FOREST ENGINEERING, RESOURCES & MANAGEMENT

FOREST MANAGEMENT EFFICIENCY IN WESTERN AND EASTERN OREGON: A STOCHASTIC FRONTIER APPROACH

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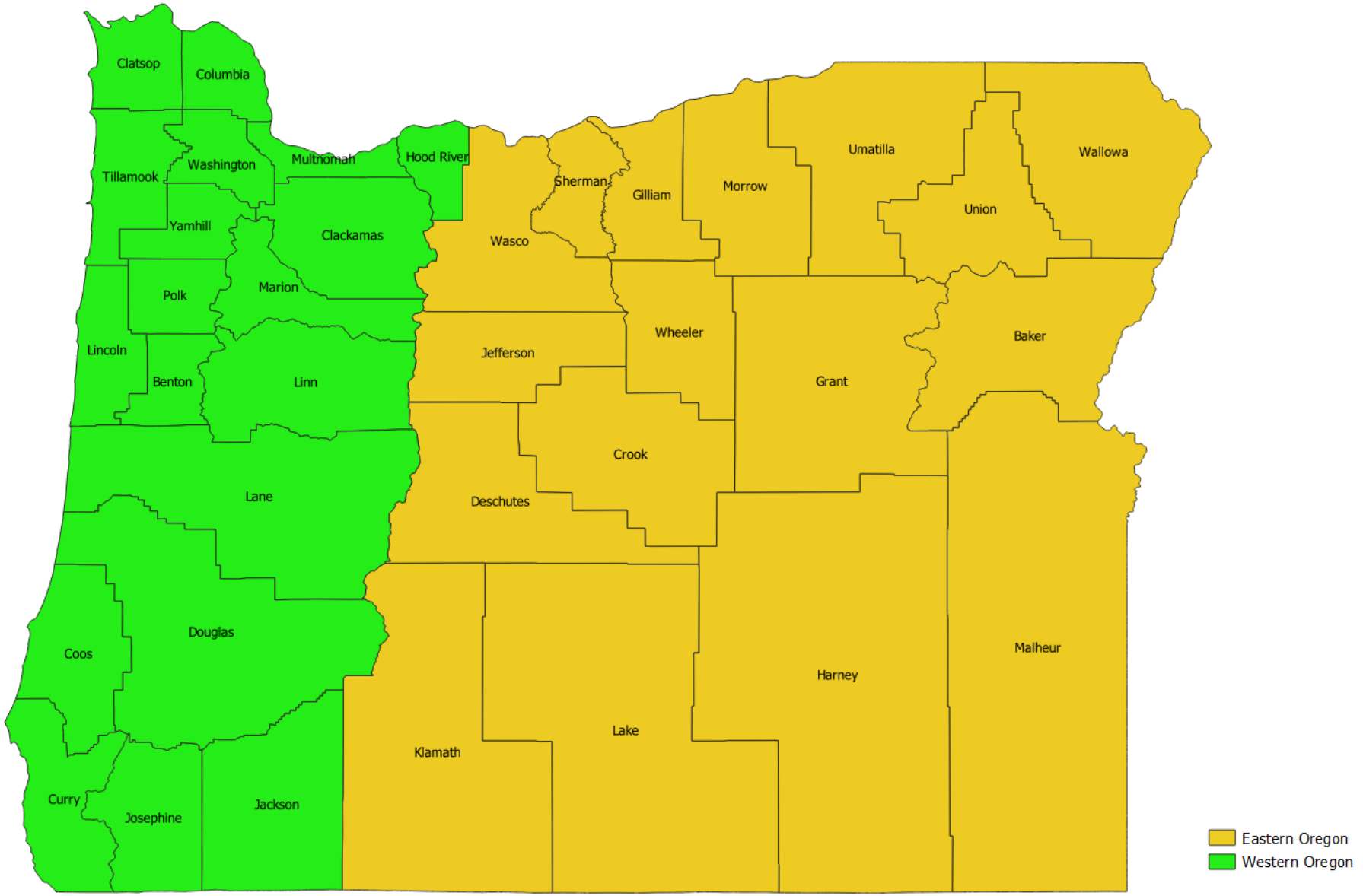
Outlines

- Background & motivation
- Research objectives
- Data source & description
- Methodology & model
- Empirical analysis & results
- Conclusions & discussion

Background

- Large areas of marginal and degraded forestlands remain underutilized in the U.S.
- Carbon-based forest management offers a pathway to increase ecosystem services (carbon, timber, water, biodiversity).
- Regional disparities in forest conditions and policy
- Growing need for multi-functional, resilient forest management
- Policy initiatives: Private Forest Accord (PFA), NW Forest Plan Amendment


Clatsop
Columbia
Tillamook
Washington
Multnomah
Hood River
Yamhill
Clackamas
Polk
Marion
Lincoln
Benton
Linn
Lane
Douglas
Coos
Curry
Josephine
Jackson
Wasco
Sherman
Gilliam
Morrow
Umatilla
Wallowa
Union
Jefferson
Wheeler
Grant
Baker
Deschutes
Crook
Klamath
Lake
Harney
Malheur
Eastern Oregon
Western Oregon

Western Oregon forest industry contribution to economy 2020–2022

	Employment				Output ($M)			
Forest Sub-sector	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
	2020							
Logging	6,628	871	3,130	10,629	819.22	90.77	513.11	1,423.10
Primary Wood Mfg.	11,605	11,203	8,217	31,025	3,515.98	1,851.35	1,346.57	6,713.90
Secondary Wood Mfg.	13,221	6,373	6,011	25,605	3,175.60	1,329.14	984.98	5,489.72
Pulp and Paper	1,135	1,971	1,352	4,459	911.99	440.00	221.62	1,573.61
Paper Converters	2,886	3,428	2,615	8,929	1,863.41	763.40	428.39	3,055.21
Wood Residue	701	587	397	1,685	314.85	114.03	65.06	493.94
Total	36,176				10,601.05			
	2021							
Logging	6,783	847	2,948	10,578	853.36	109.28	525.24	1,487.88
Primary Wood Mfg.	11,776	10,902	8,591	31,269	5,062.11	2,010.90	1,530.40	8,603.41
Secondary Wood Mfg.	13,328	5,558	5,835	24,721	3,679.31	1,373.32	1,039.40	6,092.03
Pulp and Paper	1,099	1,569	1,161	3,830	848.67	398.30	206.89	1,453.86
Paper Converters	2,886	2,930	2,391	8,208	1,816.18	733.13	425.94	2,975.25
Wood Residue	723	482	373	1,577	290.98	105.50	66.39	462.88
Total	36,595				12,550.61			
	2022							
Logging	6,515	723	2,872	10,110	948.93	97.37	530.50	1,576.80
Primary Wood Mfg.	11,694	13,651	9,522	34,867	6,413.42	2,940.20	1,758.47	11,112.09
Secondary Wood Mfg.	13,189	7,242	6,640	27,071	4,497.62	2,021.70	1,226.14	7,745.46
Pulp and Paper	1,137	1,631	1,210	3,978	945.54	458.11	223.63	1,627.28
Paper Converters	2,954	3,276	2,566	8,796	2,036.93	895.22	473.93	3,406.08
Wood Residue	701	576	397	1,674	403.06	134.46	73.25	610.77
Total	36,190				15,245.49			

