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Working Paper

Nonlinear tail dependence between the housing and energy markets

ADB Working Paper Series, No. 1133

Provided in Cooperation with:

Asian Development Bank Institute (ADBI), Tokyo

Suggested Citation: Stenvall, David; Hedström, Axel; Yoshino, Naoyuki; Uddin, Mohammed Gazi Salah; Taghizadeh-Hesary, Farhad (2020) : Nonlinear tail dependence between the housing and energy markets, ADB Working Paper Series, No. 1133, Asian Development Bank Institute (ADBI), Tokyo

This Version is available at:

<https://hdl.handle.net/10419/238490>

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ADB Working Paper Series

NONLINEAR TAIL DEPENDENCE BETWEEN THE HOUSING AND ENERGY MARKETS

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No. 1133
May 2020

Asian Development Bank Institute

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Suggested citation:

Stenvall, D., A. Hedström, N. Yoshino, G. S. Uddin, and F. Taghizadeh-Hesary. 2020. Nonlinear Tail Dependence between the Housing and Energy Markets. ADBI Working Paper 1133. Tokyo: Asian Development Bank Institute. Available: <https://www.adb.org/publications/nonlinear-tail-dependence-between-housing-energy-markets>

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Gazi S. Uddin is thankful for the financial support provided by the Jan Wallander and Tom Hedelius Foundations (Ref. W2016:0364:1), Sweden. Gazi Salah Uddin and David Stenvall are also thankful for the financial support provided by the Swedish Energy Agency. Authors are thankful to the Trinity Business School, University of Dublin for the academic facilities provided to Gazi S. Uddin during his stay at Trinity where important parts of this research work was completed. Earlier version of this paper presented the Economics Division, Linköping University, Sweden.

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Abstract

This paper examines the tail dependence between energy and housing markets in the United States by using cross-quantilogram approach. Our main finding shows a housing returns are dependent on the oil returns in a large part of the return distribution, and that the housing returns are more likely to be low after extremely high oil market returns. Furthermore, we find a heterogeneous response for the housing market in different regions with regard to all commodities. This appears in terms of the size of the dependence structures, but also for the sign of the dependence on the commodities. The findings in this study are robust to controls of economic state variables. Our contribution to the literature is showing the effect of energy returns on the housing market in the full part of the housing return distribution. Furthermore, we study the relationship between housing returns on more energy commodities other than crude oil. Last, we find regional differences in the relationship between different energy commodities and housing returns.

Keywords: housing market, oil, coal, natural gas, tail-dependence, cross-quantilogram

JEL Classification: C14, C46, R31

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1. INTRODUCTION

In recent decades, there have been large price fluctuations in the housing market and global energy markets. The United States (US) housing crash during the financial crisis along with the sharp increase in oil prices before the crisis led to huge issues for policymakers all over the world due to their importance for the real economy. The theoretical linkages that connect these two markets have been established in previous literature suggesting several different transmission channels. While some studies, such as Breitenfeller, Cuaresma, and Mayer (2015), have pointed to the impact of oil prices on house price corrections, exhaustive empirical results regarding their relationship are lacking. As the relationship between these two markets could have macroeconomic implications, it is important to broaden this empirical literature. According to the Federal Reserve (2019), US households hold over \$29 trillion worth of real estate assets, and the US housing crash that triggered the global financial crisis was preceded by an increase in housing prices in larger cities. Leamer (2007) argues that 8 out of 10 US recessions since World War II have been preceded by disturbances in the housing sector. Further, Nyakabawo et al. (2015) found causal links from the US housing price index to real GDP per capita during both the global financial crisis and the recession in 2001. Given the large value of the housing market, it can have a significant impact on the state of the economy. As regards the energy market, there are papers connecting, for instance, the increase in oil prices with the outbreak and severity of the financial crises. Hamilton (2011) argues that 10 out of the 11 recessions in the US since the war have been preceded by sharp increases in oil prices. Kilian and Vigfusson (2014) suggest that oil price shocks accounted for a cumulative reduction of about 5% in US real GDP during the financial crisis. Kaufmann et al. (2011) suggest a role for energy prices in the Great Recession by identifying a relationship between household energy expenditures and US mortgage delinquency rates.

