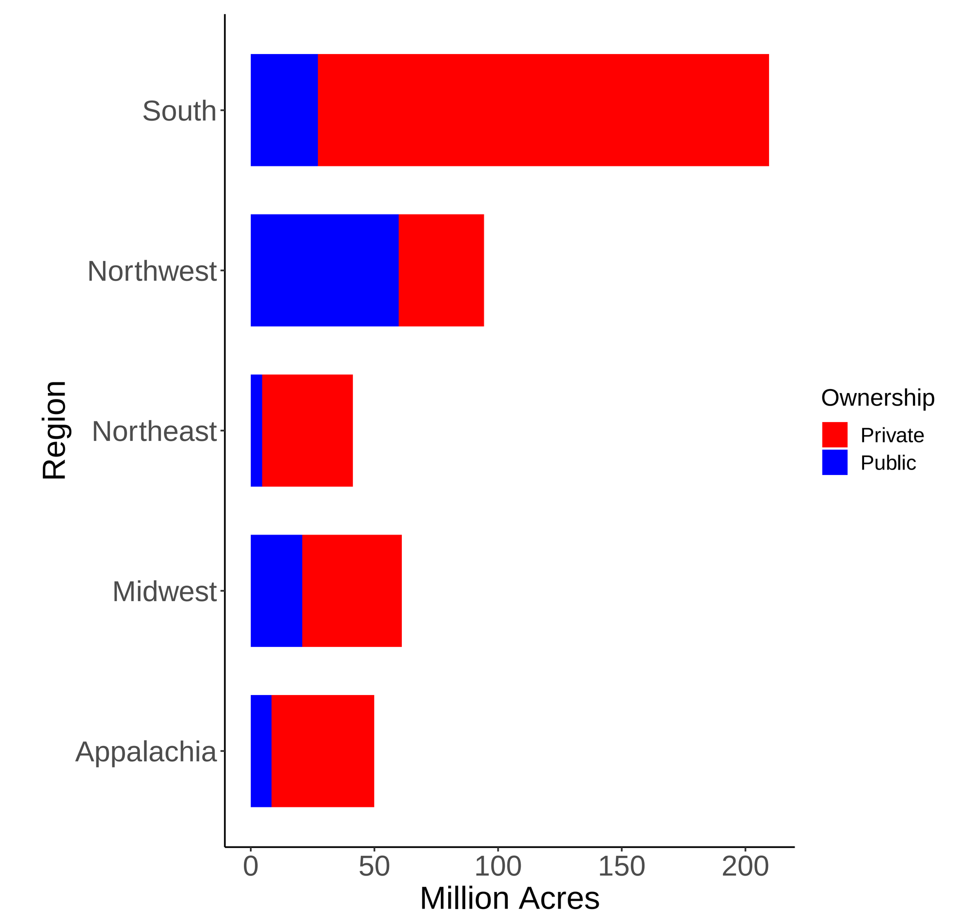

Figure 2. Public vs Private Timberland Ownership by Region

Source: Forest Inventory and Analysis (FIA) Database 2017

- A confluence of factors contributed to the expanded softwood production of the South. Pine species predominate due to their short rotation periods and suitability in the Southern climate and soils.
- In addition, the productivity gains from Southern land grant university research trials contributed significantly to increasing pine wood production. Before the 1970s, for instance, the South had only 32 million acres of private timberland. And, in 2020, the South had over 98 million acres.
- Moreover, by one measure of yield, the mean annual increment, or the average growth per year a stand of trees has exhibited up to a specified age (MAI), pine plantations in the South more than doubled the MAI in the region.

