Supplemental Information for Wang and Lewis (2025)

Appendix A

Table A.1: Estimation results without wildfire variables

Log (price per acre)	
Average insect damage (thousand acre)	-0.010**
	(0.004)
Max Temp in Growing Season	-0.519
	(0.650)
Max Temp in Growing Season Squared	0.009
	(0.014)
Min Temp in Winter	0.083
	(0.069)
Min Temp in Winter Squared	0.003
	(0.011)
Soil quality	-0.025
	(0.017)
Elevation (km)	-0.001*
	(0.000)
Slope (degree)	-0.005
	(0.004)
Distance to road (km)	-0.001
	(0.009)
Distance to urban area (km)	-0.007*
	(0.004)
Constant	15.041**
	(7.502)
Year FE	Yes
County FE	Yes
Observations	28,433
R-squared	0.213

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the county level.

Table A.2: Estimation results with finer scale spatial fixed effects

Log (price per acre)	Model (1)	Model (2)
Average insect damage (thousand acre)	-0.009**	-0.006*
	(0.004)	(0.004)
Max Temp in Growing Season	-0.880*	-0.575
	(0.455)	(0.442)
Max Temp in Growing Season Squared	0.014	0.008
	(0.009)	(0.009)
Min Temp in Winter	0.122**	0.172***
	(0.048)	(0.053)
Min Temp in Winter Squared	-0.022***	-0.019**
	(0.007)	(0.008)
Large wildfires per decade on parcel	-0.330	-0.112
	(0.319)	(0.267)
Large wildfires per decade nearby (0-15 km away)	0.006	-0.003
	(0.007)	(0.005)
Soil quality	-0.022	-0.030**
	(0.014)	(0.012)
Elevation (km)	-0.001***	-0.001***
	(0.000)	(0.000)
Slope (degree)	-0.007**	-0.007**
	(0.003)	(0.003)
Distance to road (km)	-0.007	-0.014**
	(0.007)	(0.006)
Distance to urban area (km)	-0.010***	-0.009**
	(0.003)	(0.004)
Constant	25.376***	20.365***
	(5.752)	(6.242)
Year FE	Yes	Yes
Grid50 FE	Yes	No
Grid60 FE	No	Yes
Observations	28,260	28,260
R-squared	0.227	0.245

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the county level.

Table A.3: Estimation results for subsamples under different thresholds to urban boundaries

Log (price per acre)	10km buffer	15km buffer
Average insect damage (thousand acre)	-0.010*	-0.008
	(0.005)	(0.008)
Max Temp in Growing Season	-1.046	-1.346
	(0.986)	(1.525)
Max Temp in Growing Season Squared	0.019	0.027
	(0.021)	(0.032)
Min Temp in Winter	0.115	0.169*
	(0.081)	(0.091)
Min Temp in Winter Squared	-0.005	0.001
	(0.015)	(0.025)
Large wildfires per decade on parcel	0.119	-0.594
	(0.487)	(0.435)
Large wildfires per decade nearby (0-15 km away)	0.020***	0.012
	(0.008)	(0.009)
Soil quality	-0.040**	-0.069***
	(0.017)	(0.020)
Elevation (km)	-0.000	-0.000
	(0.001)	(0.001)
Slope (degree)	0.003	0.008
	(0.004)	(0.005)
Distance to road (km)	-0.001	-0.006
	(0.010)	(0.011)
Distance to urban area (km)	-0.007	0.003
	(0.005)	(0.008)
Constant	21.815*	23.796
	(11.594)	(17.831)
Year FE	Yes	Yes
County FE	Yes	Yes
Observations	18,149	10,017
R-squared	0.241	0.239

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the county level.