In light of the suggested roles of the housing market and energy commodities in recessions, the recent literature investigates the relationship between energy prices and the housing market. For instance, Breitenfeller, Cuaresma, and Mayer (2015) establish five theoretical linkages from previous literature by which the oil price can affect the housing market. First, the housing market is connected to the oil price by an income channel where rising oil prices may lead to lower household wealth and reduced housing demand. The second linkage comes through the effect on building costs. Higher energy prices lead to rising transportation costs of building material, and other construction and maintenance costs.¹ The third link is the monetary policy channel. Higher inflation due to rising oil prices may lead to a tightening of monetary policy and dampening of the housing demand.² The fourth channel is a financial market channel where real estate investments may be dampened by higher investments in commodity derivatives (Caballero, Farhi, and Gourinchas 2008; Basu and Gavin 2011; El-Gamal and Jaffe 2008). The last channel is through lagged joint effects such as global liquidity, monetary channels, or regulations that may affect the variables at different times (Frankel 2008; Bjørnland and Jacobsen 2010; Goodhart and Hofmann 2008).

The empirical studies in the field are scarce, however, and mainly focus on the relationship between housing and oil prices and ignore other commodities. Antonakakis,

¹ Quigley (1984), for instance, estimated, based on data from newly constructed owner-occupied housing, that a doubling of energy prices would be associated with an increase of 11%–15% in the price of housing services.

² This channel is also empirically investigated by Luciani (2010), who suggests that monetary policy shocks may have been a driver in the downturn of US residential investments in 2006.

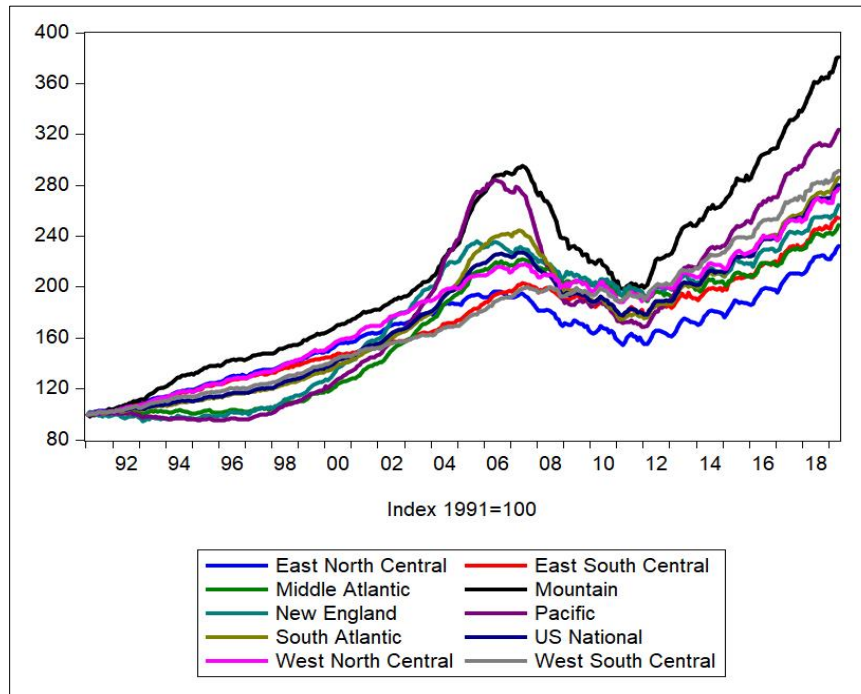
Gupta, and Muteba Mwamba (2016) investigates the dynamic co-movements between housing and oil market returns using a DCC-GARCH approach with annual data on the US national housing market spanning from 1859 to 2013. They find that the relationship has been consistently negative throughout history except during a few recessions in the 19th century. Breitenfeller, Cuaresma, and Mayer (2015) investigate how downward house price corrections may be determined by oil price increases. Using conditional logit models and quarterly data from 18 OECD countries spanning from 1971 to 2008, they found evidence that increasing oil price inflation raises the probability of house price corrections. The literature also separates the effects of oil on housing depending on the trading status of the country or region. Killins, Egly, and Escobari (2017) study the housing market's reactions to oil price shocks in Canada and the US and conclude that the effect varies depending on whether the oil price shocks are caused by demand or supply shocks in the oil market, but also on whether the country is a net importer or net exporter, with stronger effects for the former. Killins, Egly, and Escobari (2017) also found that some oil-specific demand shocks ("precautionary demand") influence the housing prices in the US positively in the short term even after controlling for macroeconomic variables. In addition, Kilian and Zhou (2018) analyze the effect of an oil shock on the Canadian housing market. Their results suggest that rising real oil prices increase the regional housing prices, not only in regions characterized by oil production, but also in regions that are not. The authors argue that this might be explained by government redistributions of the oil revenue. Khiabani (2015) uses a Bayesian structural VAR model and finds that housing prices in Iran are positively affected by an oil price shock. Last, Leung, Shi, and Tang (2013) investigate the relationship between energy commodities and housing prices in Australia and New Zealand and conclude that energy commodities affect the housing prices through macroeconomic variables.