Housing, Lumber, and Stumpage Prices

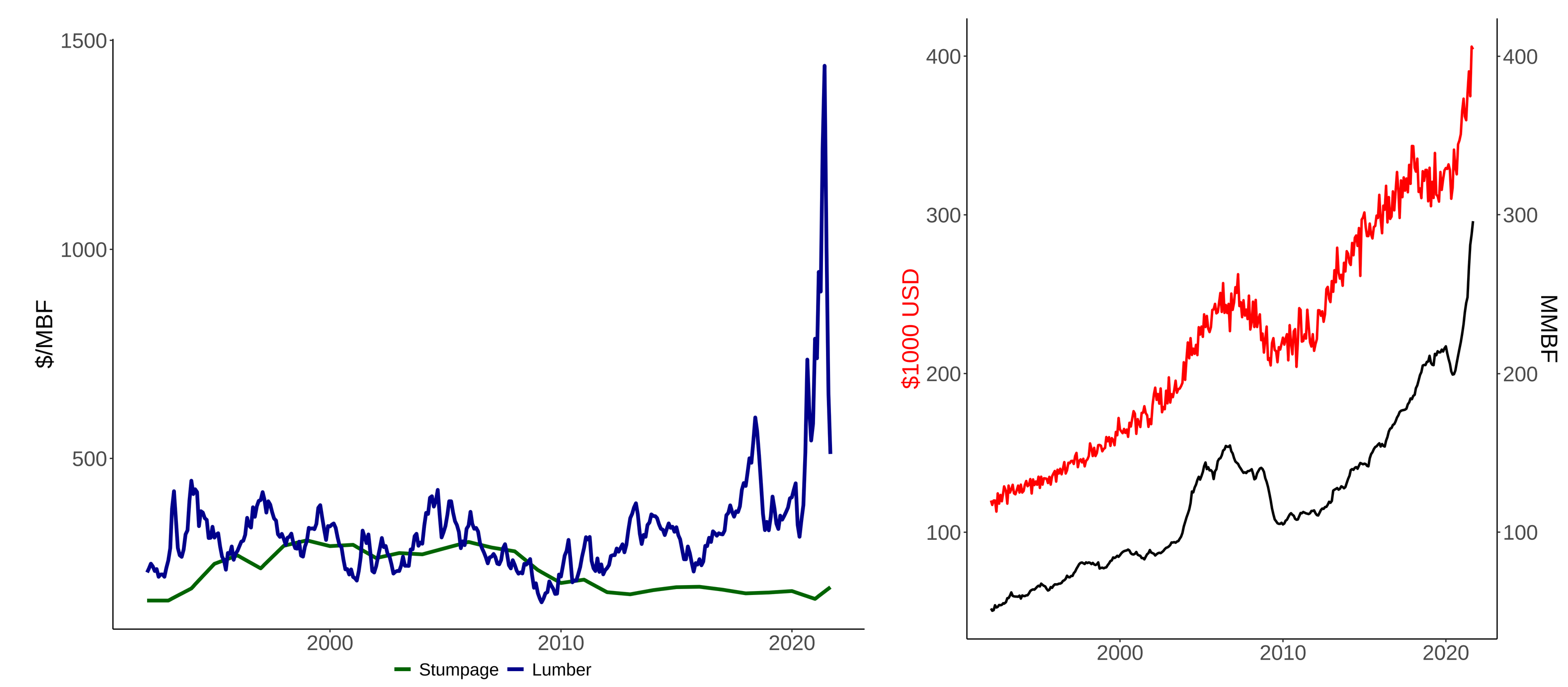

Figure 3. Monthly average South-wide stumpage prices (dark green), average continuous front-month lumber futures price (dark blue), monthly median price of new approved housing units (red) and whole-sale lumber inventory (black) 1992-2021

Source: FRED 2022, Bloomberg 2022, Timber-Mart South 2022, and CME 2022

- An important industry measure of home builder expectations is new approved housing units. In December 2021, new approved housing units peaked at more than 1.8 million units, a 29% increase from December 2019 (FRED, 2022).
- Timely completion of new home construction requires a consistent supply of lumber. The National Association of Home Builders estimates that for 2021 the average price of a new single-family home increased by more than $18,600 due to framing lumber costs (NAHB, 2022).
- Strong housing demand pushed framing lumber prices up, driving mills (primarily in the South) to expand production creating more inventory. Figure 3 shows the monthly median price of approved housing units and total merchantable wholesale lumber inventory from 1992 to 2021.
- Stumpage and lumber prices remained relatively stationary prior to the jump in housing demand in 2020. When lumber prices increased exponentially in March 2020, stumpage prices remained low.

Econometric Model

As Figure 3 illustrates, the stumpage-lumber-housing supply chain is characterized by asymmetry and nonlinearity. Previous work on lumber price dynamics utilize traditional vector error correction models (VECM) to capture these market dynamics. However, in 2013, Greenwood-Nimo and Shin proposed an alternative approach (Nonlinear Autoregressive Distributed Lag or NARDL) to estimate nonlinear asymmetric price transmission that improves upon the shortcomings of traditional VECM analysis (Greenwood-Nimmo and Shin, 2013 and Fousekis, 2016).

