FHFA STAFF WORKING PAPER SERIES

Applying Seasonal Adjustments to Housing Markets

William M. Doerner
Wenzhen Lin

November 2022

Working Paper 22-03

FEDERAL HOUSING FINANCE AGENCY
Division of Research and Statistics
Office of Research and Analysis
400 7th Street SW
Washington, DC 20219, USA

Please address correspondence to William Doerner (william.doerner@fhfa.gov). Helpful feedback was provided by Justin Contat and Albert Yoon as well as conference participants from the American Real Estate Society.

Applying Seasonal Adjustments to Housing Markets

William M. Doerner and Wenzhen Lin

FHFA Staff Working Paper 22-03

November 2022

Abstract

House price seasonality has been increasing over the last decade, but adjustments have remained largely unchanged in commonly used public data. This paper shows how seasonal adjustments work—both theoretically and applied to observed transactions—when constructing house price indices (HPIs). In this paper, we find the seasonality in the housing market is not uniform across geographies. Evidence is provided about where adjustments are more necessary, how often they should be recalculated, and how the weather-related variables, social and industry characteristics impact difference between adjusted and non-adjusted HPI. Using the Federal Housing Finance Agency's (FHFA's) entire suite of public indices, we update adjustments that have been provided by the FHFA and offer new adjustments for over 400 metropolitan areas and other geographies, which haven't been provided before. We find the difference between previous and updated adjusted indices are relatively small, with slight improvement in recent years.

Keywords: seasonality · house price · real estate valuation · X-13

JEL Classification: C5 · E3 · R1 · R3

William M. Doerner
Federal Housing Finance Agency
Division of Research and Statistics
Office of Research and Analysis
400 7th Street SW
Washington, DC 20219, USA
william.doerner@fhfa.gov

Wenzhen Lin
Syracuse University
Maxwell School
Economics Department
110 Eggers Hall
Syracuse, NY, 13244-1020, USA
wlin18@syr.edu

1. Introduction

House price seasonality has been increasing over the last decade, and regularly utilized and reported house price indices (HPIs) are known to fluctuate due to seasonal events such as changes in weather, major holidays, and school schedules. Mismeasurement could affect how quickly or intensely public policy responds to housing market issues. Nonetheless, seasonal adjustment terms and processes have remained largely unchanged in commonly used public data. Seasonal adjustment is a statistical technique that attempts to measure and remove the influences of predictable patterns, which allows data users to better to understand the changes in housing market conditions. This report contains two parts. At first, the authors show how seasonal adjustments work and recalculate the entire suite of public indices provided by the Federal Housing Finance Agency (FHFA). Then, the authors study how adjusted and non-adjusted HPIs have been impacted by changes in weather, such as temperature ranges, average temperature, and precipitation, for both state and metropolitan statistical area (MSA) levels.[1]

Many studies, such as Reichert (1990), Goodman (1993), Kaplanski and Levy (2012), and Ngai and Tenreyro (2014), have looked at certain factors to explain the housing market seasonality, such as daylight savings, marriages, school holidays, interest rates, and climate change. Granger (1978) discusses at least four classes of causes of seasonal fluctuations in economic data, including calendar, timing decisions, weather, and expectation. The changes in weather-related variables might have indirect or direct effects on moves: parents of school-age children have specific reasons for moving during the summer break of school, and marriages peak in the early summer, which influences the moving decisions for those newly married couples(Goodman, 1993). However, Miller et al. (2013) use the house price data at the Core Based Statistical Area (CBSA) level to study the seasonality components and find that the temperature variables do not significantly affect the seasonality in the house price. This paper will look closely at weather-related variables, which could help explain the seasonality in house prices. Unlike the definition of the range of temperature in Miller et al. (2013), who use the average summer temperature minus the average winter temperature, this paper utilizes the difference between the minimum temperature and maximum temperature for every quarter. Defining temperature by its range each quarter allows for weather effects to

[1]MSAs are based on delineations by the Office of Management and Budget (OMB) as of March 2020 in OMB Bulletin No. 20– 01. The file can be accessed at https://www.whitehouse.gov/wp-content/uploads/2020/03/Bulletin-20– 01.pdf.

capture larger shifts, which uncovers the impact of the extreme hot or cold seasons on seasonality. Perhaps not surprisingly, the range of temperature is significant and different across quarters. Compared with the impact of the range temperature in Q4, extreme cold winter (with a larger range of temperature in Q1) and extreme hot summer (with a larger range of temperature in Q3) increase the seasonality because it is less pleasant for homebuyers and sellers to engage in market transactions

Several methods have been used to explore the seasonality in the housing market. The study by Ngai and Tenreyro (2014) uses a search-and-matching model with thick-market effects to study hot and cold seasons of the housing market in the United States and the United Kingdom from 1991 to 2007. Harding et al. (2003) use the hedonic price model to identify the influence of buyer and seller characteristics on bargaining power. Miller et al. (2013) use linear regression with the dependent variable being the variation in seasonality in the CBSAs as measured by standard deviation. This paper takes a different route by addressing the actual seasonally adjusted terms.[2] This alternative methodology is conducted in two steps: demonstrate the seasonal adjustments are computed correctly and show whether the changes matter. In the first step, the challenge is that program versions have changed and newer data are available. To isolate the moving parts, a replication is done for the prior program results with prior data before switching to the newer program with prior data and, ultimately, using the newer program on newer data. This switching involves X-13ARIMA-SEATS (X-13), a seasonal adjustment program that merges X-12-ARIMA (X-12) and the seasonal adjustment module of the TRAMO-SEATS program (Gomez and Maravall), to make the seasonal adjustment. The difference between previous and updated adjusted indices is relatively small, but with slight improvement in recent years. In the second step of the methodology, seasonality in the housing market is shown not to be uniform across geographies. To study where adjustments are more necessary, a combination of linear and quantile regressions investigate what impacts the difference between a nonseasonally and seasonally adjusted HPI. The results show that the weather-related variables would help to explain the difference, and the effects are larger in the higher seasonality level areas than in the lower seasonality level areas.

The remainder of this paper is organized as follows. The next section discusses the data

[2] To be fair, other studies have not had the advantage of accessing the entire databases used to create public measures.

and methodology adopted, followed by the empirical results and robustness tests. In the last section, the conclusion reflects on the implications of adjusting more frequently for seasonality and how that choice is complicated by the large housing market changes during the COVID-19 pandemic.

2. Data and Methodology

The core focus of this study is to test whether or not there is seasonality in home prices. The technical methodology has two steps. At first, attention is given to the programs used for seasonal adjustment, X-12 and X-13, to show how optimal terms are calculated and applied. After that, a new seasonally adjusted HPI is calculated from the first step to determine the absolute value of the difference between the nonseasonally and seasonally adjusted HPI as the dependent variable in the second step. Moreover, linear regression and quantile regressions try to uncover what might impact the seasonality.

2.1 Step 1: Seasonal Adjustment

Cyclical price adjustments can be diagnosed and corrected with automated statistical routines. Seasonal adjustment is easily demonstrated with standard simulations but is less straightforward when multiple data-generating methods are combined. The optimal choice is seldom unique and is sensitive to choices such as sequence lengths and whether outliers are downweighted. When transitioning from simulated to actual data, the challenge becomes even tougher to recalculate cyclical price adjustments for public repeat-sales indices that vary in sales transaction samples and geographic coverage. Below is a demonstration of how seasonal adjustments work theoretically and on actual data by using X-13. The appendix provides more detailed exercises about how the program and options were calibrated with simulated data.

2.1.1 X-13ARIMA-SEATS Routine

FHFA has used the X-12 routine in the past, and the X-12 software is one of the most popular methods for seasonal adjustment; however, the software functionality has since been upgraded to X-13, which is downloadable from the Census Bureau. X-13 merges with the version of X-12 and SEATS. The version of X-12 used in X-13 is version 0.3, and a crucial new feature of Version 0.3 of X-12 is an updated automatic AutoRegressive Integrated Moving Average (ARIMA) model identification procedure, based on Gomez and Maravall. Three stages are needed to complete the seasonal adjustment: model building, seasonal adjustment, and diagnostic checking. In the first stage, regARIMA performs prior adjustments for various effects, such as trading-day effects, moving holiday effects, and outliers. In the second stage, X-12 estimates its parameters by maximum likelihood using an iterated generalized least-squares algorithm. The third stage is diagnostic checking, examining the residuals from the fitted model, including outlier detection, normality test, and the Ljung-Box Q test.

To present the general regression for an regARIMA model, a formula is used similar to in Wang and Wu (2012), and it can be written as

$$\phi(B)\Phi(B^s)(1-B^s)^D(y_t - \sum_{i=1}\beta_i x_{it}) = \theta(B)\Theta(B^s)\epsilon_t, \tag{1}$$

where y_t is the dependent variable to be adjusted; B is the lag operator, $By_t = y_{t-1}$; s denotes the seasonal period; $\phi(B) = 1-\phi_1 B - ... - \phi_p B^p$ denotes the regular autoregressive operator; $\Phi(B^s) = 1 - \Phi_1 B^s - ... - \Phi_P B^{Ps}$ denotes the seasonal autoregressive operator; $\theta(B) = 1 - \theta_1 B - ... - \theta_q B^q$ denotes the regular moving average operator; $\Theta(B^s) = 1 - \Theta_1 B - ... - \Theta_Q B^{Qs}$ denotes the seasonal moving average operator; and the ϵ_t are independent and identically distributed (i.i.d.) with mean 0 and variance σ^2.

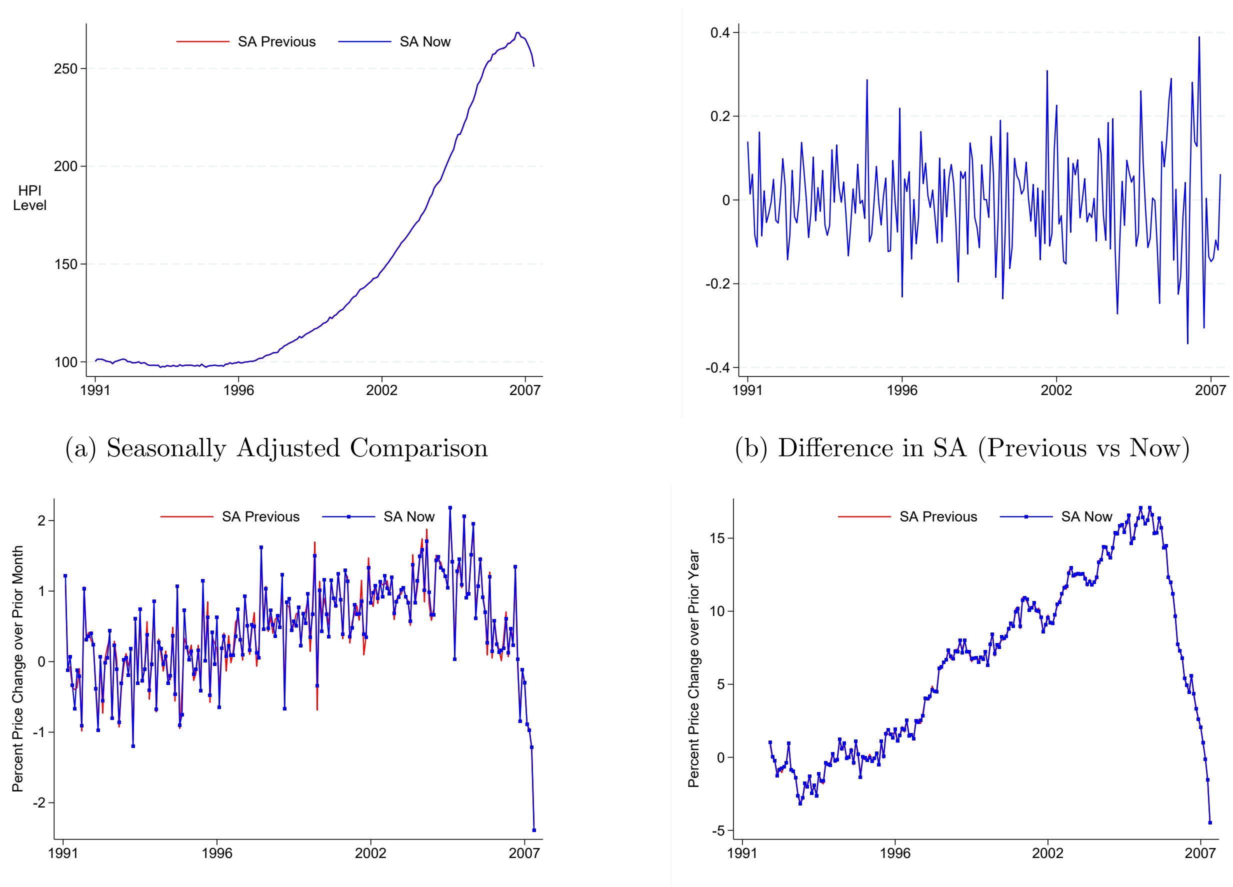
2.1.2 Seasonality in Housing Markets

The seasonally adjusted term structures are updated in two steps. First, it is necessary to show what happens to the seasonally adjusted HPI when switching from one program (X-12) to a new version (X-13) but while retaining the original optimal term structure. Figure 1 compares the prior seasonally adjusted HPIs performed by X-12 and the new seasonally adjusted HPIs done by X-13. The adjusted indices are extremely similar. The results show that the lines of previous and current seasonally adjusted house prices, monthly appreciation rates, and annual appreciation rates are overlapping, and the difference between them is very small (almost visually not noticeable) across the panels.

Second, the optimal parameters are recomputed with newer data, and those newly adjusted indices are compared to the entire suite of public indices provided by FHFA.[3] Figure 2 also illustrates the differences with the new HPIs are relatively minor, but the newly adjusted

[3] As noted later, the exercise extends slightly further by offering adjustments that have not been provided for 400 MSAs and other geographies. Previously, ARIMA routines were not run regularly because of computational challenges, but these have largely been overcome as shown in the appendix, which lists the approximate production times as estimated by each type of index and geography.

Figure 1: SA Terms after Switching from X-12 to X-13



(a) Seasonally Adjusted Comparison

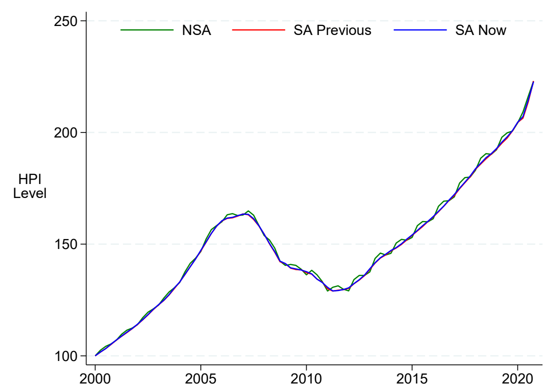
(b) Difference in SA (Previous vs Now)

(c) Changing Monthly Appreciation Rates

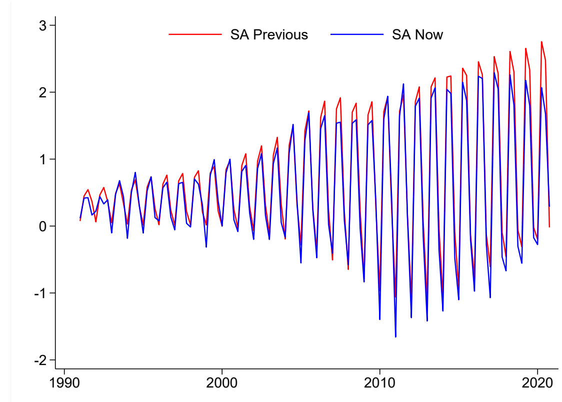
(d) Changing Annual Appreciation Rates

indices (labeled as "now") have a slightly tighter range when computing differences with the suite of public indices (labeled as "previous").