Table A.4: Estimation results controlling for larger timberland parcels

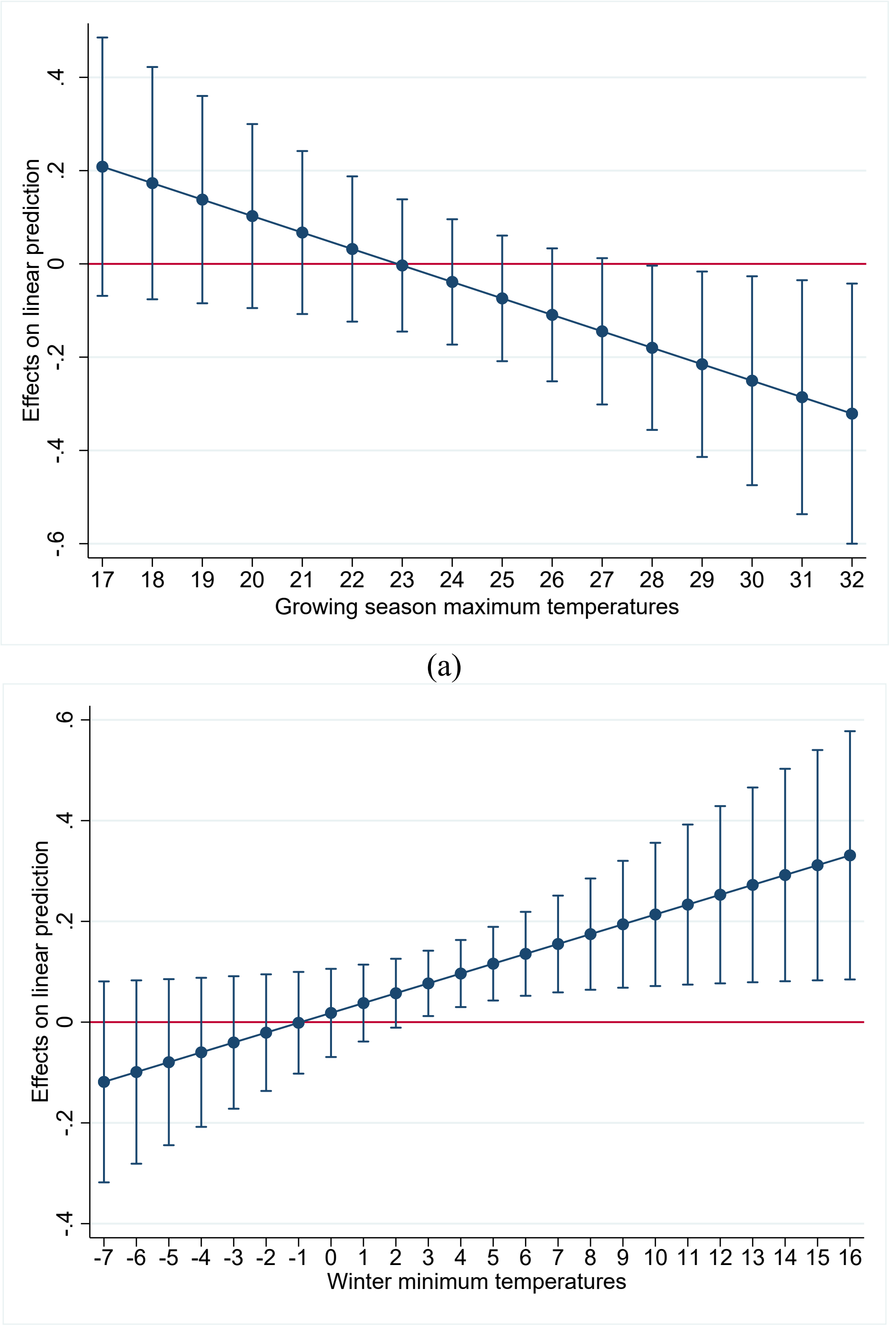
Log (price per acre)	Model (1)	Model (2)
Average insect damage (thousand acre)	0.003	-0.010**
	(0.005)	(0.004)
Max Temp in Growing Season	0.730*	-0.478
	(0.410)	(0.640)
Max Temp in Growing Season Squared	-0.016*	0.008
	(0.008)	(0.014)
Min Temp in Winter	0.026	0.089
	(0.043)	(0.064)
Min Temp in Winter Squared	0.010**	0.004
	(0.005)	(0.011)
Large wildfires per decade on parcel	0.055	0.506
	(0.526)	(0.523)
Large wildfires per decade nearby (0-15 km away)	-0.001	0.008
	(0.011)	(0.009)
Larger timberland parcel indicator	-0.233**	-0.136
	(0.100)	(0.096)
Soil quality	-0.025	-0.022
	(0.017)	(0.016)
Elevation (km)	-0.000	-0.001*
	(0.000)	(0.000)
Slope (degree)	-0.004	-0.005
	(0.004)	(0.004)
Distance to road (km)	-0.007	0.001
	(0.010)	(0.009)
Distance to urban area (km)	-0.010***	-0.008**
	(0.003)	(0.004)
Constant	-0.296	14.662**
	(5.257)	(7.405)
Year FE	Yes	Yes
State FE	Yes	No
County FE	No	Yes
Observations	28,433	28,433
R-squared	0.044	0.216

Notes: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors are clustered at the county level.