Eastern Oregon forest industry contribution to economy 2020–2022

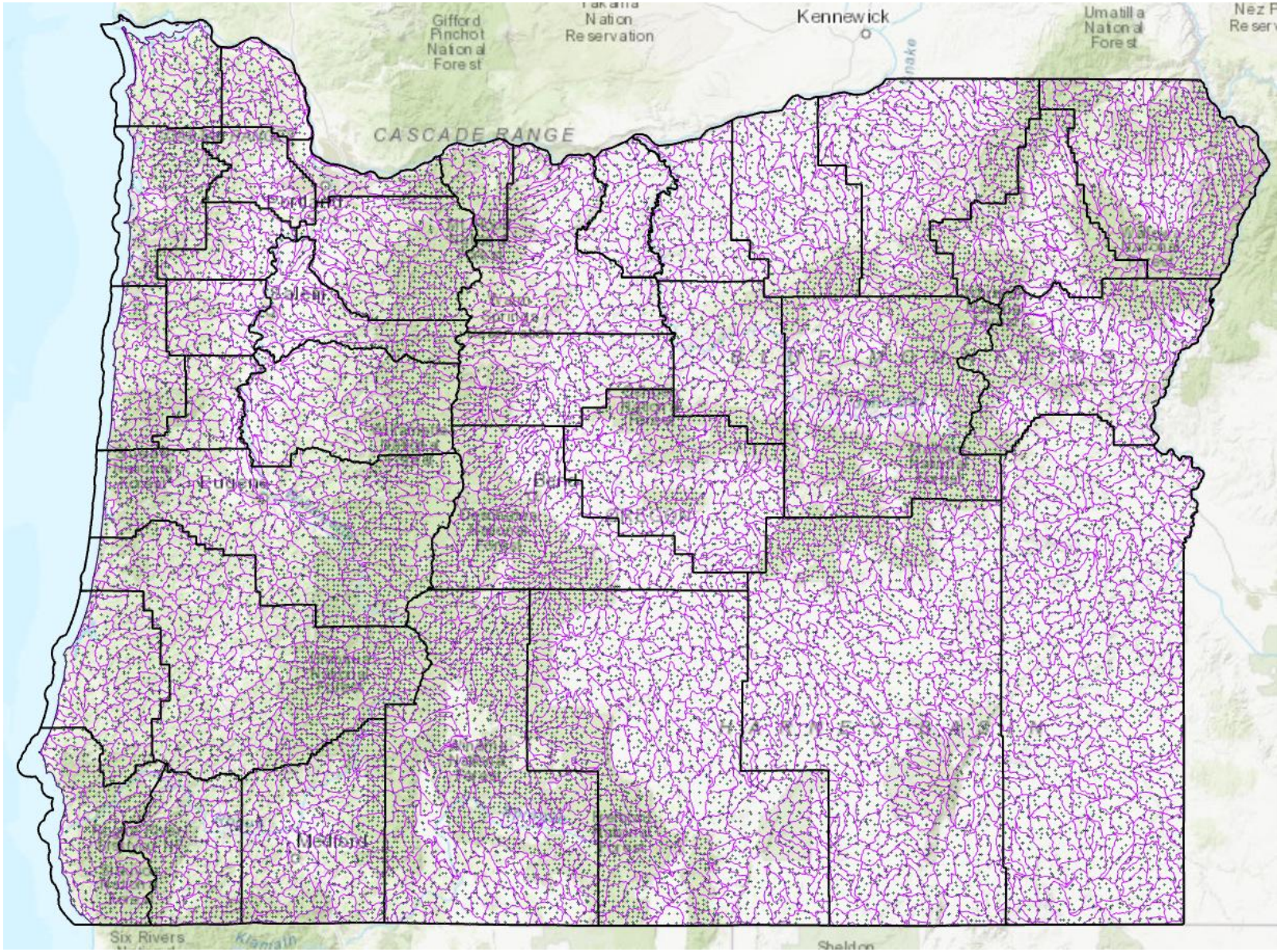
	Employment				Output ($M)			
Forest Sub-sector	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
	2020							
Logging	1,393	246	435	2,074	134.11	21.28	63.34	218.73
Primary Wood Mfg.	1,021	1,197	632	2,850	312.00	173.65	93.13	578.78
Secondary Wood Mfg.	3,216	1,607	1,221	6,045	875.57	298.63	180.22	1,354.41
Pulp and Paper	90	135	77	303	71.95	27.18	11.42	110.55
Paper Converters	3	2	2	7	1.55	0.48	0.27	2.30
Wood Residue	115	82	47	244	36.85	14.63	6.91	58.39
Total	5,838				1,432.02			
	2021							
Logging	1,173	197	400	1,770	133.79	21.25	63.77	218.80
Primary Wood Mfg.	1,049	1,125	635	2,809	445.44	198.00	102.32	745.76
Secondary Wood Mfg.	3,587	1,524	1,320	6,431	1,163.58	343.98	213.04	1,720.60
Pulp and Paper	74	92	50	216	52.36	21.56	8.12	82.04
Paper Converters	62	48	36	145	32.95	11.22	5.75	49.91
Wood Residue	109	49	37	195	25.23	9.86	6.01	41.10
Total	6,054				1,853.36			
	2022							
Logging	1,210	187	360	1,756	147.54	19.72	60.16	227.41
Primary Wood Mfg.	1,044	1,359	673	3,075	557.77	283.40	113.87	955.04
Secondary Wood Mfg.	3,890	2,228	1,632	7,750	1,693.32	578.06	276.26	2,547.63
Pulp and Paper	60	72	43	176	48.30	18.67	7.30	74.27
Paper Converters	65	53	38	156	38.41	13.48	6.42	58.30
Wood Residue	107	54	36	197	32.81	11.48	6.01	50.30
Total	6,377				2,518.14			

Research Objectives

- Assess how efficiently Oregon's forests produce multiple ecosystem services, including timber, carbon storage, and biodiversity.
- Compare technical efficiency across Western and Eastern Oregon, identifying regional strengths and management gaps.
- Inform region-specific strategies for improving forest performance under evolving policy and environmental conditions.