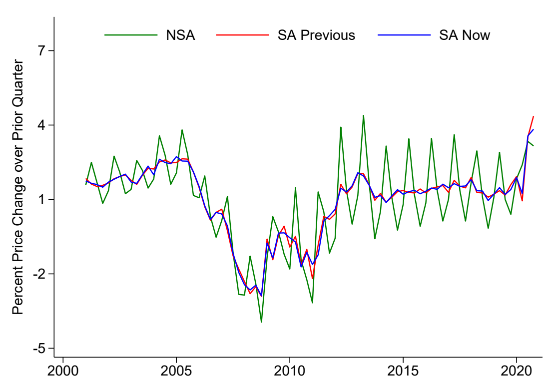
Figure 2: Computing New Optimal SA Terms



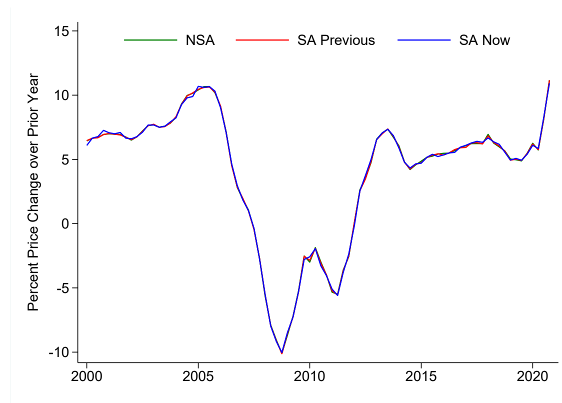
(a) Seasonally Adjusted Comparison



(b) Difference in SA vs NSA



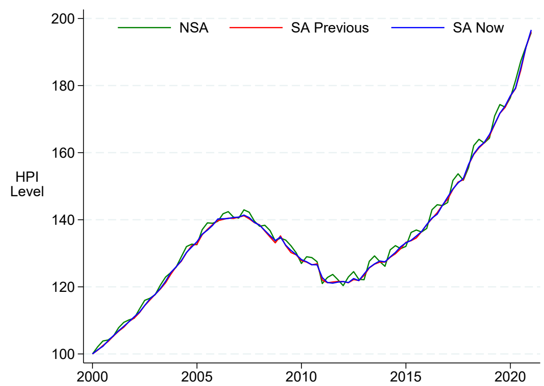
(c) Changing Quarterly Appreciation Rates



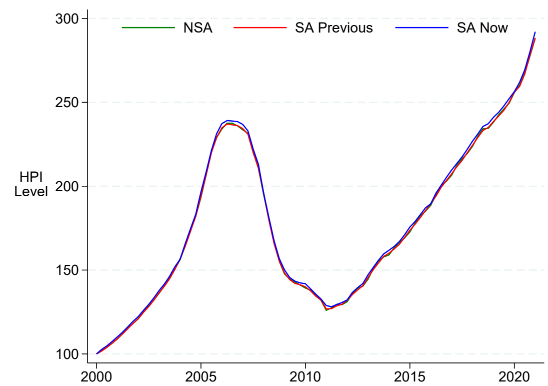
(d) Changing Annual Appreciation Rates

Next, evidence is provided about where adjustments are more necessary; in other words, the seasonality in the housing market is not uniform across areas. In Figure 3, seasonal adjustments are compared between two states and two MSAs. Looking across the top row, there is a larger difference between the nonseasonally and seasonally adjusted house price index, which is larger in Wisconsin than in Florida. The same result happens when comparing among MSAs; a seasonal adjustment in Chicago-Naperville-Evanston is more necessary than in Los Angeles-Long Beach-Glendale.

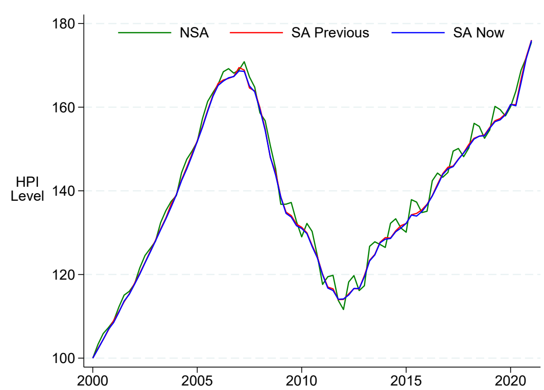
Figure 3: Seasonally Adjusted Comparison between Two States and Two MSAs



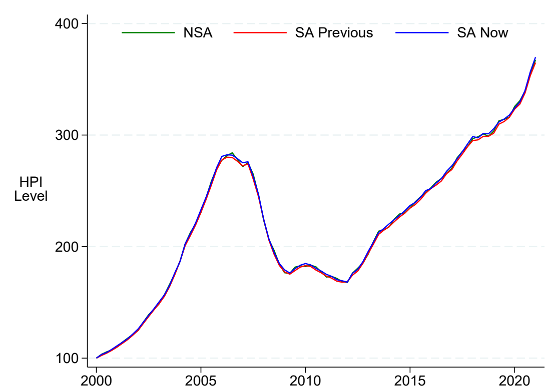
(a) Wisconsin



(b) Florida



(c) Chicago-Naperville-Evanston



(d) Los Angeles-Long Beach-Glendale

2.1.3 Forecast

A reasonable question is whether the newly adjusted indices provide more accurate gauges for how housing markets might perform in future periods. The exercise is particularly relevant with modeling the COVID-19 era because it is not clear whether the last several years have been transitory and should be treated as an outlier event or if the pandemic has made a permanent impression on housing markets that will require new seasonally adjusted terms for proper measurement.

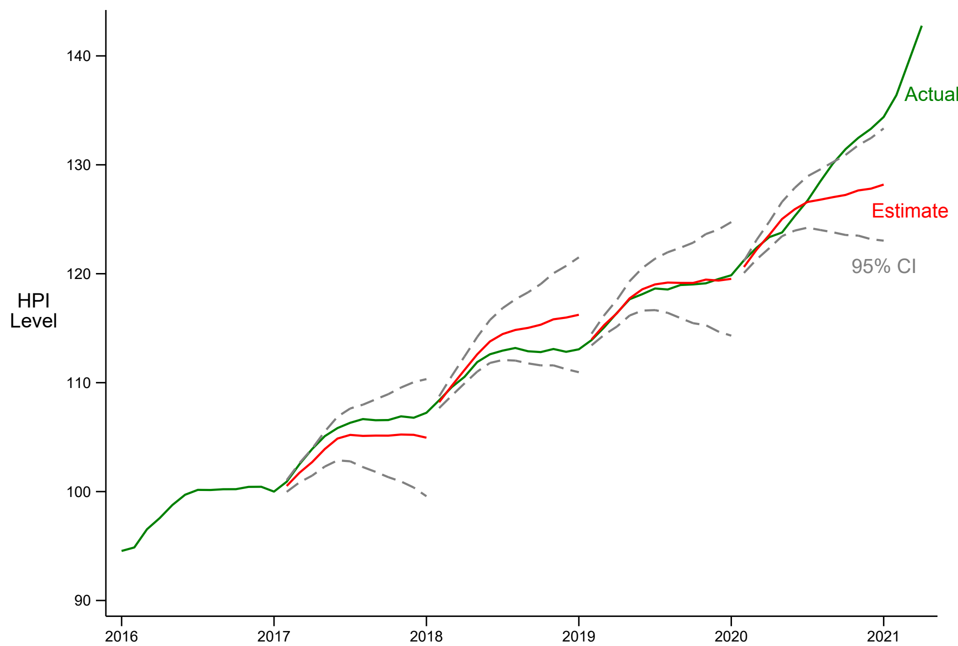
Several reports analyze seasonal adjustments during COVID-19 and make comparisons among different seasonally adjusted methods. Bógalo et al. (2022) compares X-13 with newly introduced nonparametric Circulant Singular Spectrum Analysis (CiSSA) in COVID-19 times and find that X-13 with outlier detection seems a better option. For outlier options in X-13, Tiller et al. (2021) explore various options for automatic outlier selections during pandemic using unemployment series in 421 metro areas, and they find that LSs in combination with TCs and AOs provides the best fit overall. Abeln and Jacobs (2021), on the other hand, compare X-13 with CAMPLET before and after the COVID-19 pandemic of the quarterly series real GDP, and they find that differences in SA values are generally small.

In this paper, X-13 is used to forecast the following year's price index. As shown in figure 4, the forecasting performs very well during 2017, 2018, and especially 2019. For 2020, March is approximately when the house price started derailing due to COVID-19. House prices have risen substantially since the COVID-19 pandemic; the annual gains are two to three times greater than before. Will house prices keep increasing or revert back? Given this context, determining the optimal seasonal adjustment for housing prices has become a difficult task. Two main options stand out depending on the future trend of housing prices: use concurrent seasonal adjustment with outlier commands in X-13 if the housing markets revert back (Bógalo et al. (2022); Tiller et al. (2021)), or establish a structural break and estimate new optimized terms if the house prices keep increasing at a higher rate.

2.2 Step 2: Causation of the Seasonality

The prior step has shown that there is seasonality in home prices, and the seasonality is not uniform across areas. The remaining question is: What may lead to the different seasonality in housing markets across states and MSAs, and where are adjustments more necessary? The absolute value of the difference between the nonseasonally adjusted and seasonally adjusted

Figure 4: Forecasting House Prices at the Start of Each Year

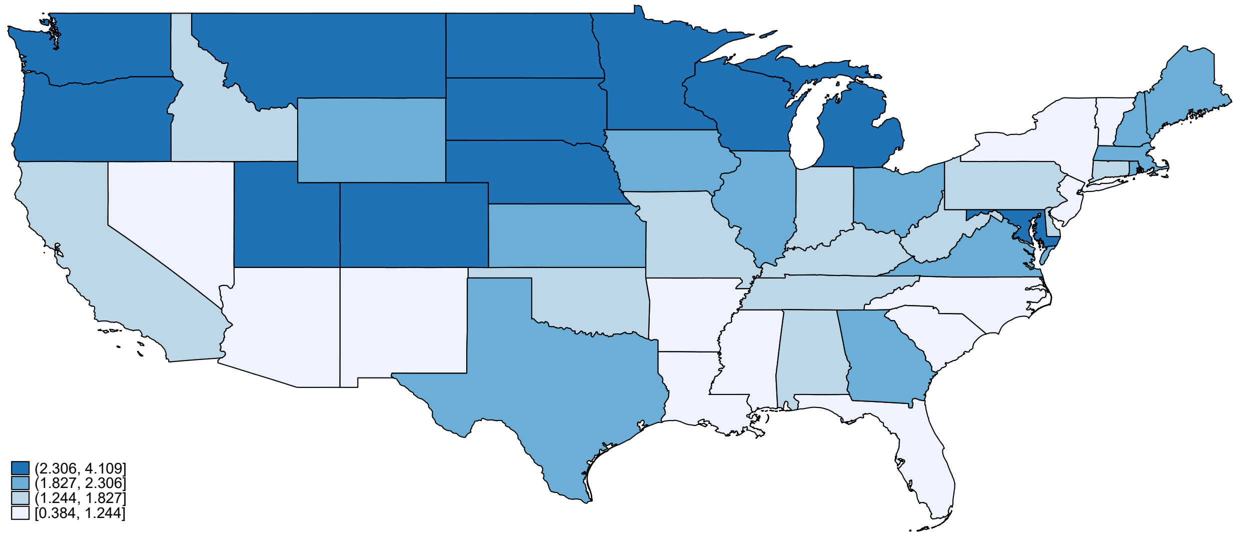


house prices is used as a measurement of seasonality. Adjustments are more necessary when there are larger absolute values of the difference.

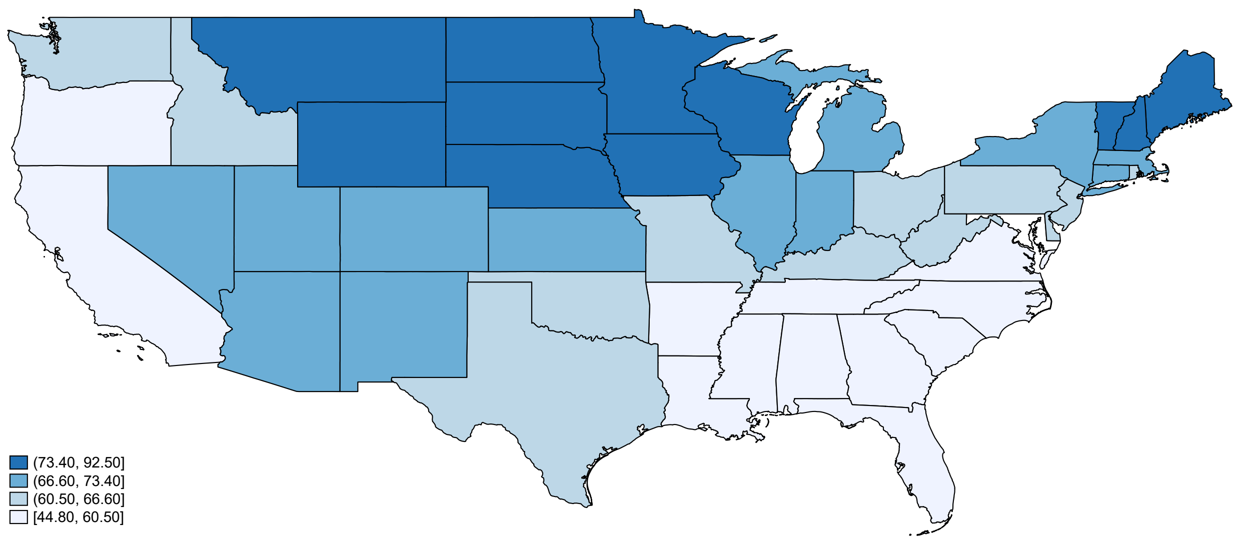
The actual causation of seasonality in housing prices may be due to a complicated mix of many factors, which might directly or indirectly impact the housing market. Actual changes in temperature, average temperature, and rainfall have direct effects on various economic series, such as those concerned with agricultural production, construction, and transportation, and consequent indirect effects on housing prices. Figure 5 shows the absolute value of the difference between the nonseasonally and seasonally adjusted house price index.In the top panel, HPI differences are larger in states with a darker shade. The bottom panel shows the range of temperatures, which is defined as the difference between the maximum and minimum temperatures. Comparing the two exhibits, it is clear that the distribution of colors is very close, and the greater range of temperatures is likely correlated with increased seasonality in house prices

Two different empirical methods, linear regression and quantile regression, examine the differences in NSA and SA terms on weather-related variables, social and industry characteristics,

Figure 5: Geographic Similarities of HPI Seasonality and Weather Data



(a) Difference between NSA and SA HPI Values



(b) Range of Temperatures

and temporal and geographic controls. The data and specifications are explained below.

2.2.1 Data

The HPI data used in the regression are the public-use quarterly data from 1991 to 2020 for both state and MSA levels from FHFA. Weather data are obtained from the National Oceanic and Atmospheric Administration (NOAA). Moreover, demographic data on household and industry variables come from census data in 2010.

2.2.2 Linear and Quantile Regression

Some studies (e.g., Goodman (1993); Kaplanski and Levy (2012)) have looked at certain factors to explain seasonality, such as daylight savings, marriages, summer relocations, school holidays, etc. This paper runs a regression to test other factors, with the dependent variable being the absolute value of the difference between the seasonally and nonseasonally adjusted HPI in both state and MSA levels:

$$y_{it} = \alpha + \beta_1 W_{it} + \beta_2 N.sales_{it} + \beta_3 Char_{i,2010} + \beta_4 Industry_{i,2010} + \gamma_i + f(year) + \epsilon_{it} \tag{2}$$

Unlike the linear regression model, based on the conditional mean of the dependent variable, quantile regression is based on the conditional τ^{th} quantile of the dependent variable. Quantile regressions uncover the hidden seasonality factors that exist depending on the relatively distributional level of seasonality. The quantile regression for the τ^{th} quantile is

$$Q_\tau(y_{it}) = \alpha_\tau + \beta_{1\tau} W_{it} + \beta_{2\tau} N.sales_{it} + \beta_{3\tau} Char_{i,2010} + \beta_{4\tau} Industry_{i,2010} + \gamma_{i\tau} + f_\tau(year) + \epsilon_{it} \tag{3}$$

where y_{it} is the absolute value of the difference between nonseasonally adjusted and seasonally adjusted (from step one) house price index for i^{th} MSA/State at each quarter, W_{it} weather-related variables included the range of temperature, average temperature, and precipitation. Unlike the definition of the range of temperature in Miller et al. (2013), they define it as the difference between the average summer temperature and the average winter temperature; ours is measured as the difference between the minimum temperature and maximum temperature for every quarter. $N.sales_{it}$ is the average number of houses sold in each quarter. $Char_{i,2010}$ contains the characteristic of the population in the area: average household income, the percentage of white, the percentage of the population older than 65 years old, the percentage of the population with the education of bachelor's or higher, and the percentage of single-family sales. $Industry_{i,2010}$ includes the percentage share of the top 10 industries in the i^{th} MSA/State. Also, γ_i is MSA/State fixed effect. $f(year)$ is linear splines for years, which allow estimating the relationship between seasonality and year as a piecewise linear function. ϵ_{it} is the error term, which is assumed to be normally distributed.