The literature to date has several studies investigating the relationship between oil and housing, but the other energy commodities have received less attention. This is despite the fact that the theoretical linkages concerning oil and housing could be argued as being valid for the rest of the energy commodities and the housing market. Another limitation is the lack of focus on regional aspects. While Kilian and Zhou (2018) and Leung, Shi, and Tang (2013) have some regional focus, other studies concerning regional aspects of energy shocks or co-movements with the housing market are scarce. Nor does the previous literature in general capture the left and right tails of the housing return distribution and it might therefore be missing out information on the relationships between energy commodities and housing during booms and busts.

In this study, we will fill these research gaps by studying the quantile dependence between coal (COAL), natural gas (GAS), crude oil (OIL), and heating oil and regional housing markets in the US between 1991 and 2019. To measure the quantile dependence, we use the cross-quantilogram (CQC) developed by Han et al. (2016). This method allows us to study the dependence in arbitrary quantiles of both the dependent and independent variables, allowing us to capture the full return distribution. This is important as previous literature has shown a relationship between energy commodities and the housing market in terms of crisis periods, hence the relationship may be asymmetric. Last, we run panel quantile regressions (PQR) to control for the influence of economic variables. Our focus on the US is motivated both by the role played by the US housing market in the global financial crisis and by their large share of the world energy market. According to the US Energy Information Administration (2019), the US primary energy consumption in 2016 accounted for 17% of the world total. The last few decades have seen a big change in the US energy mix from a relatively high dependence on the coal industry to a rising share of natural gas in the energy production. According to the OECD (2019), the US natural gas production in 2018 was almost 706,000 ktoe compared to 438,000 ktoe in 1990. However, this can be contrasted to the primary supply

of coal that decreased from over 460,000 ktoe in 1990 to 317,000 in 2018. The decrease may partly be explained by the progress made in shale gas production, reducing the demand for coal. The US have also had large regional differences in the growth of housing prices as well as differences in the energy mix between regions. As depicted by Figure 1, although the trends are positive, the regional differences in price development in the housing market are apparent. While the housing prices in the mountain regions have almost increased fourfold, the prices in East North Central have slightly more than doubled.

Figure 1: Housing Price Development of the US Regions from 1991–2019



Notes: This figure shows the time trends between for the US national housing index and the regional housing indices represented as price series. The data have been retrieved from the Federal Housing Finance Agency (2019). The vertical axis represents the price index of the indices and the horizontal axis the time period.

Source: Federal Housing Finance Agency

Table 1 depicts the IEA (2019) projections of the US regional total energy consumption during 2019 divided by type of energy source for all sectors of the economy. From the table we can see the large differences in the energy mix between the regions.

As the literature points to regional differences in the energy-housing relationship and the recent change in the US energy mix, we are interested in finding out both whether there is a difference in importance between the commodities and whether the energy commodities affect the regional housing market in the US differently.

Table 1: Total Energy Consumption per US Region 2019
(%)

Region	Petroleum	Gas	Coal	Other
US National (US)	38.70	30.61	12.55	18.15
East North Central (ENC)	32.32	30.73	21.01	15.94
East South Central (ESC)	33.37	26.20	20.69	19.75
Middle Atlantic (MA)	35.99	35.22	8.04	21.75
Mountain (MT)	33.37	30.07	20.21	16.35
New England (NE)	45.91	30.38	0.62	23.09
Pacific (PF)	46.70	27.47	1.43	24.41
South Atlantic (SA)	37.58	28.66	11.49	22.27
West North Central (WNC)	33.21	23.41	24.11	19.27
West South Central (WSC)	46.04	35.90	7.72	10.34

Notes: Total energy consumption per US region in percent. This table shows the (IEA 2019) projections of total energy consumption per US region in 2019. In this case petroleum consists of petroleum and other liquid fuels.

Source: International Energy Agency (2019).

We contribute to the literature in several ways. First, we contribute by studying the effect of energy returns on the housing market in the full return distribution, displaying the relationship between housing and energy commodities during different states of the market. Second, we contribute by studying the relationship between housing returns and other energy commodities rather than oil on an aggregated level. Given the scarce literature on regional housing markets and energy commodities, we provide more information on this issue.