Data Source

- FIA data
  - Tree, Plot, Condition
  - 11,555 plots from 1995 to 2015
- Daymet
  - Day length
  - Shortwave solar radiation
  - Snow water equivalent
  - Daily maximum and minimum temperature
- Water Supply Stress Index Model (WaSSI)
  - Precipitation
  - Mean temperature
  - Evapotranspiration
  - Water Yield
  - Soil Plant Saturation


Gifford Pinchot National Forest
Yakama Nation Reservation
Kennewick
Umatilla National Forest
CASCADE RANGE
Eugene
Bend
Medford
Six Rivers
Sheldon

Data description

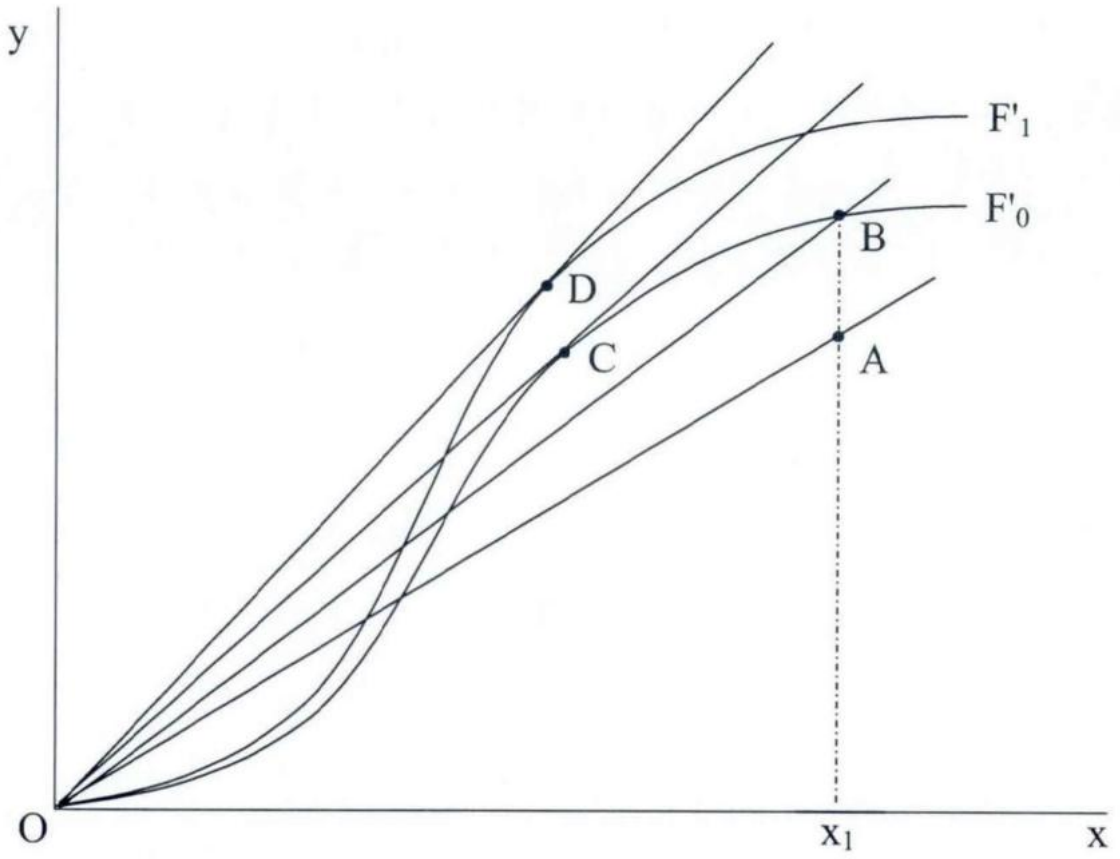
Variable	Whole	Western	Eastern
Tree Density (trees/ha)	344 (±412)	325 (±446)	369 (±361)
Site Index	90.4 (±22.5)	83.7 (±18.4)	98.2 (±24.3)
Stand Age (yrs)	101.6 (±80.1)	95.8 (±54.5)	108.7 (±102.7)
Timber Volume (ft^3/ha)	3,594 (±3,999)	1,888 (±1,836)	5,772 (±4,863)
Carbon Stock (tons/ha)	76.6 (±27.1)	68.4 (±8.2)	86.8 (±37.0)
Species Richness	2.84 (±1.46)	2.39 (±1.27)	3.42 (±1.48)
Water Yield (mm)	46.5 (±51.6)	12.8 (±17.4)	89.4 (±48.8)
Public Ownership (%)	18.1%	12.3%	25.6%
Disturbed Plots (%)	99.5%	99.2%	99.9%
Treated Plots (%)	99.1%	98.4%	99.9%

Stochastic Frontier model

$$y_{it} = f(x_{it})e^{v_{it}-u_{it}}$$

- where y_{ijt} denotes the observed output for unit *i* at time *t*; x_{ijt} is a vector of input variables; v_{it} is a random noise term, independent and identically distributed normal random variable with mean 0 and variance σ_v^2; u_{it} is a one-sided non-negative random variable capturing inefficiency.