3. Results

Table 1 summarizes the results for the linear regression analysis[4]. Throughout the table, the dependent variable, the difference between nonseasonally and seasonally adjusted HPI, is regressed on weather-related variables, social and industry characteristics, and temporal and geographic controls.

In model 1, the outcome of interest is regressed against weather controls—range of temperature, average temperature, and precipitation. While controlling only for weather, the findings show that 9.9% of HPI seasonality can be explained by weather controls at the State level, and only 3.4% in MSA level. Then, in model 2, controls are added for household characteristics and industry concentration shares. The presence of contemporaneous controls has no large impact on the estimates for weather controls. In model 3, a linear spline is used for a variable year, which allows estimating the relationship between the seasonality of HPI and year as a piecewise linear function; in other words, the average growth rate of the difference between nonseasonally and seasonally adjusted HPI can be different at different periods of time. Estimates show that the seasonality increases slowly over time from 1991 to 1998; the seasonality increases at a higher rate from 1999 to 2011; the increasing rate of seasonality slows down from 2012 to 2020.

Then for model 4, instead of controlling for time trends, State/MSA fixed effects are included. Model 5 allows for both time trends and State/MSA fixed effects. After adding the controls for all variables (model 5), the R-squared increases from 0.099 to 0.494 for State level and goes up from 0.034 to 0.438 for MSA level. This gain in model fit does not mean the geographic fixed effects are the most important contribution, though, because a comparison between models 3 and 5 suggests that the time trends capture a greater share of the explained variation in classical linear regression. Generally, the regression results for the temperature variables are significant and have consistent patterns among models. Model 5 shows that an increase of one degree for the range of temperature in Q4 reduces the difference between non-

[4] The full table 1 is presented in the appendix (Table A.1).

seasonal and seasonal adjusted HPI on average by 1.55% for State level and only 0.39% for MSA[5]. Compared with Q4: a one degree increase in the range of temperature in Q1 increases the seasonality on average by about 0.95% for the State level and about 1.40% for the MSA level; a one-degree increase in the range of temperature in Q2 increases the seasonality on average by about 1.21% for State level and about 0.47% for MSA level; one degree increased in the range of temperature in Q3 increases the seasonality on average by about 2.33% in the State level and 0.47% in the MSA level. The results for the range of temperature show extreme cold winter (larger the range of temperature in Q1) would increase the seasonality of HPI in the MSA level, and extreme hot summer (larger range of temperature in Q3) would increase the seasonality of HPI in the State level.

Along with the linear regression results, estimates of the 10th, 25th, 50th, 75th, and 90th quantiles are provided to demonstrate the effects of the explanatory variables at each quantile. The results for quantile regression are shown in table 2[6]. Unlike linear regression, quantile regression allows the impact of a specific variable to be distinguished according to the dependent variable threshold. The range of temperature in Q4 has a significant adverse effect on the seasonality, and the pattern of the quantile parameters shows an increasing trend of this negative effect at the State and MSA levels. For Q1 and Q3, the pattern of quantile parameters shows an increasing trend of this positive effect in both State and MSA levels. Extreme hot summer and extreme cold winter aggravate the seasonality of HPI for places with higher seasonality levels. However, for Q2, the quantile regression reveals that the parameter reaches the maximum point at the center of the distribution for both State and MSA levels. The quantile regression provides additional information that the impact of the range temperature is different across quantiles. For the impact of year trend, in general, the seasonality increases over time, and the quantile parameters show an increasing trend from 1991 to 2011. However, the story is different from 2012 to 2020: the seasonality has been reduced for places with lower seasonality levels (10th, 25th, and 50th quantiles); the seasonality does not change for states with the higher seasonality level; the seasonality increases for MSAs in the 90th quantile.

To explain the empirical patterns, this paper uses the magnitude of the difference between the nonseasonally and seasonally adjusted HPI as the variation in seasonality. Two major factors

[5] The average of the difference between nonseasonally and seasonally adjusted HPI is 1.158 in State level, and 1.290 in MSA level. We calculate 0.011/1.158 = 1.55% and 0.005/1.290 = 0.39%.

[6] The full table of quantile regression is presented in the appendix (Table A.2).

affect the seasonality: weather controls and time trends. Throughout models, the impacts of temperature variables are significant and different across quarters, and the coefficients for weather-related variables remain fairly constant. Comparing with the weather controls, time trends are a much stronger driver. Additionally, the quantile regression indicates that the pattern of the quantile parameters generally shows an increasing trend for temperature variables. Although many papers have discovered that house price seasonality has increased over time, the findings in this report offer a nuance that that seasonal impacts have persisted for well over the past 30 years. However, the patterns are different—seasonality rose slowly from 1991 to 1998, increased fast from 1999 to 2011, and slowed down in recent years.

Table 1: The Impact of Seasonality on House Price Measures

	State					MSA				
Estimate	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Weather										
Range Temp Q1	0.014***	0.017***	0.015***	0.016***	0.011***	0.018***	0.017***	0.018***	0.016***	0.018***
	(11.58)	(13.46)	(15.59)	(11.00)	(9.93)	(18.69)	(18.60)	(23.29)	(17.45)	(23.80)
Range Temp Q2	0.010***	0.006***	0.008***	0.005***	0.014***	0.005***	0.006***	0.005***	0.008***	0.006***
	(10.28)	(4.66)	(7.84)	(3.27)	(10.25)	(5.45)	(6.56)	(6.92)	(9.28)	(7.45)
Range Temp Q3	0.020***	0.011***	0.016***	0.009***	0.027***	0.006***	0.006***	0.006***	0.008***	0.006***
	(12.92)	(5.13)	(9.38)	(2.91)	(11.14)	(5.87)	(6.97)	(7.44)	(9.38)	(7.92)
Range Temp	-0.018***	-0.014***	-0.016***	-0.013***	-0.018***	-0.003**	-0.001	-0.004***	-0.004**	-0.005***
	(-7.78)	(-5.95)	(-8.36)	(-5.29)	(-9.04)	(-2.01)	(-0.57)	(-3.15)	(-2.41)	(-3.41)
Average Temp	-0.017***	-0.003	-0.011***	0.003	-0.025***	-0.003***	0.002**	0.001	0.003***	0.001*
	(-11.73)	(-1.30)	(-6.26)	(0.93)	(-8.78)	(-3.33)	(2.47)	(1.02)	(3.77)	(1.94)
Precipitation	-0.032***	-0.014	-0.018**	-0.006	-0.013	-0.010**	-0.014***	-0.021***	-0.000	-0.004
	(-3.36)	(-1.31)	(-2.14)	(-0.54)	(-1.48)	(-2.25)	(-3.02)	(-5.38)	(-0.07)	(-0.95)
ln(Number of Sales)		-0.192***	0.044**	-0.609***	0.004		-0.182***	-0.035***	-0.605***	-0.084***
		(-9.27)	(2.43)	(-19.05)	(0.11)		(-12.86)	(-2.93)	(-23.43)	(-3.57)
Year Spline										
Year [1991-1998]			0.023***		0.027***			0.020***		0.021***
			(3.85)		(4.48)			(3.76)		(4.08)
Year [1999-2007]			0.100***		0.099***			0.127***		0.126***
			(21.20)		(21.06)			(29.78)		(30.54)
Year [2008-2011]			0.107***		0.103***			0.075***		0.071***
			(9.69)		(9.03)			(7.69)		(7.34)
Year [2012-2020]			-0.009		-0.006			0.014**		0.015***
			(-1.37)		(-0.88)			(2.34)		(2.68)
Household Characteristics		Y	Y	Y	Y		Y	Y	Y	Y
Industry Concentration Shares		Y	Y	Y	Y		Y	Y	Y	Y
Fixed Effect				State	State				MSA	MSA
Goodness of Fit										
R^2	0.099	0.171	0.467	0.231	0.494	0.034	0.111	0.389	0.185	0.438
BIC	16,835	16,465	13,847	16,322	13,842	38,684	37,832	33,373	37,579	33,177
N	6,000	6,000	6,000	6,000	6,000	11,963	11,963	11,963	11,963	11,963

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data on weather. Industries are ordered based on popularity, and the 10 most popular industries are listed. Top 100 MSA are included in our models. N is calculated by the number of states/MSA × 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

4. Robustness Tests

These results indicate that the weather-related variables had a significant impact on the difference between adjusted and non-adjusted HPI. Four sensitivity exercises help test specifications for the analysis.

In the first robustness check, the original model is reestimated (model 5) conditional on

Table 2: Splitting up Seasonality by Quantile

	State					MSA				
Estimate	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9
Weather										
Range Temp Q1	0.005***	0.011***	0.015***	0.018***	0.019***	0.006***	0.012***	0.017***	0.022***	0.024***
	(3.89)	(11.74)	(14.05)	(13.40)	(10.39)	(8.98)	(15.78)	(21.92)	(19.95)	(15.75)
Range Temp Q2	0.004***	0.006***	0.007***	0.006***	0.004**	0.002***	0.003***	0.003***	0.002*	0.001
	(3.33)	(6.29)	(6.06)	(4.61)	(2.18)	(3.03)	(4.72)	(3.96)	(1.65)	(0.75)
Range Temp Q3	0.007***	0.011***	0.015***	0.018***	0.015***	0.003***	0.006***	0.006***	0.006***	0.007***
	(3.52)	(7.13)	(8.11)	(7.99)	(4.78)	(5.17)	(7.66)	(8.04)	(5.49)	(4.37)
Range Temp	-0.005**	-0.009***	-0.010***	-0.010***	-0.014***	-0.001	-0.004***	-0.004***	-0.003*	-0.005**
	(-2.18)	(-5.03)	(-4.85)	(-3.98)	(-4.06)	(-0.52)	(-3.19)	(-3.04)	(-1.81)	(-2.18)
Average	-0.005**	-0.007***	-0.011***	-0.014***	-0.012***	-0.000	-0.001	-0.001	0.001	0.002
	(-2.23)	(-3.82)	(-5.24)	(-5.74)	(-3.48)	(-0.10)	(-0.97)	(-0.91)	(0.85)	(1.46)
Precipitation	-0.004	-0.005	-0.006	-0.007	-0.008	-0.001	-0.005	-0.008**	-0.020***	-0.038***
	(-0.43)	(-0.60)	(-0.61)	(-0.63)	(-0.50)	(-0.33)	(-1.35)	(-2.03)	(-3.73)	(-5.06)
ln(Number of Sales)	0.046**	0.078***	0.053***	0.013	-0.059*	0.018*	0.036***	0.007	-0.052***	-0.136***
	(2.15)	(4.51)	(2.67)	(0.52)	(-1.76)	(1.77)	(3.11)	(0.61)	(-3.06)	(-5.83)
Year Spline										
Year [1991,1998]	0.015**	0.018***	0.020***	0.019**	0.026**	0.009**	0.015***	0.018***	0.016**	0.018*
	(2.10)	(3.11)	(3.08)	(2.33)	(2.39)	(2.03)	(2.93)	(3.49)	(2.11)	(1.75)
Year[1999,2007]	0.028***	0.064***	0.091***	0.119***	0.132***	0.028***	0.069***	0.117***	0.165***	0.207***
	(5.03)	(14.19)	(17.43)	(18.24)	(14.89)	(8.01)	(17.03)	(27.27)	(27.28)	(25.09)
Year[2008,2011]	0.049***	0.076***	0.119***	0.144***	0.183***	0.041***	0.072***	0.087***	0.103***	0.098***
	(3.75)	(7.22)	(9.79)	(9.46)	(8.85)	(5.04)	(7.73)	(8.83)	(7.40)	(5.16)
Year[2012,2020]	-0.016**	-0.019***	-0.019***	-0.011	0.005	-0.020***	-0.031***	-0.014**	0.008	0.061***
	(-2.08)	(-3.08)	(-2.65)	(-1.26)	(0.37)	(-4.14)	(-5.61)	(-2.42)	(0.92)	(5.47)
Controls										
Household Char	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry Shares	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Goodness of Fit										
R^2	0.092	0.199	0.312	0.387	0.438	0.064	0.149	0.260	0.332	0.373
N	6,000	6,000	6,000	6,000	6,000	11,963	11,963	11,963	11,963	11,963

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data on weather. Industries are ordered based on popularity, and the 10 most popular industries are listed. Top 100 MSA are included in our models. N is calculated by the number of states/MSA × 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

the time between sales to examine whether the conclusions change. The HPI data used are repeat-sales data from FHFA.[7] Moreover, the change in the transaction prices is found to be a function of the time between sales based on the assumption that the vectors of physical and location characteristics do not change over time in repeat-sales data. We use the sample selection criteria based on the time between sales to test the sensitivity of our findings. In Table 3[8], the estimates for subsamples are separated by the time between sales—"Short Time", "Average Time", and "Long Time". "Short Time" is defined for those MSAs or States whose average time between sales is in the lower 33% among the top 100 MSAs or States; "Average Time" is between 34% and 66%; "Long Time" is above 67%. The estimated sign is consistent and the pattern of effects are similar across these columns. In addition, weather controls provide the larger improvement for the MSAs or States with longer average time between sales, but the estimated effects remain similar to the main findings.

In the second robustness check, controls are introduced for unobserved effects sensitive to MSA sizes based on MSA population (10th, 25th, 75th, and 90th quantiles). Estimations are rerun for model 5 conditional on different MSA sizes, and the results are shown in table 4[9]. In general, the coefficients of the temperature range are similar for MSAs whose population is between the 10th and 90th quantiles. However, the range of temperature has larger and significant impact on seasonality for extremely large MSAs (higher than 90th quantile) and smaller or insignificant effects for extremely small MSAs (lower than 10th quantile).

In the third robustness check, consideration is given to how the industry types affect the estimates (table 5). Sensitivity is tested by creating subsample selections for the top 10 MSAs in each type of industry. The magnitude of the estimate is sometimes different across different types of industry, but the patterns for the weather controls provide support for common trends with the previous findings. The results are likely confounded by overlaps across sample selections.

For the last robustness check, the sensitivity of previous findings are tested by using two alternative household samples. In table 6, the regression results from model 5 are separated by the distribution of the percentage of white and older than 65 years old. The MSAs are grouped by 10th, 25th, 75th, and 90th quantiles of the respective demographic control. The

[7]The repeat-sales methodology is introduced in the appendix.
[8]The full table 3 is presented in the appendix (table A.3).
[9]The full table 4 is presented in the appendix (table A.4).

patterns for the results in each subsample are coincident with the main findings. Meanwhile, the findings further suggest that in cities with more diversity (i.e., a lower percentage of white), the weather controls have higher influence on seasonality in house prices. MSAs with a higher percentage of aging people are more likely to be impacted by weather-related variables.