Table A.5: Estimation results without weighting by acreage

Log (price per acre)	Model (1)	Model (2)
Average insect damage (thousand acre)	-0.001	-0.007**
	(0.003)	(0.003)
Max Temp in Growing Season	0.884***	0.000
	(0.263)	(0.300)
Max Temp in Growing Season Squared	-0.020***	-0.002
	(0.005)	(0.006)
Min Temp in Winter	0.060**	0.091***
	(0.025)	(0.034)
Min Temp in Winter Squared	0.012***	-0.001
	(0.003)	(0.005)
Large wildfires per decade on parcel	-0.265	-0.294
	(0.252)	(0.218)
Large wildfires per decade nearby (0-15 km away)	-0.004	-0.007***
	(0.004)	(0.003)
Soil quality	-0.034***	-0.037***
	(0.010)	(0.008)
Elevation (km)	0.000	-0.000*
	(0.000)	(0.000)
Slope (degree)	-0.005*	-0.007***
	(0.003)	(0.002)
Distance to road (km)	-0.020***	-0.015***
	(0.004)	(0.003)
Distance to urban area (km)	-0.016***	-0.012***
	(0.003)	(0.002)
Constant	-1.164	9.836***
	(3.594)	(3.761)
Year FE	Yes	Yes
State FE	Yes	No
County FE	No	Yes
Observations	28,433	28,433
R-squared	0.083	0.191

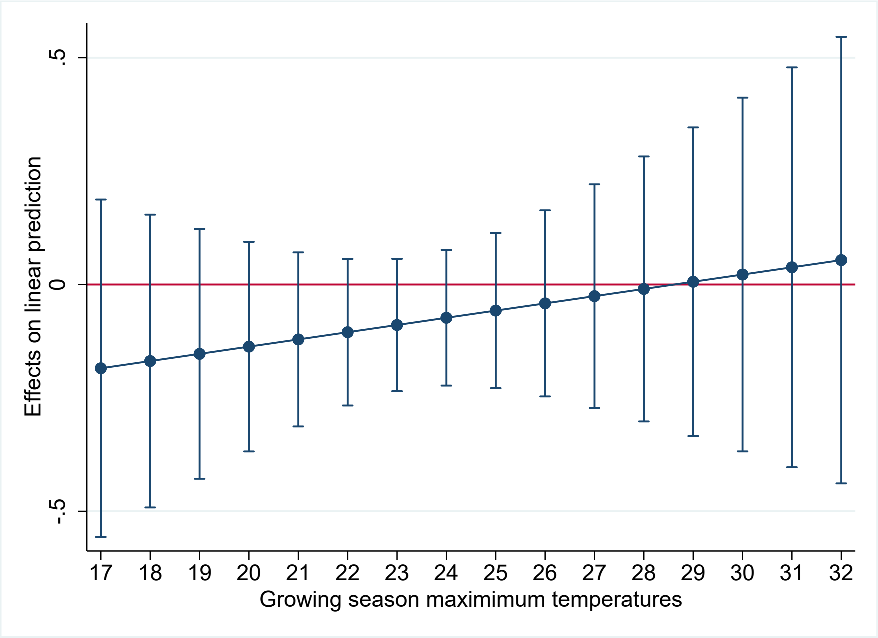
Notes: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors are clustered at the county level.



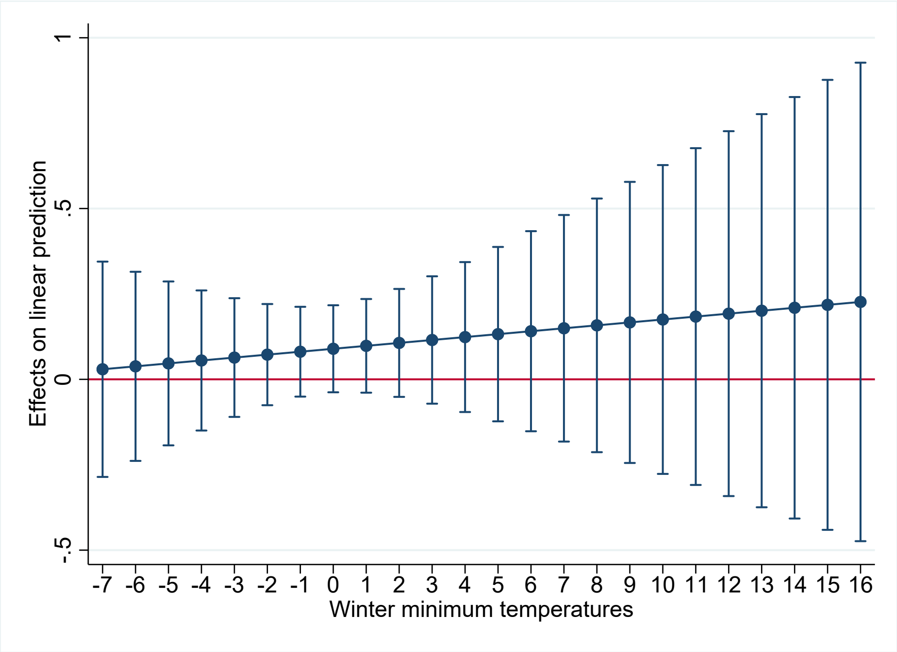
(a)