Production Frontiers, Productivity and Efficiency



Multioutput Stochastic Frontier Analysis

- Euclidean Form
  - $Y^* = \sqrt{y_1^2 + y_2^2 + y_3^2 + \cdots + y_n^2}$

- Distance Function
  - Output-oriented distance function $D_o(X_{it}, Y_{it}) = \min\{\theta > 0: (\frac{y_{it}}{\theta}) \in T(X_{it})\}$
  - Input-oriented distance function $D_i(X_{it}, y_{it}) = \max\{\lambda > 0: (\lambda \cdot X_{it}) \in T^{-1}(Y_{it})\}$

Translog form

$$\ln y_{kit}$$

$$= \beta_0 + \sum_n \beta_n \ln X_{nit} + \frac{1}{2}\sum_n \sum_k \beta_{nk} \ln X_{nit} \ln X_{kit} + \frac{1}{2}\beta_{tt} t^2 + \sum_n \beta_{nt} \ln X_{nit}\, t$$

$$+ \beta_t t + \sum_n \gamma_n \ln Y_{nit} + \frac{1}{2}\sum_n \sum_k \gamma_{nk} \ln Y_{nit} \ln Y_{kit} + \sum_n \gamma_{nt} \ln Y_{nit}\, t + v_{it} - u_{it}$$

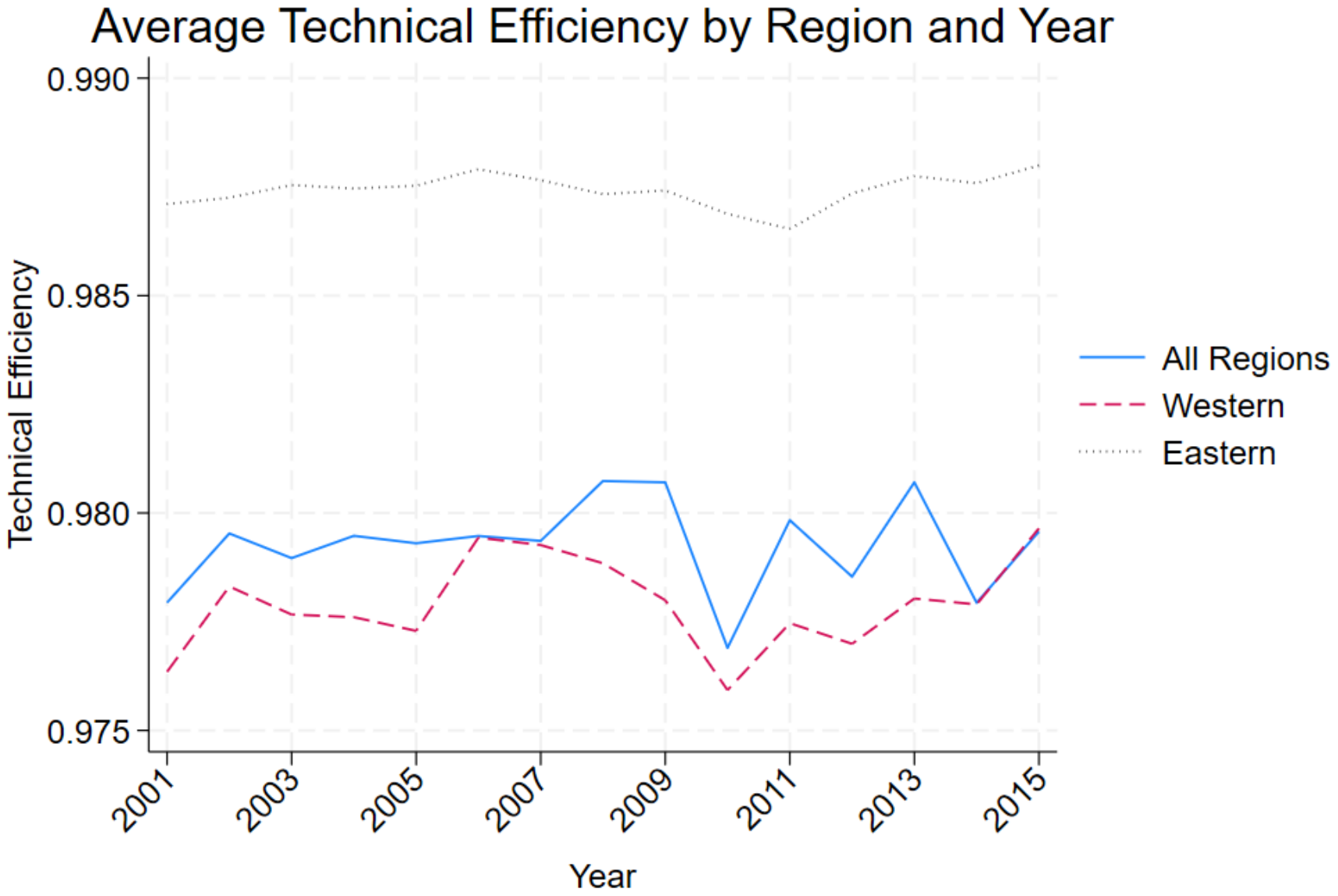
- where y_{ikt} represents the *k*-th output of plot *i* at time *t*; X_{nit} is the *n*-th input. $Y_{nit}=\frac{y_{nit}}{y_{kit}}$ for all n≠k