Table 3: Stratifying Seasonality by Time-between-Sales

	State			MSA		
Estimate	Short Time	Average Time	Long Time	Short Time	Average Time	Long Time
Weather						
Range Temp Q1	0.010***	0.011***	0.014***	0.011***	0.022***	0.022***
	(5.13)	(6.44)	(5.89)	(10.19)	(19.43)	(13.56)
Range Temp Q2	0.010***	0.012***	0.018***	0.002	0.007***	0.009***
	(4.30)	(5.58)	(7.58)	(1.48)	(5.94)	(5.58)
Range Temp Q3	0.025***	0.019***	0.038***	-0.001	0.011***	0.009***
	(5.83)	(4.95)	(8.11)	(-0.95)	(9.63)	(5.62)
Range Temp	-0.017***	-0.013***	-0.023***	0.001	-0.009***	-0.009***
	(-5.46)	(-3.76)	(-6.31)	(0.56)	(-4.01)	(-2.86)
Average	-0.023***	-0.021***	-0.035***	0.003**	0.001	-0.000
	(-4.35)	(-4.38)	(-6.47)	(2.42)	(0.86)	(-0.01)
Precipitation	-0.027*	-0.025	0.010	-0.004	0.005	-0.007
	(-1.67)	(-1.40)	(0.73)	(-0.54)	(0.59)	(-1.11)
Year Spline						
Year [1991,1998]	0.030***	0.013	0.023**	0.005	0.021***	0.026**
	(2.85)	(1.26)	(2.27)	(0.55)	(2.60)	(2.54)
Year [1999,2007]	0.074***	0.115***	0.118***	0.121***	0.134***	0.128***
	(9.48)	(13.66)	(14.17)	(17.13)	(20.53)	(15.79)
Year [2008,2011]	0.102***	0.127***	0.110***	0.132***	0.029*	0.065***
	(5.19)	(6.41)	(5.50)	(7.85)	(1.86)	(3.55)
Year [2012,2020]	-0.007	-0.000	-0.024**	-0.007	-0.001	0.045***
	(-0.67)	(-0.04)	(-2.06)	(-0.67)	(-0.15)	(4.17)
Controls						
Household Char	Y	Y	Y	Y	Y	Y
Industry Shares	Y	Y	Y	Y	Y	Y
Fixed Effect	MSA	MSA	MSA	MSA	MSA	MSA
Goodness of Fit						
R^2	0.420	0.556	0.521	0.462	0.480	0.406
BIC	4,693	4,334	4,780	10,446	9,973	12,361
N	2,040	1,920	2,040	3,940	3,953	4,070
Num. State/MSA	17	16	17	33	33	34
Percentile	<33%	34%-66%	>67%	<33%	34%-66%	>67%

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data on weather. Short Time cities are defined if the time between sales are in the lower 33% among the top 100 MSA; Average cities are between 34% and 66%; Long Time cities are above 67%. N is calculated by the number of states/MSA × 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

Table 4: The Impact of Seasonality by City Size

Estimate	Smallest City	Small City	Medium City	Large City	Largest City
Weather					
Range Temp Q1	0.011***	0.016***	0.017***	0.020***	0.033***
	(4.80)	(11.07)	(15.01)	(10.96)	(14.73)
Range Temp Q2	0.002	0.002	0.007***	0.009***	0.007***
	(0.75)	(1.16)	(6.02)	(4.79)	(3.22)
Range Temp Q3	0.006***	0.007***	0.004***	0.006***	0.022***
	(2.66)	(4.81)	(3.10)	(3.18)	(10.12)
Range Temp	0.005	-0.007**	-0.005**	-0.006	-0.014***
	(1.01)	(-2.36)	(-2.20)	(-1.55)	(-3.52)
Average	0.003	-0.000	0.002**	0.000	-0.003
	(1.57)	(-0.01)	(2.19)	(0.11)	(-1.64)
Precipitation	0.027*	0.011	-0.018**	-0.000	-0.006
	(1.94)	(0.89)	(-2.23)	(-0.10)	(-0.33)
Year Spline					
Year [1991,1998]	0.026	0.025**	0.019**	0.027**	0.037***
	(1.54)	(2.41)	(2.46)	(2.31)	(2.61)
Year[1999,2007]	0.104***	0.090***	0.142***	0.121***	0.104***
	(7.84)	(10.66)	(22.02)	(13.00)	(8.57)
Year[2008,2011]	0.024	0.031	0.076***	0.103***	0.078***
	(0.77)	(1.54)	(5.07)	(4.91)	(3.06)
Year[2012,2020]	0.053***	0.004	0.038***	-0.039***	-0.030**
	(2.83)	(0.35)	(4.31)	(-3.14)	(-2.02)
Controls					
Household Char	Y	Y	Y	Y	Y
Industry Shares	Y	Y	Y	Y	Y
Fixed Effect	MSA	MSA	MSA	MSA	MSA
Goodness of Fit					
R^2	0.411	0.398	0.452	0.471	0.481
BIC	3,269	4,045	18,116	4,495	2,588
N	1,186	1,794	6,109	1,798	1,076
Num. MSA	10	15	51	15	9
Percentile	<10%	10%-25%	25-75%	75%-90%	>90%

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference the between maximum and minimum temperature. Hawaii is not included because of missing data on weather. Tiny cities are defined if the population are in the lower 10% of the top 100 MSA; Small cities are lower 25%; Median cities are between 25% and 75%; large cities are above 75%; Huge cities are above 90%. N is calculated by the number of states/MSA $\times$ 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

Table 5: Seasonality Effects Based on Industry Concentration

Estimate	H.C.S.A	MFG	PS	Retail	Education	F.I.R.E	Public Admin	Constrn.	Transp.	Agriculture
Weather										
Range Temp Q1	0.032***	0.020***	0.017***	0.018***	0.022***	0.027***	0.014***	0.004*	0.014***	0.009***
	(15.92)	(9.52)	(4.56)	(7.41)	(9.55)	(13.90)	(6.59)	(1.83)	(8.18)	(4.33)
Range Temp Q2	0.008***	0.009***	0.016***	-0.000	0.002	0.009***	0.007***	-0.001	0.004**	0.000
	(3.91)	(4.23)	(4.24)	(-0.14)	(0.80)	(4.84)	(3.18)	(-0.44)	(2.37)	(0.03)
Range Temp Q3	0.020***	0.008***	0.000	0.004*	0.011***	0.013***	0.005**	-0.008***	0.003	0.001
	(9.94)	(3.90)	(0.00)	(1.68)	(4.74)	(6.52)	(2.30)	(-3.55)	(1.60)	(0.70)
Range Temp	-0.014***	-0.011***	-0.002	-0.007	-0.007	-0.006	-0.004	-0.001	-0.007*	-0.000
	(-3.63)	(-2.80)	(-0.21)	(-1.42)	(-1.51)	(-1.63)	(-0.97)	(-0.18)	(-1.81)	(-0.07)
Average	0.001	0.001	-0.000	0.003	0.001	0.001	-0.005**	-0.001	-0.001	0.000
	(0.75)	(0.79)	(-0.04)	(1.34)	(0.32)	(0.64)	(-2.51)	(-0.37)	(-0.49)	(0.14)
Precipitation	0.022	0.012	-0.039	-0.004	0.007	-0.018	-0.011	0.006	-0.004	-0.002
	(1.02)	(0.58)	(-1.40)	(-0.44)	(0.29)	(-1.12)	(-0.62)	(1.23)	(-0.47)	(-0.17)
Characteristics										
ln(Number of Sales)	-0.105	-0.185***	-0.130	-0.108*	0.015	-0.165***	-0.151**	-0.003	-0.282***	-0.125**
	(-1.29)	(-3.02)	(-1.24)	(-1.78)	(0.18)	(-2.67)	(-2.10)	(-0.05)	(-4.69)	(-1.98)
Over 65 Years Olds	-3.775**	0.034	0.290***	-0.695*	0.383***	-0.263*	-0.122**	0.178***	0.047	-0.021
	(-2.48)	(0.64)	(2.59)	(-1.66)	(4.56)	(-1.71)	(-2.23)	(4.15)	(1.12)	(-0.39)
Pct of Non-White	0.354**	0.043***	0.035***	-0.424*	-0.002	0.025***	0.011**	0.003	-0.005	-0.005
	(2.24)	(3.46)	(3.20)	(-1.69)	(-0.19)	(3.11)	(2.09)	(0.04)	(-0.68)	(-0.56)
Pct of Bachelor or Higher	0.225**	-0.063***	-0.024	-0.687	-0.149***	0.065***	0.019	0.155	0.033***	0.046***
	(2.35)	(-2.65)	(-0.21)	(-1.63)	(-4.39)	(4.28)	(0.79)	(1.12)	(4.31)	(2.91)
Pct of Single Family Sales	-1.141**	-0.068***	0.001	-0.310*	-0.011	0.003	-0.001	0.030	-0.077*	0.055***
	(-2.54)	(-7.36)	(0.01)	(-1.66)	(-0.87)	(0.40)	(-0.05)	(0.15)	(-1.84)	(2.89)
Year Spline										
Year [1991,1998]	0.014	0.030**	0.072***	-0.012	0.038**	0.030**	0.003	0.009	0.024**	0.026*
	(0.94)	(1.98)	(3.00)	(-0.96)	(2.32)	(2.29)	(0.21)	(0.60)	(2.04)	(1.95)
Year [1999,2007]	0.147***	0.107***	0.155***	0.111***	0.114***	0.131***	0.173***	0.091***	0.094***	0.093***
	(12.63)	(8.62)	(8.21)	(10.67)	(8.53)	(12.17)	(14.51)	(7.51)	(9.61)	(8.54)
Year [2008,2011]	0.023	0.146***	0.072*	-0.039	0.104***	0.079***	0.020	0.128***	0.015	0.001
	(0.82)	(5.19)	(1.68)	(-1.58)	(3.20)	(3.08)	(0.71)	(4.55)	(0.64)	(0.03)
Year [2012,2020]	-0.040**	0.027	0.093***	0.035**	-0.010	-0.029*	-0.019	0.009	-0.006	0.011
	(-2.37)	(1.62)	(3.67)	(2.40)	(-0.51)	(-1.90)	(-1.15)	(0.54)	(-0.46)	(0.71)
Goodness of Fit										
R^2	0.509	0.538	0.405	0.305	0.444	0.511	0.459	0.435	0.431	0.361
BIC	3,025	3,207	4,242	2,805	3,440	2,907	3,148	3,071	2,546	2,879
N	1,195	1,196	1,198	1,189	1,199	1,196	1,197	1,187	1,195	1,196

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Columns are ordered based on how popular the industries are, and the 10 most popular industries are listed. Top 100 MSA are included in our models. N is calculated by the number of states/MSA × 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

Table 6: The Lack of Population Diversity and Seasonality

	White				Over 65 Years Old			
Estimate	10%	25%	75%	90%	10%	25%	75%	90%
Weather								
Range Temp Q1	0.007*	0.018***	0.021***	0.024***	0.008***	0.009***	0.032***	0.037***
	(1.72)	(10.27)	(14.86)	(11.17)	(3.62)	(5.82)	(23.12)	(16.03)
Range Temp Q2	0.011***	0.008***	0.008***	0.005***	0.007***	0.006***	0.011***	0.009***
	(3.00)	(4.72)	(5.34)	(2.61)	(3.12)	(3.61)	(7.61)	(3.92)
Range Temp Q3	-0.005	0.006***	0.007***	0.009***	-0.008***	-0.006***	0.020***	0.023***
	(-1.39)	(3.69)	(5.28)	(4.48)	(-3.46)	(-4.18)	(14.64)	(10.11)
Range Temp	-0.002	-0.008**	-0.001	-0.000	-0.001	-0.001	-0.014***	-0.015***
	(-0.30)	(-2.42)	(-0.24)	(-0.02)	(-0.16)	(-0.27)	(-5.22)	(-3.44)
Average	-0.004	-0.002	0.003**	0.002	-0.002	0.000	0.002*	0.004*
	(-1.14)	(-1.24)	(2.38)	(0.90)	(-0.83)	(0.29)	(1.73)	(1.83)
Precipitation	-0.043*	-0.024**	-0.002	-0.004	0.005	0.002	0.002	0.004
	(-1.76)	(-1.99)	(-0.17)	(-0.19)	(0.85)	(0.38)	(0.22)	(0.33)
Year Spline								
Year [1991-1998]	0.011	0.021*	0.015	0.014	0.024	0.017	0.006	-0.004
	(0.49)	(1.92)	(1.40)	(0.88)	(1.57)	(1.63)	(0.64)	(-0.26)
Year [1999-2007]	0.172***	0.132***	0.146***	0.125***	0.136***	0.127***	0.141***	0.150***
	(9.94)	(15.07)	(16.61)	(10.20)	(10.94)	(14.68)	(19.56)	(13.67)
Year [2008-2011]	-0.007	0.045**	0.069***	0.128***	0.130***	0.110***	-0.016	-0.029
	(-0.18)	(2.21)	(3.41)	(4.32)	(4.51)	(5.43)	(-0.94)	(-1.12)
Year [2012-2020]	0.098***	0.022*	0.023*	0.013	0.002	0.042***	-0.007	0.009
	(4.22)	(1.84)	(1.85)	(0.76)	(0.09)	(3.49)	(-0.66)	(0.59)
Controls								
Household Char	Y	Y	Y	Y	Y	Y	Y	Y
Industry Shares	Y	Y	Y	Y	Y	Y	Y	Y
Fixed Effect	MSA	MSA	MSA	MSA	MSA	MSA	MSA	MSA
Goodness of Fit								
R^2	0.396	0.401	0.472	0.487	0.492	0.468	0.466	0.472
BIC	4,570	9,684	8,417	3,188	3,706	9,083	7,039	3,328
N	1,317	3,232	2,983	1,199	1,318	3,115	2,864	1,309
Num. MSA	11	27	25	10	11	26	24	11
Percentile	≤10%	≤25%	≥75%	≥90%	≤10%	≤25%	≥75%	≥90%

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data on weather. N is calculated by number of MSA × 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

5. Conclusions

Using the FHFA HPI data, this study explores seasonality in house prices at both State and MSA levels. The FHFA HPI has long used the Census Bureau's X-12 procedure to adjust for seasonality. This report shows that X-13, a successor to X-12, can be used to recalculate the entire suite of public indices provided by FHFA and offer adjustments that have not been provided for 400 metropolitan areas and other geographies. The new adjusted indices yield some improvements but indicate that the resulting optimization does not change drastically over time in real estate markets. Frequent recalculations yield limited upside and may even invite model specification risks. For example, with the COVID-19 pandemic, adjustment routines and forecasts perform poorly when including the recent period. For pre-COVID periods, the growing seasonal impact is tested against impacts from changes in weather, social and industry concentrations, temporal trends, and geographic controls. Fluctuations are muted in locations with thicker housing markets, weather controls give minor improvements, and time trends are the strongest driver, which suggests it is crucial to provide adjusted indices, but regular updates are less necessary.

References

Abeln, B. and Jacobs, J. P. (2021). COVID-19 and seasonal adjustment. *Journal of Business Cycle Research*, 18:159–169.

Bógalo, J., Llada, M., Poncela, P., and Senra, E. (2022). Seasonality in COVID-19 times. *Economics Letters*, 211:110206.

Gomez, V. and Maravall, A. Programs TRAMO (time series regression with arima noise, missing observations, and outliers) and SEATS (signal extraction in arima time series). instructions for the user. *Documento de Trabajo*, 9628:56.

Goodman, J. (1993). A housing market matching model of the seasonality in geographic mobility. *Journal of Real Estate Research*, 8(1):117–137.

Granger, C. W. (1978). Seasonality: Causation, interpretation, and implications. In *Seasonal analysis of economic time series*, pages 33–56. NBER.

Harding, J. P., Rosenthal, S. S., and Sirmans, C. (2003). Estimating bargaining power in the market for existing homes. *Review of Economics and Statistics*, 85(1):178–188.

Kaplanski, G. and Levy, H. (2012). Real estate prices: An international study of seasonality's sentiment effect. *Journal of Empirical Finance*, 19(1):123–146.

Miller, N. G., Sah, V., Sklarz, M., and Pampulov, S. (2013). Is there seasonality in home prices—evidence from CBSAs. *Journal of Housing Research*, 22(1):1–15.

Ngai, L. and Tenreyro, S. (2014). Hot and cold seasons in the housing market. *The American Economic Review*, 104(12):3991–4026.

Reichert, A. K. (1990). The impact of interest rates, income, and employment upon regional housing prices. *The Journal of Real Estate Finance and Economics*, 3(4):373–391.

Tiller, R., Oh, J., and Liu, L. (2021). Adapting the seasonal adjustment of local area unemployment statistics to the COVID-19 pandemic. Bureau of Labor Statistics.