(b)

Figure A.1: Average marginal effects of growing season maximum temperatures (a) and winter minimum temperatures (b) with 95% Cis based on model (1) with state FEs



(a)



(b)

Figure A.2: Average marginal effects of growing season maximum temperatures (a) and winter minimum temperatures (b) with 95% Cis based on model (2) with county FEs

Appendix B Impacts of seasonal weather on insect damage

B.1 Hypothesized responses of forest insects to seasonal variations in temperature and precipitation: Evidence from literature

This section establishes the conceptual framework for linking insect damage to seasonal variations in temperature and precipitation, drawing on evidence from previous natural science studies with a focus on the southeastern U.S.

First, previous studies suggest that forest insects display strong sensitivity to changes in short-term temperature (Ungerer et al., 1999; Ayres and Lombardero, 2000; Duehl et al., 2011). One such example is the southern pine beetle (SPB) in the southeastern region, known for its short life cycles (within a year), high mobility, and reproductive potential, making it highly responsive even to moderate changes in temperature. Several natural science studies have explored the relationship between seasonal temperatures and insect population dynamics. Consistent findings from these studies highlight the significance of cold winter temperatures in limiting insect growth and range expansion (Ungerer et al., 1999; Gan, 2004; Munro et al., 2022). As winter temperatures rise with climate change, there are fewer limits to insect survival during winter and an expected expansion of their geographical range (Hain et al., 2011). However, in contrast to temperature, there is more uncertainty in the relationship between precipitation and insect populations. Previous studies suggest that while precipitation plays an important role, its impact on insect dynamics is mixed and relatively minor in comparison to temperature (Gan, 2004; Munro et al., 2022).

There is also evidence showing that temperature and precipitation may interact, as summertime drought from increased summer temperatures and decreased precipitation contributes to increased insect outbreaks by weakening trees' defense mechanisms, reducing their ability to protect against bark beetle attacks (Raffa et al., 2008; Weed et al., 2013). The drought impact has been mostly observed and analyzed in bark beetle outbreaks in the western U.S. (Chapman et al., 2012; Kolb et al., 2016), with little consistent evidence found in the southeastern U.S. Finally, earlier research has also indicated that lagged seasonal climatic conditions play a crucial role in affecting insect populations (Kroll and Reeves, 1978; Gan, 2004). For example, Gan (2004) finds that the SPB in the southeastern region demonstrates a response to lagged seasonal temperatures for a period of up to three years due to the response time for SPB populations to develop.

B.2 Data

Our county-level insect damage data comes from the USDA Forest Service's Forest Inventory Analysis (FIA) between 2004 and 2019 across 10 states in the southeastern U.S. As discussed in Sec. 2.2 in the manuscript, we have excluded insect data prior to 2000 due to inconsistencies within the data collection methodology. The dependent variable is annual insect-damaged forest acres per county and year.

An alternative source of insect data is the USDA Forest Service's Insect & Disease Detection Survey (IDS). The IDS data provides the annual and spatially explicit data on major forest disturbances including both biotic factors such as insects, and abiotic factors such as drought, wind, and hurricanes across the entire U.S. The IDS dataset contains detailed information on the extent and severity of each forest disturbance, as well as the characteristics of host trees. While the IDS data provides valuable spatial information on species-specific damage, it has two major limitations that make it unsuitable for our study. First, the IDS data is primarily collected through ground or aerial surveys, which are subjective in nature (Hicke et al., 2020). This subjectivity introduces potential measurement errors or inconsistencies in evaluating insect severity, damage areas, and tree mortality due to differences in surveyors' knowledge, methodology, and experience, view conditions, and the flying conditions (Bright et al., 2020). Additionally, the IDS survey was not conducted in a systematic and comprehensive manner, resulting in varying areas being surveyed within each state across years (Kosiba et al., 2018; Asaro et al., 2023). This lack of uniform coverage means that there may be areas affected by insect activities that were not detected or captured in the IDS database. Therefore, although the IDS dataset is valuable for illustrating the spatial extent of forest insect damage, we find the FIA data more suitable for our analysis due to its consistency, comparability, and reliability across a large scale.

We construct seasonal mean temperature and total precipitation variables for each county using historical monthly climate data at 4 km resolution from Oregon State University's Parameter-elevation Regressions on Independent Slope Model (PRISM) dataset. We define four seasons: winter (December-February), spring (March-May), summer (June-August), and fall (September-November). Specifically, we compute county-level seasonal variables by averaging grid cell values of temperature and precipitation that fall within each county using ArcGIS Pro Extract Values to Points function based on the monthly PRISM data.

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