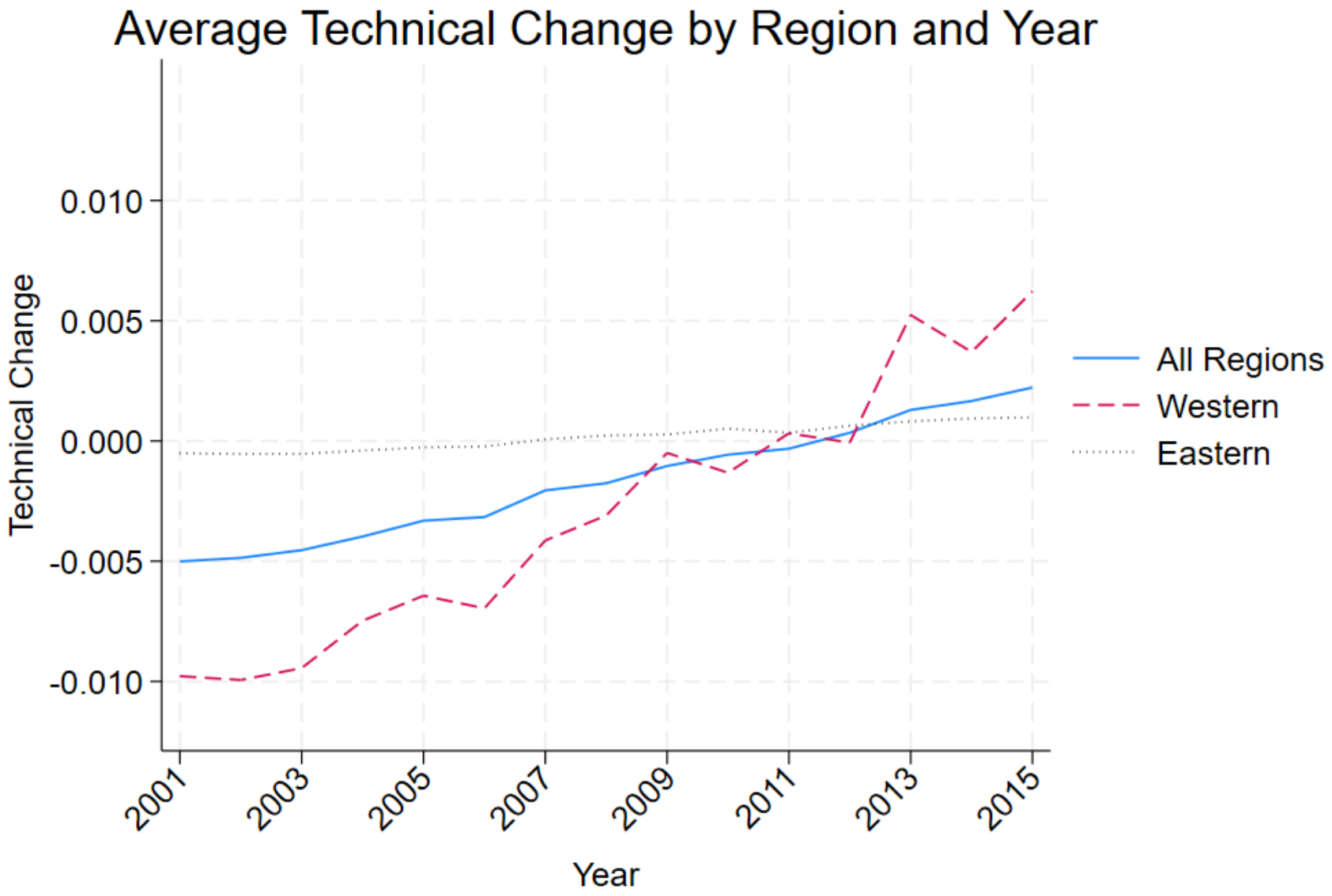
Results for inefficiency part

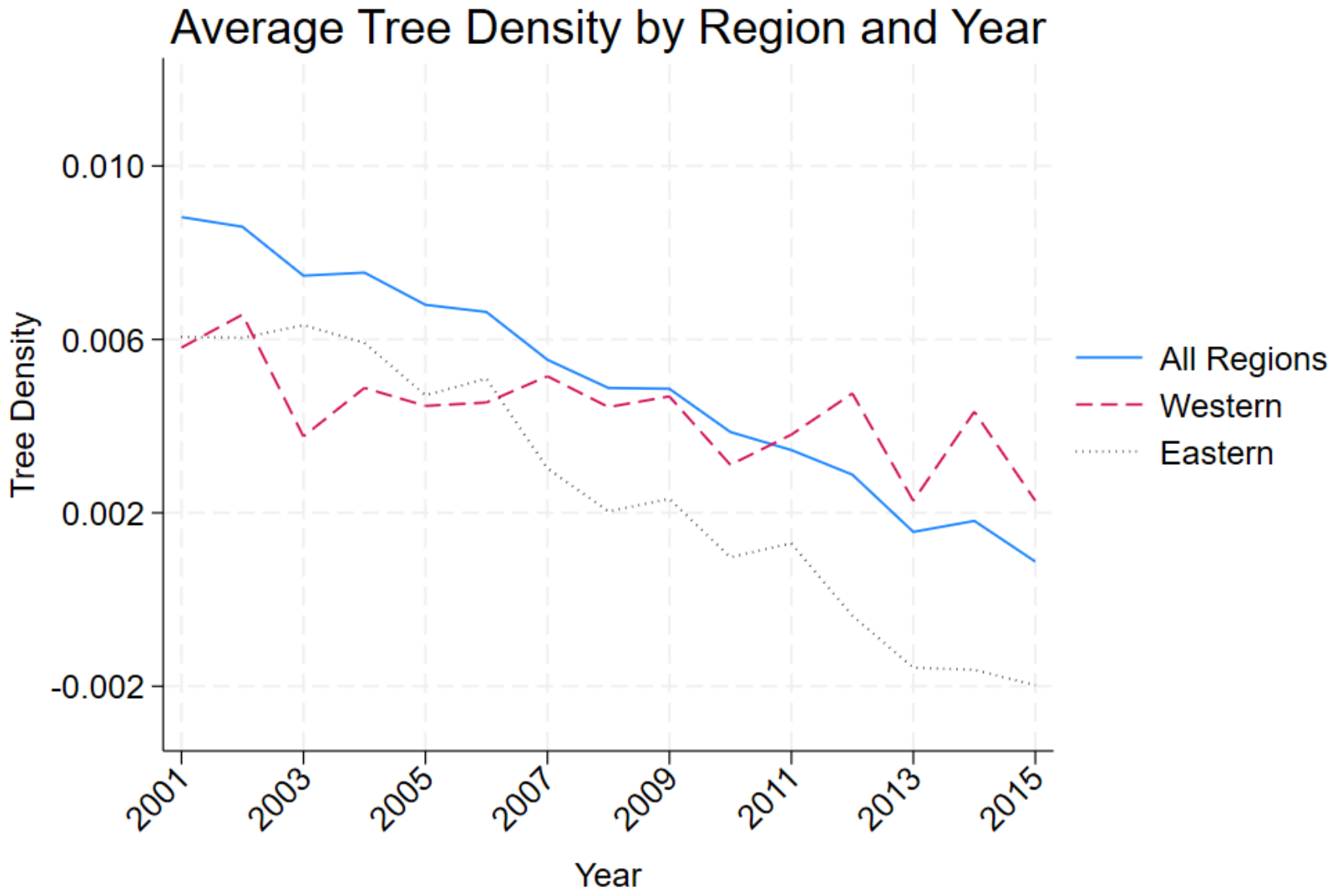
	Whole		Western		Eastern	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Owner	-0.0402***	0.0030	-1.0350***	0.1190	-2.1457	5.1626
Disturbance	0.2500	0.2000	0.0370	0.1600	0.0046	0.0100
Treatment	0.1500	0.3100	0.0240	0.4100	0.0032	0.0200
Region	-0.1127***	0.0036				
Constant	4.1206***	1.2905	2.7466***	0.3775	5.4276***	0.3594
σ_u	0.1631		0.3470		0.2187	
σ_v	0.0994		0.1038		0.0763	
$\lambda = \sigma_u / \sigma_v$	1.6407		3.3404		2.8671	
N	12,075		5,589		6,486	