- The NARDL produces a more efficient estimator and is consistent under small samples compared to alternatives.
- The NARDL does not require the restrictive assumption that all series are integrated of the same order allowing for the inclusion of both I(0) and I(1) series in a long-run relationship.
- The NARDL allows for nonlinear asymmetric price adjustments by decomposing price shocks into partial sums based upon the sign of the shock.

The NARDL(p,q) is obtained for two time series $\{y_t, x_t\}$, where y_t is downstream prices and x_t is the upstream price, by partitioning x_t into positive and negative partial sums and combining the resulting long-run equilibrium relationship with the standard linear ARDL(p,q):

$$\Delta y_t = a_0 + \rho y_{t-1} + \theta^+ x^+_{t-1} + \theta^- x^-_{t-1} + \gamma z_{t-1} + \sum_{j=1}^{p-1} a_j \Delta y_{t-j} + \sum_{j=0}^{q-1} (\pi^+_j \Delta x^+_{t-j} + \pi^-_j \Delta x^-_{t-j}) + \epsilon_t \quad (1)$$

$$\text{s.t.} \quad x^+_t = \sum_{j=1}^{t} \Delta x^+_j = \sum_{j=1}^{t} \max(\Delta x_j, 0) \quad \text{and} \quad x^-_t = \sum_{j=1}^{t} \Delta x^-_j = \sum_{j=1}^{t} \min(\Delta x_j, 0)$$

We estimate two equations of the above form: (**Model I**) median new housing prices → wholesale lumber; and (**Model II**) median new housing prices → stumpage. In Model I-II, the nonlinear long-run asymmetric relationship is given by $\theta^+ x^+_{t-1} + \theta^- x^-_{t-1}$, where x^-_t an x^+_t are the negative and positive partitions of the partial sums. z_{t-1} is a vector of controls including the average 30-year fixed rate mortgage (in Model I) and lumber inventories (in Model II); lagged differences for y_t are included to account for seasonals and tends. π^+_j, π^-_j are the asymmetric distributed-lag parameters, and ϵ_t is an i.i.d. process with zero mean and constant variance, σ_ϵ.

Results

Table 1. Estimated NARDL Model I Results

Coefficient	Estimate	S.E.	t-stat	p-value
Intercept	0.34	0.078	4.40	<0.01
$\hat{\rho}$	0.38	0.053	7.23	<0.01
$\hat{a}_1$	-0.67	0.088	-7.63	<0.01
$\hat{a}_2$	0.21	0.061	3.42	<0.01
$\hat{\theta}^+$	-0.13	0.037	-3.46	<0.01
$\hat{\theta}^-$	-0.012	0.10	-0.12	0.90
$\hat{\gamma}_{1,0}$	-0.0033	0.0041	-0.81	0.417
$\hat{\gamma}_{2,0}$	0.000043	0.00001	4.16	<0.01

Residual standard errpr 0.043 on 344 DF

Adjusted-R^2 0.23

F-statistic: 14.35 on 8 and 344 DF, p.value: <0.01

The long-run relationships between positive and negative housing price changes and lumber prices are:

$$\hat{\beta}^+ = -\frac{\theta^+}{\rho} = -\frac{-0.13}{0.38} \approx 0.34\%$$
$$\hat{\beta}^- = -\frac{\theta^-}{\rho} = -\frac{-0.012}{0.38} \approx 0.032\% \quad (2)$$

Table 2. Estimated NARDL Model II Results

Coefficient	Estimate	S.E.	t-stat	p-value
Intercept	0.012	0.017	0.68	0.49
$\hat{\rho}$	0.88	0.023	37.7	<0.01
$\hat{a}_1$	-0.89	0.023	-39.0	<0.01
$\hat{\theta}^+$	0.0029	0.0033	0.87	0.38
$\hat{\theta}^-$	0.0047	0.0037	1.2	0.204
$\hat{\gamma}_{1,0}$	0.0028	0.0022	1.3	0.190

Residual standard error: 0.003333 on 348 degrees of freedom

Adjusted R-squared: 0.8564

F-statistic: 422.1 on 5 and 348 DF, p.value: <0.01

References

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[2] Matthew Greenwood-Nimmo and Yongcheol Shin. Taxation and the asymmetric adjustment of selected retail energy prices in the uk. *Economics Letters*, 121(3):411–416, 2013.