Wang, Q. and Wu, N. (2012). Menu-driven X-12-ARIMA seasonal adjustment in Stata. *The Stata Journal*, 12(2):214–241.

A The Repeat-Sales Methodology

This paper uses housing price index data, repeat-sales from FHFA. The repeat-sales methodology is explained below. The explicit intertemporal hedonic model measures house prices by involving a dummy variable for each index period.

$$P_{it} = x_{it}^{'}\beta + D_t^{'}\delta + \epsilon_{it}, \tag{4}$$

where x is a vector of property characteristics, β denotes the vector of estimated coefficients for the attributes, δ is a vector of estimated coefficients for each of the time dummies, and D_t, the time dummies, are set equal to 1 if the ith house is sold in period t, otherwise 0. Taking the difference between the second sale price and the first sale price, we obtain

$$P_{it}^2 - P_{it}^1 = (x_{2,it}^{'}\beta - x_{1,it}^{'}\beta) + (D_{2,t}^{'}\delta - D_{1,t}^{'}\delta) + (\epsilon_{2,it} - \epsilon_{1,it}). \tag{5}$$

Under the assumption that the vectors of physical and location characteristics do not change over time, the equation (2) can be simplified to

$$P_{it}^2 - P_{it}^1 = (D_{2,t}^{'}\delta - D_{1,t}^{'}\delta) + (\epsilon_{2,it} - \epsilon_{1,it}), \tag{6}$$

we have the change in the transaction prices is found to be a function of the time between sales.

B Simulation

As alluded to earlier, a series of simulations were used before evaluating actual house price data and applying an optimal seasonality adjustment. A white noise process was seeded over a substantial period. After that, several typical problems are introduced by simple models: moving average, autoregression, and time trend processes. For a simple time series model, autocorrelations and partial autocorrelations can help identify the order of an MA or AR model. The diagnosis gets complicated when combining the moving average, the autoregressive, and the time trend process into one series. Proper data generation adjustments are extremely hard to determine when multiple events happen at once.

2.1 White Noise Process

A sequence y_t is white noise process, and y_t is a sequence of independent and identically distributed standard normal random variables:

$$y_t \sim iidN(0, 1). \tag{7}$$

Figure A.1 shows the autocorrelation and partial autocorrelation plots and finds that all the autocorrelations and the partial autocorrelations are close to 0. In practice, if all the partial autocorrelations are not statistically significantly different from 0, then the series is a white noise series.

2.2 Moving Average Process

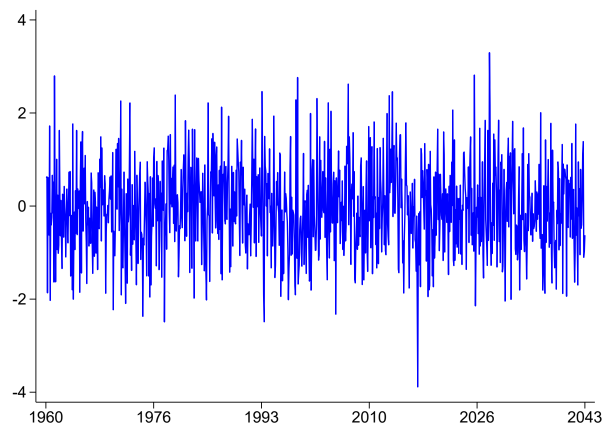
The moving average process is a function of the current and lagged unobserved shocks, a sequence of iid random variables with mean zero. Figure A.2 shows the plot of the first-order moving average process, and the formula can be written as

$$y_t = \epsilon_t + 0.6\epsilon_{t-1}, \tag{8}$$

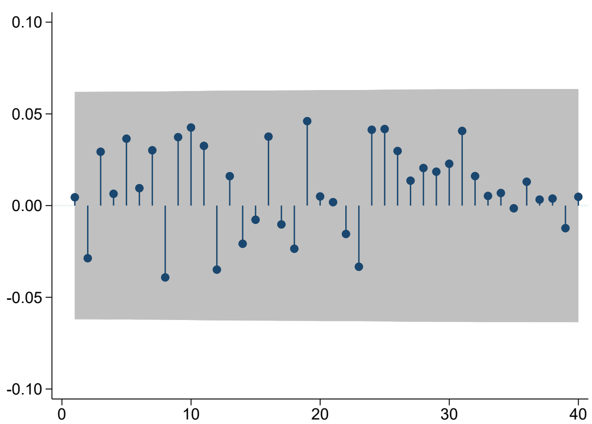
where $\epsilon_t \sim iidN(0, 1)$

In the example, the first lag of the shock positively affects the current value of the series. Figure A.2 shows the autocorrelation and partial autocorrelation plots and finds that the only term that is statistically significant from 0 in the autocorrelation plot is lag 1. The partial autocorrelation plot shows declining significant terms that are alternating in sign. Empirically, the autocorrelation function is helpful in identifying the order of an MA model.

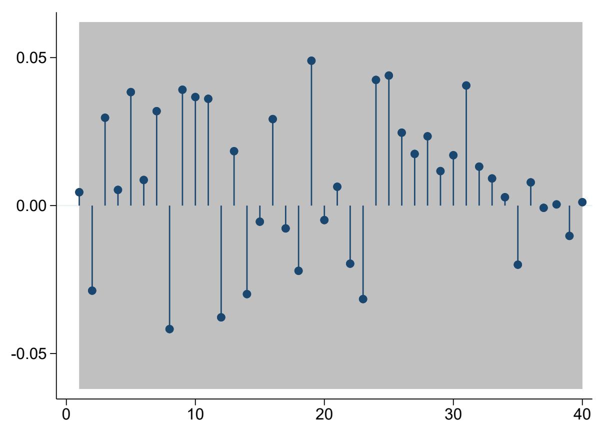
Figure A.1: White Noise Process



(a) Data

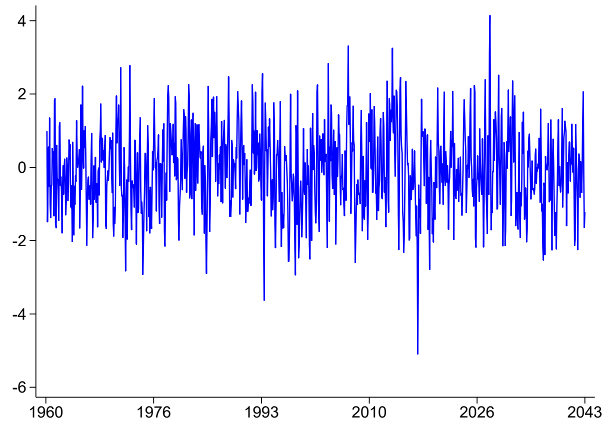


(b) ACF

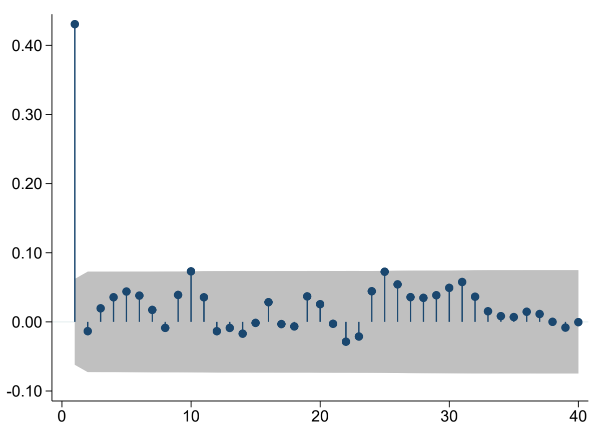


(c) PACF

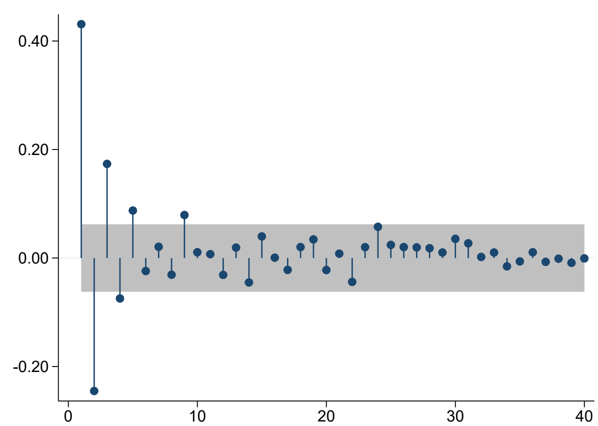
Figure A.2: First-Order Moving Average Process



(a) Data



(b) ACF



(c) PACF

2.3 Autoregressive Process

The autoregressive process shows that a series' current value is linearly related to its past values, plus an additive stochastic shock, a sequence of iid random variables with a mean zero. Figure A.3 shows the plot of the first-order autoregressive process, and the formula can be written as

$$y_t = 0.8y_{t-1} + \epsilon_t, \tag{9}$$

where $\epsilon_t \sim iidN(0,1)$. This model is like the well-known simple regression model, in which y_t is the dependent variable and y_{t-1} is the explanatory variables. Usually, the absolute value of the coefficient on y_{t-1} is less than 1 to create a convergent geometric series.

In the example, the last period's value positively affects the current value. Figure A.3 shows the autocorrelation and partial autocorrelation plots: the autocorrelation plot shows declining significant terms at a slow rate, and for the partial autocorrelations, there is one large and statistically significant term. In practice, the partial autocorrelation function is a useful tool for determining the order p of an AR model.

2.4 Time Trend Process

The time trend process shows that the current value is a function of time. Figure A.4 shows the plot of the time trend process, and the formula can be written as

$$y_t = -2.5 + 0.005t + \epsilon_t, \tag{10}$$

where $\epsilon_t \sim iidN(0,1)$.

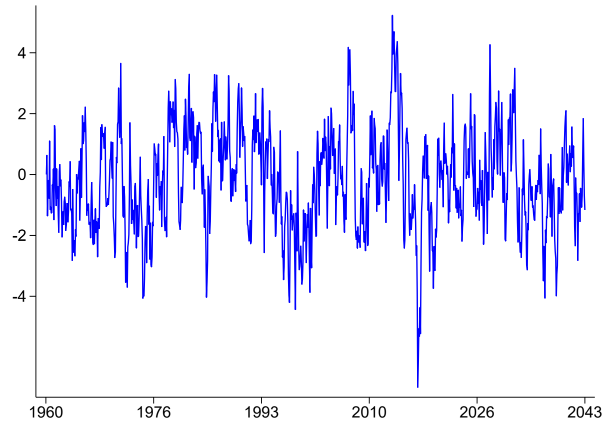
In the example here, the value has increased by 0.5% each year. Figure A.4 shows the autocorrelation and partial autocorrelation plots: the autocorrelation plot shows declining significant terms at a slow rate, and for the partial autocorrelations, there are declining significant terms at a fast rate.

2.5 Mixed Model Process

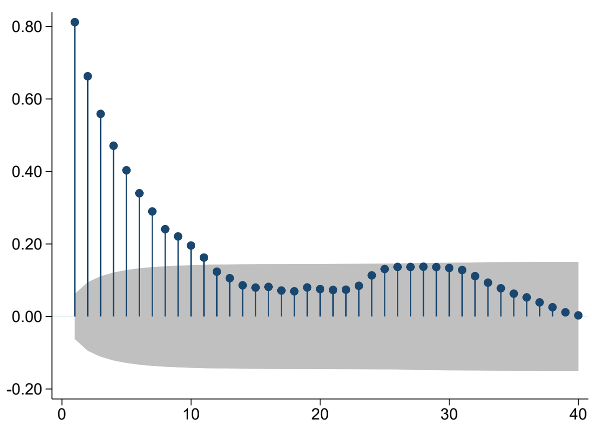
The final example combines the moving average, the autoregressive, and the time trend process into one series. Figure A.5 shows the plot of the mixed model, and the formula become

$$y_t = -2.5 + 0.6\epsilon_{t-1} + 0.8y_{t-1} + 0.005t + \epsilon_t\ , \tag{11}$$

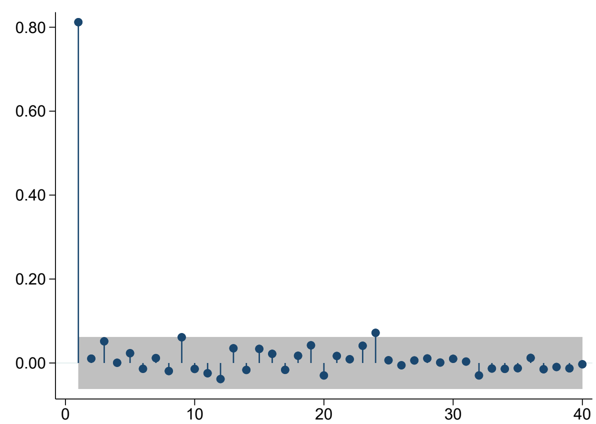
Figure A.3: First-Order Autoregressive Process



(a) Data

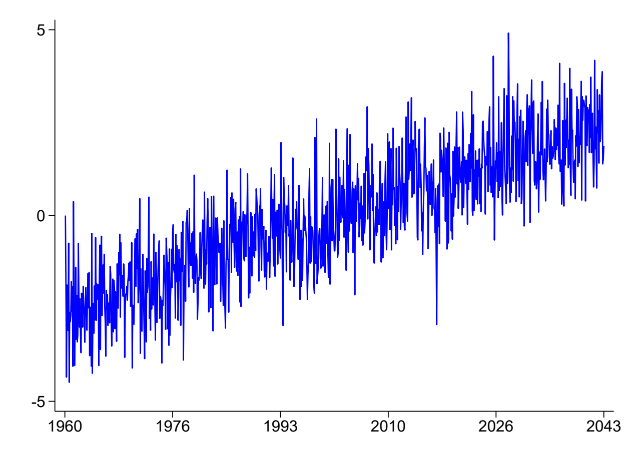


(b) ACF

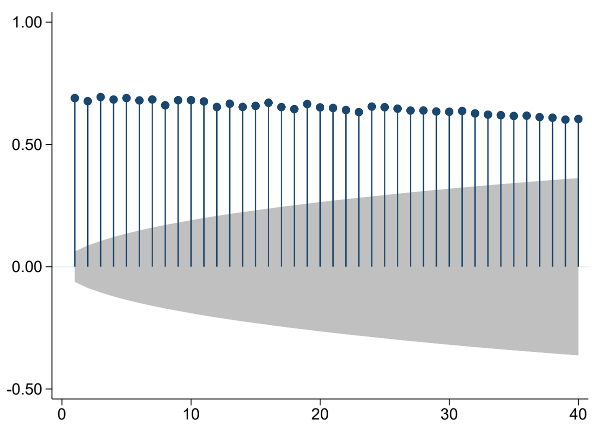


(c) PACF

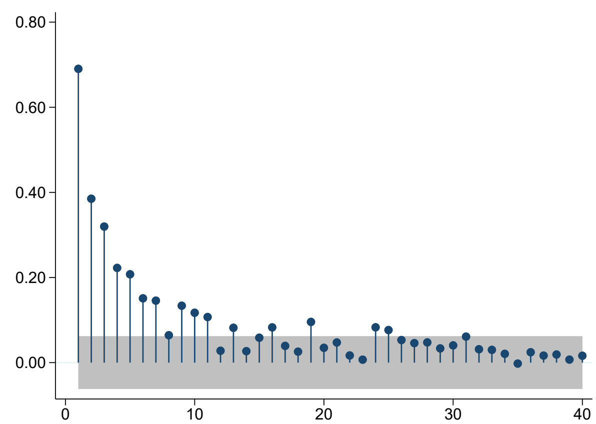
Figure A.4: Time Trend Process



(a) Data



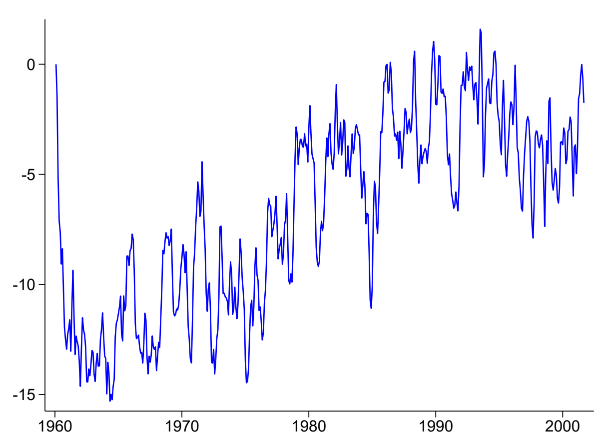
(b) ACF



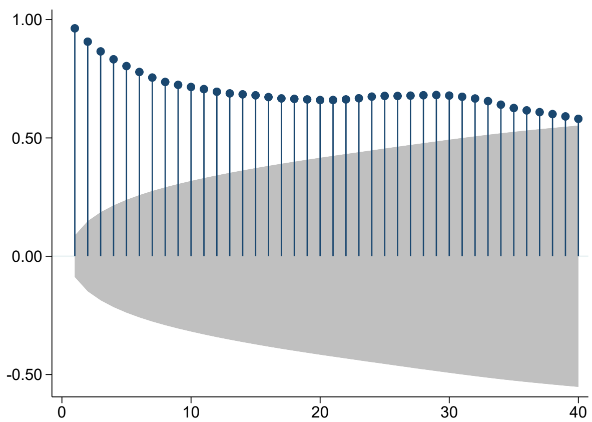
(c) PACF

where $\epsilon_t \sim iidN(0, 1)$.