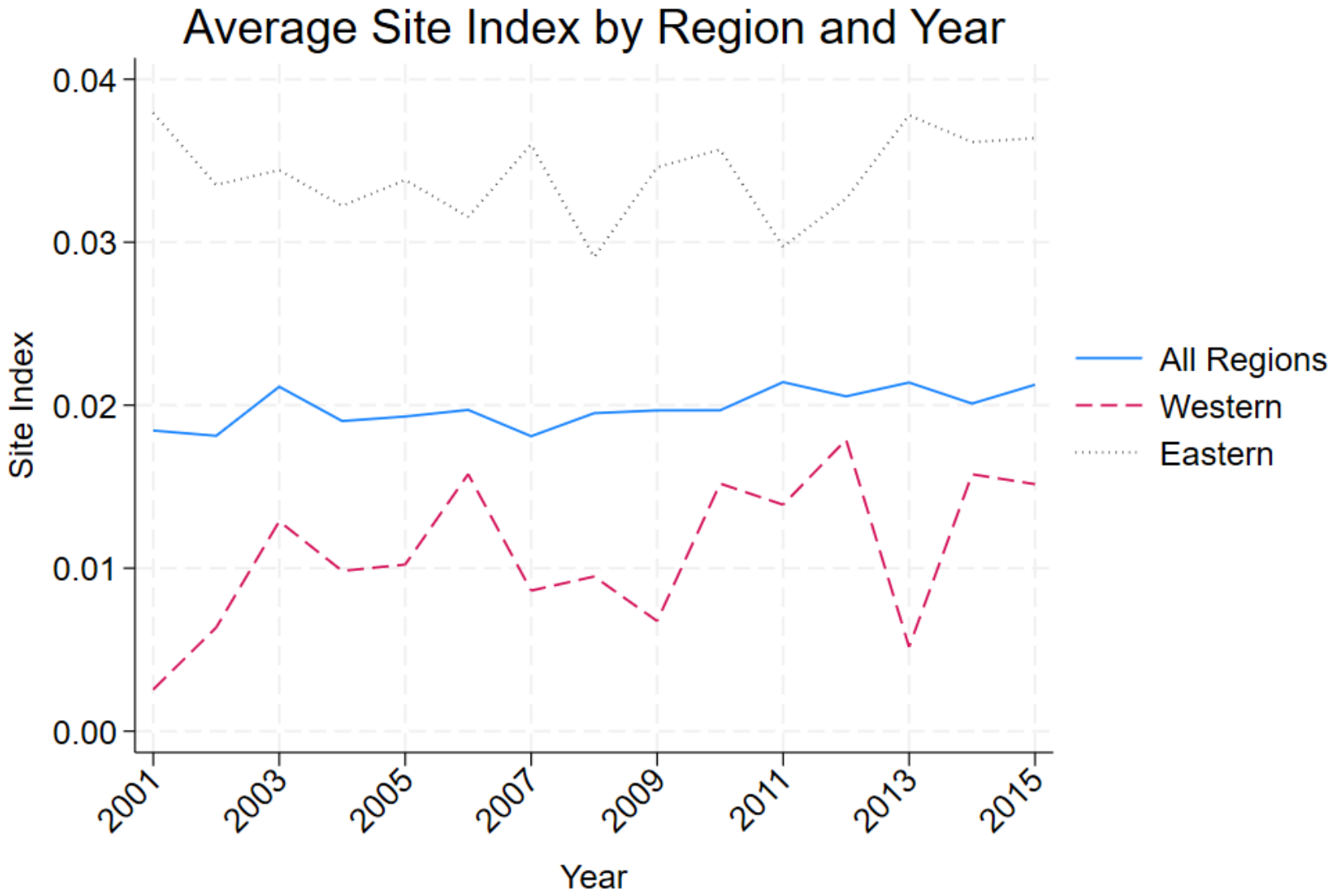
Results for frontier part

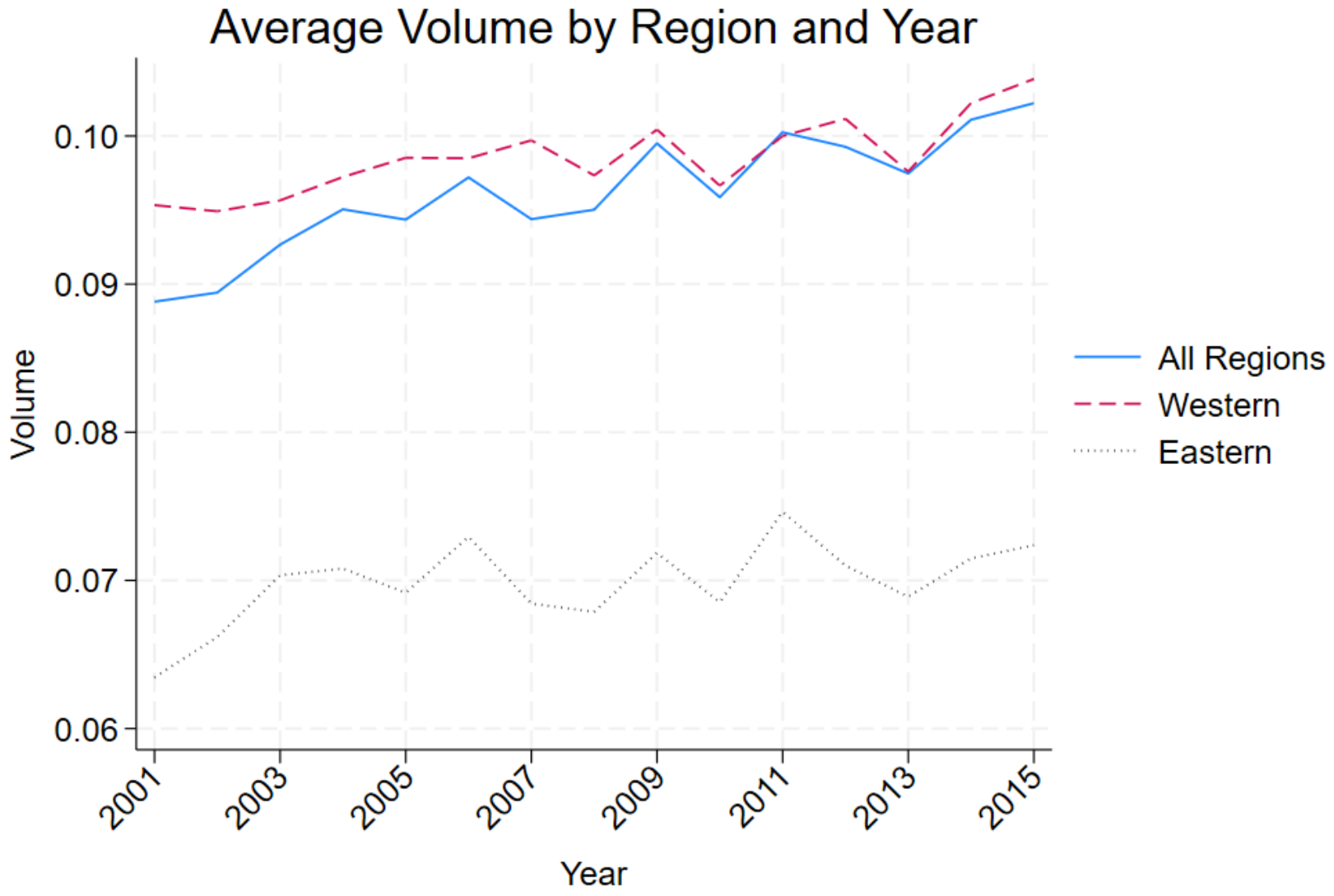
- The technical efficiency (TE) can be derived $TE = E[\exp(-u_{ijt})|e]$
- The technical change can be derived $TC = \frac{\partial \ln y_k}{\partial t}$
- The elasticity will be $\varepsilon = \frac{\partial \ln y_k}{\partial X_n}$

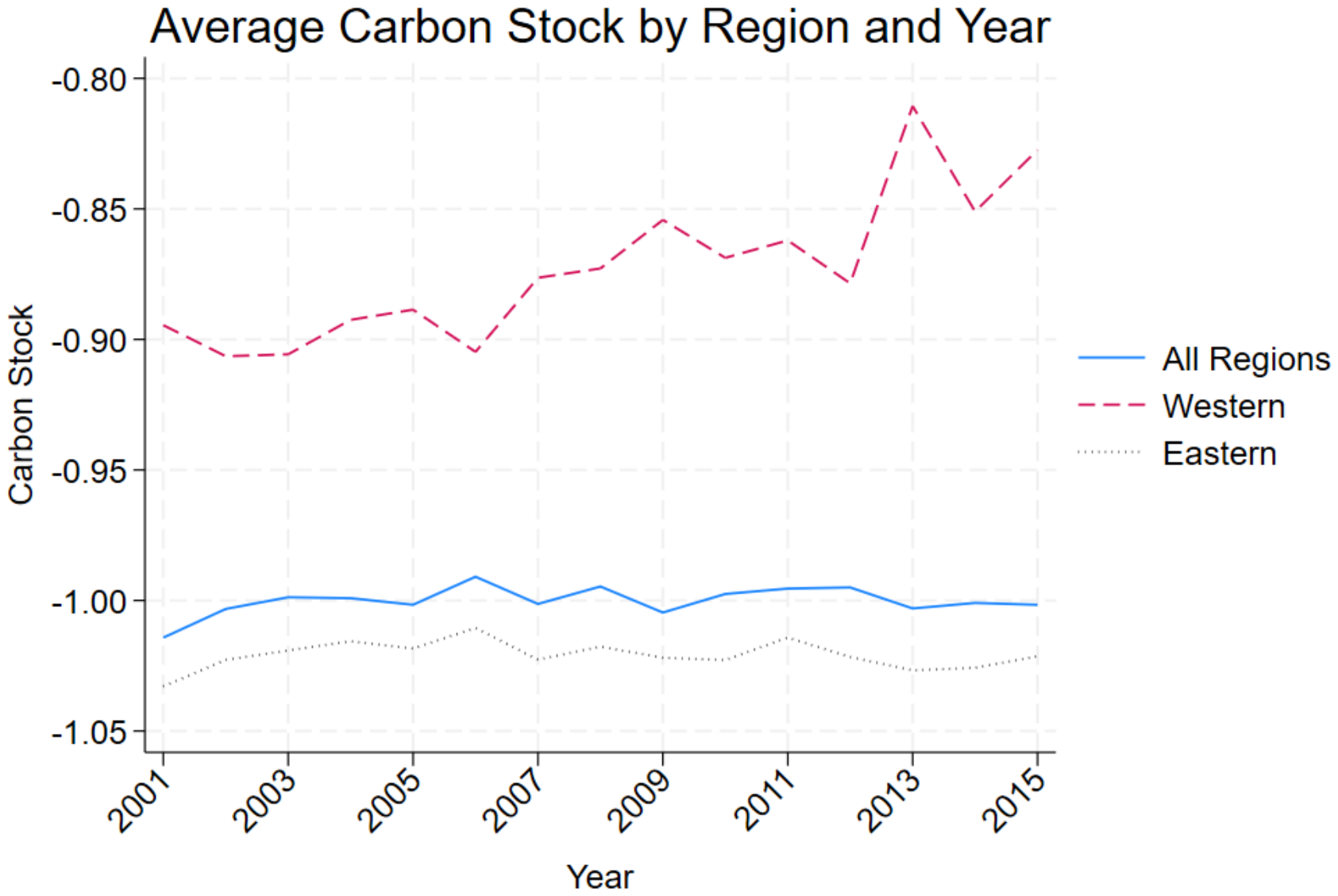

Average Technical Efficiency by Region and Year
Technical Efficiency
0.990
0.985
0.980
0.975
2001
2003
2005
2007
2009
2011
2013
2015
Year
All Regions
Western
Eastern