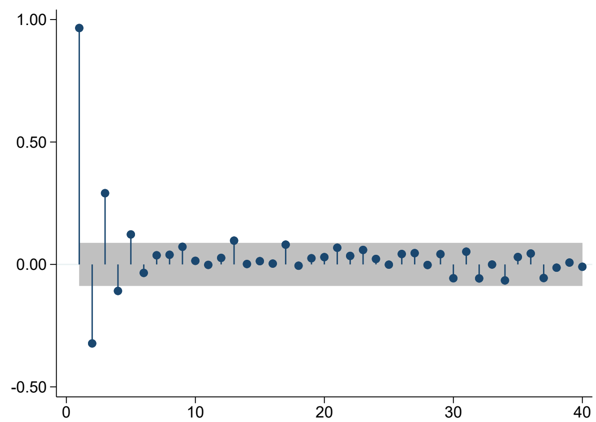
Figure A.5: Mixed Model Process



(a) Data



(b) ACF



(c) PACF

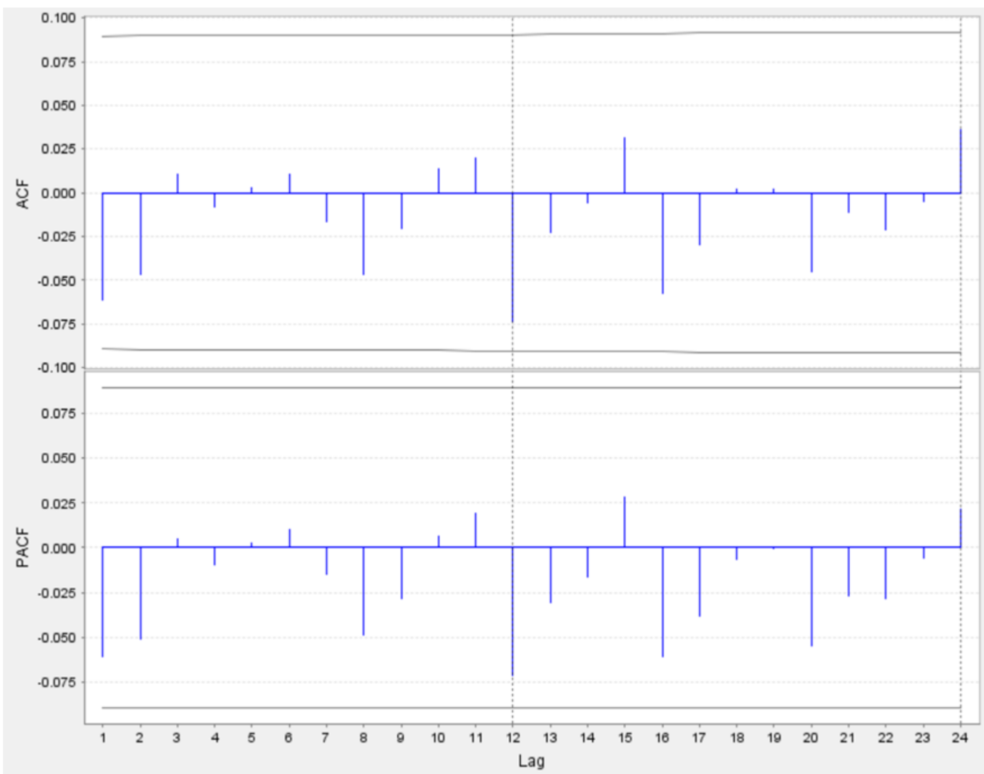
Figure A.5 shows the autocorrelation and partial autocorrelation plots. Based on the autocorrelation and partial autocorrelation, it is extremely difficult to determine suitable adjustments when multiple events are happening simultaneously. This statement is true even for simple simulation models, and it becomes even more applicable in real-world data examples.

X-13ARIMA-SEATS are used to find the optimal ARIMA model. Table 7 shows the regression results. The automated routine does not yield the exact ARIMA structure because of the mixed nature with (p,d,q) terms that mix AR and MA effects. As we know, MA(1) is an infinite-order of AR model. Figure A.6 shows the autocorrelation and partial autocorrelation after being adjusted, and it shows that the fit is very good, given that non of the terms for AC and PAC are statistically significant. Although one "optimal" term structure will be chosen by the software, data users should realize that, in practice, several term structures could be close and equally plausible.

Table 7: Regression Results for ARIMA Model

Parameter	Estimate
Nonseasonal AR	
Lag 1	0.784***
	(0.042)
Nonseasonal MA	
Lag 1	0.344***
	(0.046)
Lag 2	0.584***
	(0.037)
Test	P-value
Ljung-Box	1.00
ARIMA Model	(1, 1, 2)

Figure A.6: AC and PAC after Adjusted by X-13ARIMA-SEATS



C Approximate Production Time

Figure A.7: Approximate Production Time

Purchase-Only Indexes (Estimated using Sales Price Data)	Time	SA Available	New SA
U.S. and Census Divisions (Seasonally Adjusted and Not Adjusted)	15 min	Y	Y
States (Seasonally Adjusted and Not Adjusted)	1.5 hr	Y	Y
100 Largest Metropolitan Statistical Areas (Seasonally Adjusted and Not Adjusted)	2.5 hr	Y	Y
Select Metropolitan Areas—Distress-Free Measures (Developmental Index; Seasonally Adjusted and Not Adjusted)	30 min	Y	Y
Puerto Rico (Developmental Index; Seasonally Adjusted and Not Adjusted)	3 min	Y	Y
Manufactured Homes (Developmental Index, Not Seasonally Adjusted: 1995Q1 - 2018Q2)	3 min	N	Y
All-Transactions Indexes (Estimated using Sales Prices and Appraisal Data)			
U.S. and Census Divisions (Not Seasonally Adjusted)	15 min	N	Y
States (Not Seasonally Adjusted)	90 min	N	Y
Metropolitan Statistical Areas and Divisions (Not Seasonally Adjusted)	24 hr	N	Y
State Nonmetropolitan Areas (Not Seasonally Adjusted)	1.5 hr	N	Y
Puerto Rico (Developmental Index; Not Seasonally Adjusted)	3 min	N	Y
Three-Digit ZIP Codes (Developmental Index; Not Seasonally Adjusted)		N	N
Manufactured Homes (Developmental Index; Not Seasonally Adjusted: 1995Q1 - 2018Q2)	3 min	N	Y
House Price Changes in Largest MSAs (Ranked and Unranked)			
Expanded-Data Indexes (Estimated using Enterprise, FHA, and Real Property County Recorder Data Licensed from Data Quick for sales below the annual loan limit ceiling)			
U.S. (Not Adjusted) 1975Q1 – Present	3 min	N	Y
U.S. and Census Divisions (Seasonally Adjusted and Not Adjusted)	15 min	Y	Y
States (Seasonally Adjusted and Not Adjusted)	1.5 hr	Y	Y
50 Largest Metropolitan Statistical Areas (Seasonally Adjusted and Not Adjusted)	1.6 hr	Y	Y

Table A.1: The Impact of Seasonality on House Price Measures

	State					MSA				
Estimate	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Weather										
Range Temp Q1	0.014***	0.017***	0.015***	0.016***	0.011***	0.018***	0.017***	0.018***	0.016***	0.018***
	(11.58)	(13.46)	(15.59)	(11.00)	(9.93)	(18.69)	(18.60)	(23.29)	(17.45)	(23.80)
Range Temp Q2	0.010***	0.006***	0.008***	0.005***	0.014***	0.005***	0.006***	0.005***	0.008***	0.006***
	(10.28)	(4.66)	(7.84)	(3.27)	(10.25)	(5.45)	(6.56)	(6.92)	(9.28)	(7.45)
Range Temp Q3	0.020***	0.011***	0.016***	0.009***	0.027***	0.006***	0.006***	0.006***	0.008***	0.006***
	(12.92)	(5.13)	(9.38)	(2.91)	(11.14)	(5.87)	(6.97)	(7.44)	(9.38)	(7.92)
Range Temp	-0.018***	-0.014***	-0.016***	-0.013***	-0.018***	-0.003**	-0.001	-0.004***	-0.004**	-0.005***
	(-7.78)	(-5.95)	(-8.36)	(-5.29)	(-9.04)	(-2.01)	(-0.57)	(-3.15)	(-2.41)	(-3.41)
Average Temp	-0.017***	-0.003	-0.011***	0.003	-0.025***	-0.003***	0.002**	0.001	0.003***	0.001*
	(-11.73)	(-1.30)	(-6.26)	(0.93)	(-8.78)	(-3.33)	(2.47)	(1.02)	(3.77)	(1.94)
Precipitation	-0.032***	-0.014	-0.018**	-0.006	-0.013	-0.010**	-0.014***	-0.021***	-0.000	-0.004
	(-3.36)	(-1.31)	(-2.14)	(-0.54)	(-1.48)	(-2.25)	(-3.02)	(-5.38)	(-0.07)	(-0.95)
Characteristics										
ln(Number of Sales)		-0.192***	0.044**	-0.609***	0.004		-0.182***	-0.035***	-0.605***	-0.084***
		(-9.27)	(2.43)	(-19.05)	(0.11)		(-12.86)	(-2.93)	(-23.43)	(-3.57)
Over 65 Years Old		-0.066***	-0.028**	7.962***	3.162***		-0.022***	0.001	0.358***	0.307***
		(-4.83)	(-2.53)	(13.34)	(6.24)		(-3.14)	(0.19)	(2.77)	(2.86)
Pct of Non-White		-0.000	-0.006***	1.329***	0.513***		-0.007***	-0.006***	0.124***	0.058***
		(-0.21)	(-3.93)	(13.48)	(6.13)		(-4.71)	(-4.64)	(6.62)	(3.73)
Pct of Bachelor or Higher		0.027***	0.022***	4.341***	1.664***		0.071***	0.077***	-0.202***	-0.006
		(4.26)	(4.32)	(13.54)	(6.11)		(14.21)	(18.70)	(-5.17)	(-0.18)
Pct Single Family Sales		0.015***	0.008***	1.664***	0.666***		-0.010***	0.000	0.077***	0.061***
		(5.04)	(3.35)	(13.35)	(6.30)		(-4.78)	(0.19)	(4.39)	(4.19)
Industry Concentration Shares										
H.C.A.S.		0.040***	-0.026**	15.581***	5.852***		0.047***	0.031***	-0.065	0.063
		(2.91)	(-2.37)	(13.24)	(5.86)		(4.58)	(3.62)	(-0.92)	(1.08)
Manufacturing		0.032***	0.011*	18.701***	7.143***		0.039***	0.030***	0.446***	0.274***
		(4.55)	(1.88)	(13.39)	(6.02)		(7.24)	(6.72)	(7.86)	(5.80)
Professional Services		0.126***	0.050***	20.445***	7.835***		0.015	-0.009	1.647***	0.774***
		(8.48)	(4.06)	(13.50)	(6.08)		(1.39)	(-0.94)	(7.54)	(4.25)
Retail		-0.015	-0.006	41.494***	16.171***		0.078***	0.078***	0.288**	0.216**
		(-0.89)	(-0.45)	(13.38)	(6.15)		(5.22)	(6.29)	(2.49)	(2.24)
Education		-0.090***	-0.017	25.238***	9.808***		-0.092***	-0.069***	1.918***	0.937***
		(-6.08)	(-1.40)	(13.31)	(6.10)		(-7.60)	(-6.90)	(6.26)	(3.67)
F.I.R.E		-0.013	-0.005	16.771***	6.430***		0.004	-0.016**	-0.280**	-0.150
		(-1.15)	(-0.52)	(13.31)	(6.01)		(0.47)	(-2.30)	(-2.45)	(-1.58)
Public Administrations		-0.034***	0.019**	18.228***	7.033***		0.019***	0.021***	-0.521***	-0.155
		(-3.69)	(2.49)	(13.26)	(6.04)		(2.89)	(3.73)	(-3.59)	(-1.28)
Construction		-0.083***	-0.090***	7.499***	2.677***		-0.002	0.001	1.137***	0.796***
		(-4.12)	(-5.60)	(12.47)	(5.26)		(-0.11)	(0.04)	(3.93)	(3.31)
Transportation		0.050**	-0.009	29.988***	11.483***		0.091***	0.065***	0.699***	0.595***
		(2.47)	(-0.54)	(13.50)	(6.08)		(7.08)	(6.14)	(7.02)	(7.18)
Agriculture		0.072***	0.047***	17.144***	6.559***		0.046***	0.044***	-1.277***	-0.706**
		(7.00)	(5.70)	(13.42)	(6.04)		(5.31)	(6.21)	(-3.07)	(-2.05)
Year Spline										
Year [1991-1998]			0.023***		0.027***			0.020***		0.021***
			(3.85)		(4.48)			(3.76)		(4.08)
Year [1999-2007]			0.100***		0.099***			0.127***		0.126***
			(21.20)		(21.06)			(29.78)		(30.54)
Year [2008-2011]			0.107***		0.103***			0.075***		0.071***
			(9.69)		(9.03)			(7.69)		(7.34)
Year [2012-2020]			-0.009		-0.006			0.014**		0.015***
			(-1.37)		(-0.88)			(2.34)		(2.68)
Fixed Effect				State	State				MSA	MSA
Goodness of Fit										
R^2	0.099	0.171	0.467	0.231	0.494	0.034	0.111	0.389	0.185	0.438
BIC	16,835	16,465	13,847	16,322	13,842	38,684	37,832	33,373	37,579	33,177
N	6,000	6,000	6,000	6,000	6,000	11,963	11,963	11,963	11,963	11,963

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data on weather. Industries are ordered based on popularity, and the 10 most popular industries are listed. Top 100 MSA are included in our models. N is calculated by the number of states/MSA $\times$ 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