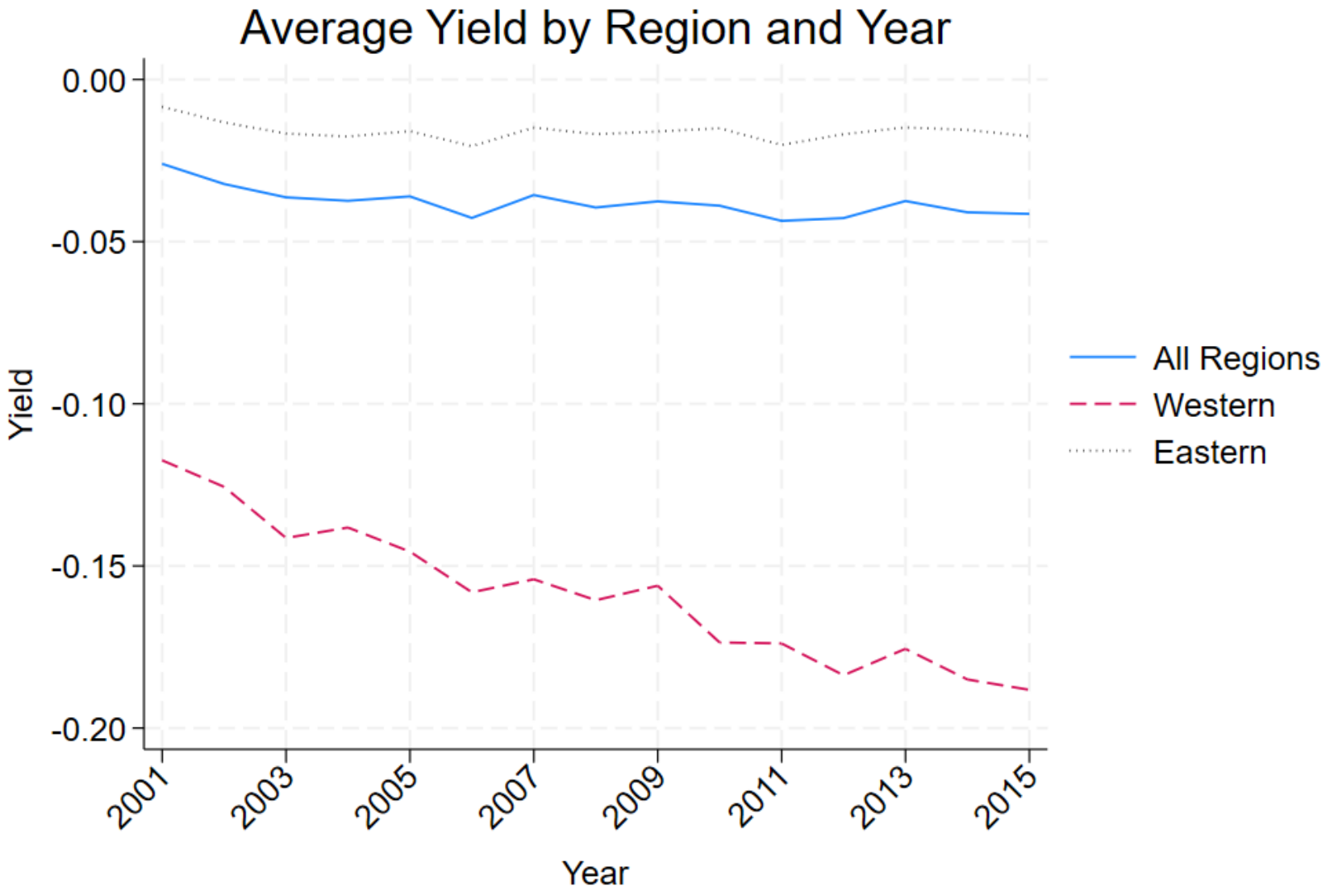

Average Technical Change by Region and Year
Technical Change
0.010
0.005
0.000
-0.005
-0.010
2001
2003
2005
2007
2009
2011
2013
2015
Year
All Regions
Western
Eastern


Average Tree Density by Region and Year
Tree Density
0.010
0.006
0.002
-0.002
2001
2003
2005
2007
2009
2011
2013
2015
Year
All Regions
Western
Eastern


Average Site Index by Region and Year
Site Index
0.04
0.03
0.02
0.01
0.00
2001
2003
2005
2007
2009
2011
2013
2015
Year
All Regions
Western
Eastern


Average Volume by Region and Year
0.10
0.09
0.08
0.07
0.06
Volume
2001
2003
2005
2007
2009
2011
2013
2015
Year
All Regions
Western
Eastern


Average Carbon Stock by Region and Year
Carbon Stock
-0.80
-0.85
-0.90
-0.95
-1.00
-1.05
2001
2003
2005
2007
2009
2011
2013
2015
Year
All Regions
Western
Eastern


Average Yield by Region and Year
0.00
-0.05
-0.10
-0.15
-0.20
Yield
2001
2003
2005
2007
2009
2011
2013
2015
Year
All Regions
Western
Eastern

Conclusion

- Eastern Oregon shows higher technical efficiency (0.987 from 2001 to 2015), indicating strong management performance relative to input levels.
- Western Oregon demonstrates higher timber volume and carbon stock, suggesting greater realized output.
- Eastern Oregon has higher tree density and site index elasticity, pointing to stronger ecological responsiveness.
- Western Oregon experienced greater technical change, reflecting adoption of improved practices post-2010.
- Overall, Eastern Oregon has more untapped potential, while Western Oregon leads in output quantity.

Discussion and Implications

- Eastern Oregon forests may benefit from investment in active management to capitalize on their high efficiency and site potential.
- Western Oregon should prioritize sustainable intensification, ensuring long-term productivity while maintaining ecosystem services.
- Policies should support adaptive practices and innovation, especially in the West where technical progress is accelerating.
- Multifunctional management—balancing timber, carbon, and biodiversity—should be tailored by region to reflect differing strengths.
- Results highlight the value of regionally disaggregated analysis in guiding future forest policy.

Thank you!