Table A.2: Splitting up Seasonality by Quantile

	State					MSA				
Estimate	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9
Weather										
Range Temp Q1	0.005***	0.011***	0.015***	0.018***	0.019***	0.006***	0.012***	0.017***	0.022***	0.024***
	(3.89)	(11.74)	(14.05)	(13.40)	(10.39)	(8.98)	(15.78)	(21.92)	(19.95)	(15.75)
Range Temp Q2	0.004***	0.006***	0.007***	0.006***	0.004**	0.002***	0.003***	0.003***	0.002*	0.001
	(3.33)	(6.29)	(6.06)	(4.61)	(2.18)	(3.03)	(4.72)	(3.96)	(1.65)	(0.75)
Range Temp Q3	0.007***	0.011***	0.015***	0.018***	0.015***	0.003***	0.006***	0.006***	0.006***	0.007***
	(3.52)	(7.13)	(8.11)	(7.99)	(4.78)	(5.17)	(7.66)	(8.04)	(5.49)	(4.37)
Range Temp	-0.005**	-0.009***	-0.010***	-0.010***	-0.014***	-0.001	-0.004***	-0.004***	-0.003*	-0.005**
	(-2.18)	(-5.03)	(-4.85)	(-3.98)	(-4.06)	(-0.52)	(-3.19)	(-3.04)	(-1.81)	(-2.18)
Average	-0.005**	-0.007***	-0.011***	-0.014***	-0.012***	-0.000	-0.001	-0.001	0.001	0.002
	(-2.23)	(-3.82)	(-5.24)	(-5.74)	(-3.48)	(-0.10)	(-0.97)	(-0.91)	(0.85)	(1.46)
Precipitation	-0.004	-0.005	-0.006	-0.007	-0.008	-0.001	-0.005	-0.008**	-0.020***	-0.038***
	(-0.43)	(-0.60)	(-0.61)	(-0.63)	(-0.50)	(-0.33)	(-1.35)	(-2.03)	(-3.73)	(-5.06)
Characteristics										
ln(Number of Sales)	0.046**	0.078***	0.053***	0.013	-0.059*	0.018*	0.036***	0.007	-0.052***	-0.136***
	(2.15)	(4.51)	(2.67)	(0.52)	(-1.76)	(1.77)	(3.11)	(0.61)	(-3.06)	(-5.83)
Over 65 Years Olds	0.003	-0.012	-0.029**	-0.016	-0.054***	0.010**	0.011**	0.012**	0.008	-0.010
	(0.26)	(-1.11)	(-2.34)	(-1.07)	(-2.59)	(2.07)	(1.98)	(2.00)	(1.02)	(-0.88)
Pct of Non-White	0.000	-0.004***	-0.005***	-0.003	-0.003	-0.002**	-0.004***	-0.003**	-0.004**	-0.006**
	(0.02)	(-2.69)	(-3.10)	(-1.53)	(-1.06)	(-2.37)	(-3.43)	(-2.03)	(-2.05)	(-2.53)
Pct of Bachelor or Higher	0.009	0.014***	0.012**	0.012	0.033***	0.014***	0.017***	0.036***	0.059***	0.082***
	(1.40)	(2.89)	(2.14)	(1.64)	(3.42)	(4.04)	(4.19)	(8.61)	(10.00)	(10.22)
Pct of Single Family Sales	0.010***	0.007***	0.002	0.007**	0.003	0.002	0.004**	0.002	0.000	-0.010***
	(3.42)	(2.89)	(0.94)	(2.03)	(0.65)	(1.42)	(2.57)	(1.18)	(0.01)	(-2.79)
Industry Concentration Shares										
H.C.S.A.	-0.010	-0.035***	-0.023*	-0.006	0.023	-0.006	-0.001	0.017*	0.034***	0.045***
	(-0.75)	(-3.27)	(-1.90)	(-0.40)	(1.10)	(-0.81)	(-0.18)	(1.96)	(2.83)	(2.77)
Manufacturing	0.006	0.007	0.007	0.011	0.014	0.007**	0.015***	0.024***	0.017***	0.026***
	(0.95)	(1.20)	(1.01)	(1.32)	(1.30)	(1.99)	(3.56)	(5.23)	(2.58)	(2.95)
Professional Services	0.012	-0.006	0.012	0.064***	0.093***	-0.007	0.003	0.005	-0.004	-0.012
	(0.82)	(-0.47)	(0.90)	(3.83)	(4.03)	(-0.97)	(0.37)	(0.52)	(-0.34)	(-0.66)
Retail	-0.017	-0.024*	-0.015	0.002	0.046*	-0.011	-0.010	0.033***	0.022	0.043*
	(-1.04)	(-1.76)	(-0.96)	(0.09)	(1.76)	(-1.08)	(-0.81)	(2.64)	(1.23)	(1.80)
Education	-0.011	-0.001	0.011	0.006	-0.046**	-0.013	-0.010	-0.025**	-0.052***	-0.108***
	(-0.78)	(-0.10)	(0.85)	(0.36)	(-2.03)	(-1.52)	(-1.08)	(-2.49)	(-3.68)	(-5.57)
F.I.R.E	0.003	0.002	0.020**	0.006	-0.027	0.002	0.011	-0.001	-0.027***	-0.055***
	(0.24)	(0.24)	(2.02)	(0.47)	(-1.62)	(0.36)	(1.57)	(-0.17)	(-2.73)	(-3.99)
Public Admin	0.010	0.016**	0.017**	0.021**	0.023*	0.007	0.014***	0.018***	0.010	0.012
	(1.17)	(2.29)	(2.11)	(2.03)	(1.65)	(1.58)	(2.59)	(3.19)	(1.30)	(1.08)
Construction	-0.025	-0.049***	-0.060***	-0.064***	-0.106***	-0.006	-0.008	-0.014	-0.004	-0.001
	(-1.30)	(-3.15)	(-3.38)	(-2.90)	(-3.51)	(-0.60)	(-0.71)	(-1.19)	(-0.22)	(-0.03)
Transportation	0.004	0.001	-0.007	-0.018	-0.042	0.007	0.010	0.031***	0.038**	0.056***
	(0.23)	(0.07)	(-0.37)	(-0.81)	(-1.36)	(0.83)	(0.98)	(2.92)	(2.53)	(2.70)
Agriculture	0.011	0.010	0.032***	0.059***	0.100***	0.007	0.002	0.029***	0.045***	0.060***
	(1.15)	(1.19)	(3.45)	(5.13)	(6.36)	(1.15)	(0.36)	(4.00)	(4.46)	(4.37)
Year Spline										
Year [1991,1998]	0.015**	0.018***	0.020***	0.019**	0.026**	0.009**	0.015***	0.018***	0.016**	0.018*
	(2.10)	(3.11)	(3.08)	(2.33)	(2.39)	(2.03)	(2.93)	(3.49)	(2.11)	(1.75)
Year[1999,2007]	0.028***	0.064***	0.091***	0.119***	0.132***	0.028***	0.069***	0.117***	0.165***	0.207***
	(5.03)	(14.19)	(17.43)	(18.24)	(14.89)	(8.01)	(17.03)	(27.27)	(27.28)	(25.09)
Year[2008,2011]	0.049***	0.076***	0.119***	0.144***	0.183***	0.041***	0.072***	0.087***	0.103***	0.098***
	(3.75)	(7.22)	(9.79)	(9.46)	(8.85)	(5.04)	(7.73)	(8.83)	(7.40)	(5.16)
Year[2012,2020]	-0.016**	-0.019***	-0.019***	-0.011	0.005	-0.020***	-0.031***	-0.014**	0.008	0.061***
	(-2.08)	(-3.08)	(-2.65)	(-1.26)	(0.37)	(-4.14)	(-5.61)	(-2.42)	(0.92)	(5.47)
Goodness of Fit										
R^2	0.092	0.199	0.312	0.387	0.438	0.064	0.149	0.260	0.332	0.373
N	6,000	6,000	6,000	6,000	6,000	11,963	11,963	11,963	11,963	11,963

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data on weather. Industries are ordered based on popularity, and the 10 most popular industries are listed. Top 100 MSA are included in our models. N is calculated by the number of states/MSA × 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

Table A.3: Stratifying Seasonality by Time-between-Sales

	State			MSA		
Estimate	Short Time	Average Time	Long Time	Short Time	Average Time	Long Time
Weather						
Range Temp Q1	0.010***	0.011***	0.014***	0.011***	0.022***	0.022***
	(5.13)	(6.44)	(5.89)	(10.19)	(19.43)	(13.56)
Range Temp Q2	0.010***	0.012***	0.018***	0.002	0.007***	0.009***
	(4.30)	(5.58)	(7.58)	(1.48)	(5.94)	(5.58)
Range Temp Q3	0.025***	0.019***	0.038***	-0.001	0.011***	0.009***
	(5.83)	(4.95)	(8.11)	(-0.95)	(9.63)	(5.62)
Range Temp	-0.017***	-0.013***	-0.023***	0.001	-0.009***	-0.009***
	(-5.46)	(-3.76)	(-6.31)	(0.56)	(-4.01)	(-2.86)
Average	-0.023***	-0.021***	-0.035***	0.003**	0.001	-0.000
	(-4.35)	(-4.38)	(-6.47)	(2.42)	(0.86)	(-0.01)
Precipitation	-0.027*	-0.025	0.010	-0.004	0.005	-0.007
	(-1.67)	(-1.40)	(0.73)	(-0.54)	(0.59)	(-1.11)
Characteristics						
ln(Number of Sales)	0.016	0.148**	0.063	0.036	-0.111***	-0.147***
	(0.30)	(2.32)	(1.04)	(0.76)	(-2.71)	(-3.14)
Over 65 Years Olds	0.055	-0.094*	-0.060	0.178***	0.032	-0.272
	(1.24)	(-1.79)	(-0.97)	(3.16)	(0.92)	(-1.49)
Pct of Non-White	-0.020*	0.003	0.050***	-0.014**	-0.039***	-0.021
	(-1.86)	(0.21)	(2.87)	(-2.00)	(-2.80)	(-0.72)
Pct of Bachelor or Higher	-0.081**	0.353**	0.063**	0.182***	-0.041	0.263
	(-2.20)	(2.04)	(2.08)	(6.21)	(-0.86)	(1.46)
Pct of Single Family Sales	-0.058***	0.045***	-0.021	0.016	0.107***	0.033
	(-2.63)	(4.23)	(-1.08)	(1.32)	(3.47)	(1.32)
Industry Concentration Shares						
H.C.S.A.	-0.399**	-0.227***	-0.364**	-0.135*	-0.087	0.381**
	(-2.49)	(-5.90)	(-2.02)	(-1.76)	(-1.59)	(2.57)
Manufacturing	-0.192**	-0.168*	0.126*	0.110**	0.143***	-0.423
	(-2.23)	(-1.72)	(1.88)	(2.16)	(3.04)	(-1.08)
Professional Services	-0.158*	-0.741*	-0.577**	-0.277***	0.314***	-0.380
	(-1.85)	(-1.78)	(-2.46)	(-3.34)	(5.48)	(-0.71)
Retail	-0.046	0.777***	0.506**	0.181	0.827***	-0.055
	(-0.75)	(4.83)	(2.47)	(1.50)	(5.84)	(-0.33)
Education	0.032	0.401**	0.371**	-0.184***	0.675***	0.304
	(0.49)	(2.14)	(2.46)	(-3.19)	(3.56)	(1.47)
F.I.R.E	0.029	-0.546	-0.390***	-0.015	0.138***	-1.195
	(0.39)	(-1.48)	(-2.74)	(-0.21)	(5.28)	(-1.19)
Public Admin	-0.099	-0.392	0.310***	0.061	0.182***	-0.286
	(-1.09)	(-1.57)	(3.39)	(1.10)	(4.52)	(-1.21)
Construction	-0.253***	-0.314**	0.598**	0.492***	-0.386***	-1.414
	(-3.21)	(-1.99)	(2.14)	(4.76)	(-3.44)	(-1.07)
Transportation	-0.087	-0.313***	0.707***	0.165***	0.317***	0.192
	(-1.02)	(-3.35)	(3.41)	(2.78)	(3.12)	(0.79)
Agriculture	-0.218**	-0.118	-0.758***	-0.269	0.201***	0.563
	(-2.16)	(-0.90)	(-2.60)	(-1.30)	(2.68)	(1.55)
Year Spline						
Year [1991,1998]	0.030***	0.013	0.023**	0.005	0.021***	0.026**
	(2.85)	(1.26)	(2.27)	(0.55)	(2.60)	(2.54)
Year [1999,2007]	0.074***	0.115***	0.118***	0.121***	0.134***	0.128***
	(9.48)	(13.66)	(14.17)	(17.13)	(20.53)	(15.79)
Year [2008,2011]	0.102***	0.127***	0.110***	0.132***	0.029*	0.065***
	(5.19)	(6.41)	(5.50)	(7.85)	(1.86)	(3.55)
Year [2012,2020]	-0.007	-0.000	-0.024**	-0.007	-0.001	0.045***
	(-0.67)	(-0.04)	(-2.06)	(-0.67)	(-0.15)	(4.17)
Fixed Effect	MSA	MSA	MSA	MSA	MSA	
Goodness of Fit						
R^2	0.420	0.556	0.521	0.462	0.480	0.406
BIC	4,693	4,334	4,780	10,446	9,973	12,361
N	2,040	1,920	2,040	3,940	3,953	4,070
Num. State/MSA	17	16	17	33	33	34
Percentile	<33%	34%-66%	>67%	<33%	34%-66%	>67%

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data of weather. Shortest Time cities are defined if the time between sales are in the lower 10% among the top 100 MSA; Less Time cities are between 10% and 25%; Average cities are between 25% and 75%; More Time cities are between 75% and 90%; Longest Time cities are above 90%. N is calculated by the number of states/MSA × 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

Table A.4: The Impact of Seasonality by City Size

Estimate	Smallest City	Small City	Medium City	Large City	Largest City
Weather					
Range Temp Q1	0.011***	0.016***	0.017***	0.020***	0.033***
	(4.80)	(11.07)	(15.01)	(10.96)	(14.73)
Range Temp Q2	0.002	0.002	0.007***	0.009***	0.007***
	(0.75)	(1.16)	(6.02)	(4.79)	(3.22)
Range Temp Q3	0.006***	0.007***	0.004***	0.006***	0.022***
	(2.66)	(4.81)	(3.10)	(3.18)	(10.12)
Range Temp	0.005	-0.007**	-0.005**	-0.006	-0.014***
	(1.01)	(-2.36)	(-2.20)	(-1.55)	(-3.52)
Average	0.003	-0.000	0.002**	0.000	-0.003
	(1.57)	(-0.01)	(2.19)	(0.11)	(-1.64)
Precipitation	0.027*	0.011	-0.018**	-0.000	-0.006
	(1.94)	(0.89)	(-2.23)	(-0.10)	(-0.33)
Characteristics					
ln(Number of Sales)	-0.373***	-0.099*	-0.059	-0.023	0.019
	(-4.33)	(-1.92)	(-1.56)	(-0.41)	(0.21)
Over 65 Years Olds	0.350*	0.047	-0.150	-0.292	-0.094
	(1.68)	(1.63)	(-1.36)	(-0.40)	(-1.59)
Pct of Non-White	0.047	-0.040***	0.005	-0.031	-0.033***
	(1.11)	(-6.82)	(0.30)	(-0.47)	(-2.81)
Pct of Bachelor or Higher	0.008	-0.191***	0.456**	0.017	0.000
	(0.35)	(-5.29)	(2.38)	(0.19)	(.)
Pct of Single Family Sales	0.116**	0.019**	-0.053	0.027	0.000
	(1.96)	(2.14)	(-1.49)	(0.74)	(.)
Industry Concentration Shares					
H.C.S.A.	-0.529**	0.092*	0.733***	0.354	0.000
	(-2.25)	(1.88)	(3.22)	(0.48)	(.)
Manufacturing	-0.115***	0.099***	-0.186	-0.229	0.000
	(-4.72)	(3.71)	(-0.61)	(-0.46)	(.)
Professional Services	0.098	0.136***	-1.497*	0.000	0.000
	(1.01)	(3.04)	(-1.66)	(.)	(.)
Retail	-0.759**	-0.320***	-0.891	0.000	0.000
	(-2.55)	(-3.37)	(-1.21)	(.)	(.)
Education	0.293	0.300***	-2.049**	0.000	0.000
	(1.22)	(7.02)	(-2.10)	(.)	(.)
F.I.R.E	0.000	0.450***	0.058	0.000	0.000
	(.)	(5.42)	(0.26)	(.)	(.)
Public Admin	0.000	0.134***	-0.443	0.000	0.000
	(.)	(3.76)	(-1.19)	(.)	(.)
Construction	0.000	0.227***	1.271***	0.000	0.000
	(.)	(4.90)	(4.01)	(.)	(.)
Transportation	0.000	-0.299***	-2.140	0.000	0.000
	(.)	(-6.22)	(-1.55)	(.)	(.)
Agriculture	0.000	0.034*	0.367	0.000	0.000
	(.)	(1.69)	(0.70)	(.)	(.)
Year Spline					
Year [1991,1998]	0.026	0.025**	0.019**	0.027**	0.037***
	(1.54)	(2.41)	(2.46)	(2.31)	(2.61)
Year[1999,2007]	0.104***	0.090***	0.142***	0.121***	0.104***
	(7.84)	(10.66)	(22.02)	(13.00)	(8.57)
Year[2008,2011]	0.024	0.031	0.076***	0.103***	0.078***
	(0.77)	(1.54)	(5.07)	(4.91)	(3.06)
Year[2012,2020]	0.053***	0.004	0.038***	-0.039***	-0.030**
	(2.83)	(0.35)	(4.31)	(-3.14)	(-2.02)
Fixed Effect	MSA	MSA	MSA	MSA	MSA
Goodness of Fit					
R^2	0.411	0.398	0.452	0.471	0.481
BIC	3,269	4,045	18,116	4,495	2,588
N	1,186	1,794	6,109	1,798	1,076
Num. MSA	10	15	51	15	9
Percentile	<10%	10%-25%	25-75%	75%-90%	>90%

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data on weather. Tiny cities are defined if the population are in the lower 10% of the top 100 MSA; Small cities are in the lower 25%; Median cities are between 25% and 75%; large cities are above 75%; Huge cities are above 90%. N is calculated by the number of states/MSA $\times$ 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

Table A.5: Stratifying Seasonality by Calendar Quarter

	State				MSA			
Estimate	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Weather								
Range Temp	-0.020***	0.002	0.006	-0.004	0.001	0.008***	-0.002	0.003
	(-4.31)	(0.41)	(1.36)	(-1.30)	(0.20)	(3.73)	(-0.87)	(1.29)
Average	-0.015***	0.003	-0.016***	0.003	0.000	0.001	-0.001	0.000
	(-3.53)	(0.74)	(-3.88)	(0.72)	(0.17)	(0.77)	(-1.10)	(0.32)
Precipitation	-0.019	-0.002	-0.014	-0.001	-0.016	-0.044***	-0.031***	-0.011**
	(-0.83)	(-0.12)	(-0.91)	(-0.09)	(-1.48)	(-5.22)	(-4.04)	(-2.02)
Characteristics								
ln(Number of Sales)	0.006	0.131***	0.044	0.009	-0.015	-0.018	0.009	-0.103***
	(0.14)	(4.56)	(1.49)	(0.26)	(-0.58)	(-0.80)	(0.45)	(-4.36)
Over 65 Years Old	0.007	-0.120***	0.036**	-0.065***	0.017	0.011	0.031***	-0.050***
	(0.26)	(-6.77)	(1.98)	(-3.20)	(1.37)	(1.05)	(3.22)	(-4.38)
Pct of Non-White	-0.002	-0.012***	-0.009***	-0.008**	-0.012***	-0.002	-0.007***	-0.002
	(-0.41)	(-4.44)	(-3.53)	(-2.58)	(-4.46)	(-0.74)	(-3.22)	(-0.77)
Pct of Bachelor or Higher	0.021	0.045***	0.013	0.027***	0.043***	0.112***	0.055***	0.098***
	(1.63)	(5.44)	(1.56)	(2.91)	(4.79)	(14.94)	(8.06)	(12.03)
Pct of Single Family Sales	0.002	0.028***	-0.009**	0.014***	-0.003	0.012***	-0.005*	-0.001
	(0.30)	(7.33)	(-2.40)	(3.21)	(-0.71)	(3.89)	(-1.73)	(-0.28)
Industry Concentration Shares								
H.C.A.S.	-0.031	0.040**	-0.073***	-0.026	0.027	0.036**	0.013	0.046***
	(-1.09)	(2.30)	(-4.01)	(-1.31)	(1.44)	(2.32)	(0.95)	(2.73)
Manufacturing	0.028*	0.002	0.005	-0.006	0.027***	0.044***	0.013*	0.034***
	(1.93)	(0.20)	(0.52)	(-0.53)	(2.74)	(5.33)	(1.70)	(3.84)
Professional Services	0.061**	0.038*	0.016	0.056**	0.002	0.012	-0.048***	-0.001
	(1.97)	(1.96)	(0.77)	(2.50)	(0.10)	(0.70)	(-3.21)	(-0.08)
Retail	-0.023	0.020	-0.058**	0.052**	-0.016	0.123***	-0.009	0.207***
	(-0.66)	(0.88)	(-2.51)	(2.08)	(-0.59)	(5.45)	(-0.46)	(8.47)
Education	-0.006	-0.079***	0.031	-0.048**	0.025	-0.124***	0.006	-0.174***
	(-0.21)	(-4.09)	(1.55)	(-2.18)	(1.13)	(-6.82)	(0.37)	(-8.80)
F.I.R.E	-0.014	-0.006	0.003	-0.011	0.021	-0.022*	-0.017	-0.047***
	(-0.63)	(-0.43)	(0.17)	(-0.70)	(1.38)	(-1.73)	(-1.43)	(-3.39)
Public Administration	0.018	0.041***	0.008	0.010	0.021*	0.022**	0.015*	0.019*
	(1.00)	(3.54)	(0.62)	(0.73)	(1.77)	(2.21)	(1.69)	(1.74)
Construction	-0.114***	-0.028	-0.183***	-0.068**	-0.044*	0.080***	-0.086***	0.066***
	(-2.87)	(-1.10)	(-6.86)	(-2.36)	(-1.74)	(3.81)	(-4.51)	(2.94)
Transportation	0.012	-0.039	0.027	-0.054*	0.055**	0.082***	0.044**	0.079***
	(0.29)	(-1.48)	(1.00)	(-1.84)	(2.35)	(4.25)	(2.48)	(3.73)
Agriculture	0.060***	0.020	0.061***	0.059***	0.024	0.064***	0.042***	0.043***
	(3.00)	(1.54)	(4.28)	(4.01)	(1.53)	(4.91)	(3.54)	(3.03)
Year Spline								
Year [1991,1998]	0.023	0.006	0.035***	0.016	0.013	0.018*	0.022**	0.026**
	(1.56)	(0.59)	(3.62)	(1.51)	(1.15)	(1.88)	(2.57)	(2.46)
Year [1998,2007]	0.142***	0.096***	0.106***	0.059***	0.168***	0.120***	0.139***	0.081***
	(12.21)	(13.00)	(13.72)	(6.94)	(18.05)	(15.46)	(19.76)	(9.61)
Year [2008,2011]	0.158***	0.107***	0.123***	0.044**	0.115***	0.121***	0.021	0.042**
	(5.73)	(6.16)	(6.89)	(2.23)	(5.35)	(6.78)	(1.32)	(2.19)
Year [2012,2020]	-0.083***	0.036***	-0.067***	0.072***	-0.079***	0.065***	-0.026***	0.097***
	(-5.19)	(3.54)	(-6.32)	(6.19)	(-6.31)	(6.19)	(-2.73)	(8.47)
Goodness of Fit								
R^2	0.448	0.588	0.552	0.382	0.379	0.529	0.403	0.370
BIC	4,181	2,835	2,941	3,215	8,976	7,891	7,306	8,377
N	1,500	1,500	1,500	1,500	2,991	2,992	2,993	2,987

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data on weather. Industries are ordered based on popularity, and the 10 most popular industries are listed. Top 100 MSA are included in our models. N is calculated by the number of states/MSA × 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

Table A.6: The Lack of Population Diversity and Seasonality

	White				Over 65 Years Old			
Estimate	10%	25%	75%	90%	10%	25%	75%	90%
Weather								
Range Temp Q1	0.007*	0.018***	0.021***	0.024***	0.008***	0.009***	0.032***	0.037***
	(1.72)	(10.27)	(14.86)	(11.17)	(3.62)	(5.82)	(23.12)	(16.03)
Range Temp Q2	0.011***	0.008***	0.008***	0.005***	0.007***	0.006***	0.011***	0.009***
	(3.00)	(4.72)	(5.34)	(2.61)	(3.12)	(3.61)	(7.61)	(3.92)
Range Temp Q3	-0.005	0.006***	0.007***	0.009***	-0.008***	-0.006***	0.020***	0.023***
	(-1.39)	(3.69)	(5.28)	(4.48)	(-3.46)	(-4.18)	(14.64)	(10.11)
Range Temp	-0.002	-0.008**	-0.001	-0.000	-0.001	-0.001	-0.014***	-0.015***
	(-0.30)	(-2.42)	(-0.24)	(-0.02)	(-0.16)	(-0.27)	(-5.22)	(-3.44)
Average	-0.004	-0.002	0.003**	0.002	-0.002	0.000	0.002*	0.004*
	(-1.14)	(-1.24)	(2.38)	(0.90)	(-0.83)	(0.29)	(1.73)	(1.83)
Precipitation	-0.043*	-0.024**	-0.002	-0.004	0.005	0.002	0.002	0.004
	(-1.76)	(-1.99)	(-0.17)	(-0.19)	(0.85)	(0.38)	(0.22)	(0.33)
Characteristics								
ln(Number of Sales)	-0.255***	-0.150***	-0.079	0.070	0.081	0.022	-0.189***	-0.178***
	(-2.79)	(-3.18)	(-1.33)	(0.82)	(1.13)	(0.44)	(-4.22)	(-2.83)
Over 65 Years Old	0.340**	0.389***	-0.140***	-0.165	-0.954***	-0.472**	-0.469***	-0.911
	(2.19)	(4.32)	(-2.91)	(-1.16)	(-3.69)	(-2.26)	(-3.78)	(-1.11)
Pct of Non-White	-0.076***	-0.044**	0.017	-0.095	-0.039***	-0.035**	0.076***	0.200
	(-2.60)	(-2.48)	(0.45)	(-0.96)	(-7.18)	(-2.52)	(3.61)	(1.32)
Pct of Bachelor or Higher	0.057***	0.025	0.284***	-0.219***	0.007	0.038	0.687***	0.470
	(2.77)	(0.29)	(2.70)	(-4.80)	(0.20)	(1.24)	(3.96)	(1.42)
Pct of Single Family Sales	0.034**	0.030	0.012	-0.042	0.051***	-0.140***	0.112***	0.106**
	(2.28)	(0.99)	(0.42)	(-1.25)	(3.29)	(-3.35)	(3.23)	(2.24)
Industry Concentration Shares H.C.A.S	-0.046	-0.190***	0.146*	0.363**	-0.302*	-0.224**	0.696***	0.241
	(-0.37)	(-3.20)	(1.81)	(2.21)	(-1.96)	(-2.01)	(5.42)	(0.63)
Manufacturing	0.002	-0.108	0.019	-0.114***	-0.156***	-0.165**	-0.333**	0.146
	(0.19)	(-0.99)	(0.24)	(-4.72)	(-7.13)	(-2.53)	(-2.25)	(0.72)
Professional Services	0.000	0.095	-0.022	0.063	0.170	-0.351	-0.689***	-2.390
	(.)	(0.76)	(-0.29)	(0.21)	(1.63)	(-1.59)	(-3.02)	(-1.25)
Retail	0.000	0.072	0.808***	-0.371	0.000	-0.098	2.671***	4.133
	(.)	(0.42)	(4.00)	(-0.68)	(.)	(-1.10)	(4.42)	(1.09)
Education	0.000	0.062	0.031	-0.593***	0.000	-0.278***	0.199***	0.000
	(.)	(0.18)	(0.22)	(-5.98)	(.)	(-4.23)	(4.45)	(.)
F.I.R.E	0.000	-0.172**	-0.415**	0.000	0.000	-0.407***	0.409***	0.000
	(.)	(-2.17)	(-2.06)	(.)	(.)	(-2.96)	(6.20)	(.)
Public Adminstration	0.000	-0.123	-0.153	0.000	0.000	-0.192***	-0.177	0.000
	(.)	(-0.80)	(-1.05)	(.)	(.)	(-2.78)	(-1.20)	(.)
Construction	0.000	-0.168	0.497	0.000	0.000	-0.690***	-0.889***	0.000
	(.)	(-0.83)	(1.36)	(.)	(.)	(-4.22)	(-3.75)	(.)
Transportation	0.000	-0.015	0.709***	0.000	0.000	-0.097	0.128	0.000
	(.)	(-0.07)	(3.33)	(.)	(.)	(-0.77)	(0.85)	(.)
Agriculture	0.000	-0.082	-1.129	0.000	0.000	-0.083	0.797***	0.000
	(.)	(-0.33)	(-1.15)	(.)	(.)	(-1.10)	(3.73)	(.)
Year Spline								
Year [1991-1998]	0.011	0.021*	0.015	0.014	0.024	0.017	0.006	-0.004
	(0.49)	(1.92)	(1.40)	(0.88)	(1.57)	(1.63)	(0.64)	(-0.26)
Year [1999-2007]	0.172***	0.132***	0.146***	0.125***	0.136***	0.127***	0.141***	0.150***
	(9.94)	(15.07)	(16.61)	(10.20)	(10.94)	(14.68)	(19.56)	(13.67)
Year [2008-2011]	-0.007	0.045**	0.069***	0.128***	0.130***	0.110***	-0.016	-0.029
	(-0.18)	(2.21)	(3.41)	(4.32)	(4.51)	(5.43)	(-0.94)	(-1.12)
Year [2012-2020]	0.098***	0.022*	0.023*	0.013	0.002	0.042***	-0.007	0.009
	(4.22)	(1.84)	(1.85)	(0.76)	(0.09)	(3.49)	(-0.66)	(0.59)
Fixed Effect	MSA	MSA	MSA	MSA	MSA	MSA	MSA	MSA
Goodness of Fit								
R^2	0.396	0.401	0.472	0.487	0.492	0.468	0.466	0.472
BIC	4,570	9,684	8,417	3,188	3,706	9,083	7,039	3,328
N	1,317	3,232	2,983	1,199	1,318	3,115	2,864	1,309
Num. MSA	11	27	25	10	11	26	24	11
Percentile	≤10%	≤25%	≥75%	≥90%	≤10%	≤25%	≥75%	≥90%

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Hawaii is not included because of missing data on weather. N is calculated by the number of MSA × 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.

Table A.7: The Impact of Seasonality on House Price Measures (MSAs)

	MSA				
Estimate	Model 1	Model 2	Model 3	Model 4	Model 5
Weather					
Range Temp Q1	0.018***	0.017***	0.018***	0.016***	0.018***
	(18.69)	(18.60)	(23.29)	(17.45)	(23.80)
Range Temp Q2	0.005***	0.006***	0.005***	0.008***	0.006***
	(5.45)	(6.56)	(6.92)	(9.28)	(7.45)
Range Temp Q3	0.006***	0.006***	0.006***	0.008***	0.006***
	(5.87)	(6.97)	(7.44)	(9.38)	(7.92)
Range Temp	-0.003**	-0.001	-0.004***	-0.004**	-0.005***
	(-2.01)	(-0.57)	(-3.15)	(-2.41)	(-3.41)
Average Temp	-0.003***	0.002**	0.001	0.003***	0.001*
	(-3.33)	(2.47)	(1.02)	(3.77)	(1.94)
Precipitation	-0.010**	-0.014***	-0.021***	-0.000	-0.004
	(-2.25)	(-3.02)	(-5.38)	(-0.07)	(-0.95)
Year Spline					
Year [1991-1998]			0.020***		0.021***
			(3.76)		(4.08)
Year [1999-2007]			0.127***		0.126***
			(29.78)		(30.54)
Year [2008-2011]			0.075***		0.071***
			(7.69)		(7.34)
Year [2012-2020]			0.014**		0.015***
			(2.34)		(2.68)
Controls					
Household Characteristics	Y	Y	Y	Y	Y
Industry Concentration Shares	Y	Y	Y	Y	Y
Fixed Effect				MSA	MSA
Goodness of Fit					
R^2	0.034	0.111	0.389	0.185	0.438
BIC	38,684	37,832	33,373	37,579	33,177
N	11,963	11,963	11,963	11,963	11,963

Note: The difference between NSA HPI and SA HPI is models as a function of weather-related variables, social and industry characteristics, and temporal and geographic controls. Quarterly frequency. Range Temp is defined as the difference between the maximum and minimum temperature. Industries are ordered based on popularity, and the 10 most popular industries are listed. Top 100 MSA are included in our models. N is calculated by the number of states/MSA $\times$ 120. t-value in parentheses. * for $p < .1$, ** for $p < .05$, and *** for $p < .01$.