From our results we conclude the following: Oil influences the price of the housing return positively in a large part of the return distribution and during different states of the commodity return. Further, coal affects the housing prices negatively, especially during housing booms. Natural gas return, however, does not seem to be as important in general for the housing return as coal and oil. Some heterogeneity among regions is found regarding the influence of all commodities on the housing market, especially in terms of the size of the dependence, but in the case of natural gas, also for the sign of the dependence structure. The findings are robust after controlling for economic variables.

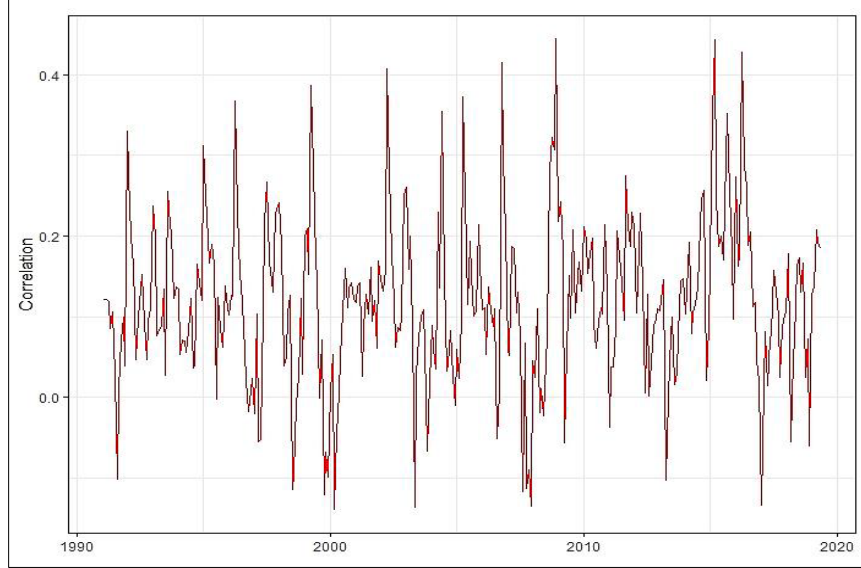
In Section 2 we present the methodology, and in Section 3 we outline the data and preliminary analysis. In Section 4 we interpret our results from the CQC and PQR, and in Section 5 we conclude our findings and present policy implications.

2. METHODOLOGY

In this paper, we apply the cross-quantilogram correlation (CQC) approach in Han et al. (2016) to measure the quantile dependence between commodities and housing indices in the US. With this method we can measure the dependence and directional predictability in arbitrary quantiles, capturing the full return quantile distributions and their relationships. This is important from an economic standpoint as this means that we can capture asymmetries in the energy housing relationship, i.e., correlations during different market states. While other methods such as DCC-GARCH have been used in earlier studies to study the relationship between housing and energy (see, for instance, Antonakakis, Gupta, and Muteba Mwamba (2016) for DCC between the oil and housing

returns), they cannot capture the tails of the distributions. In Figure 3 we present the dynamic conditional correlation (DCC) between the housing returns and the included commodities. Figure 2 denotes the dynamic conditional correlation between the US national housing index and the crude oil during the sample period. As depicted, the correlation shows large both negative and positive spikes during different time periods. Given the time-varying aspects of the correlation, a mean estimate will not capture these spikes, but an estimate of the quantiles of the distributions will. Figure 2 therefore justifies our use of CQC.

Figure 2: Dynamic conditional correlation between housing index and OIL



Notes: Dynamic conditional correlation. This figure displays the dynamic conditional correlation (DCC-GARCH (1,1)) between the US national housing index and OIL. The data for OIL have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019). The vertical axis represents the correlation and the horizontal axis the time period.

Source: The data for OIL have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019).

The cross-quantilogram was extended by Han et al. (2016) to a bivariate version of the quantilogram developed by Linton and Whang (2007). The method is based on correlations of “quantile hits” and does not require any moment conditions such as mean or variance to be calculated. The cross-quantilogram requires stationarity of the included time series, which we test for by using unit root tests. The cross-quantilogram method can be defined by letting y_t and x_t be two different stationary time series and assumes that $y_t = (y_{1t}, y_{2t})^T \in \mathbb{R}^2$ and $x_t = (x_{1t}, x_{2t})^T \in \mathbb{R}^{d1} \times \mathbb{R}^{d2}$ and $x_{it} = [x_{it}^{(1)}, \dots, x_{it}^{(di)}]^T \in \mathbb{R}^{di}$. The conditional distribution function of y_t and x_t is given by $F_{y_i|x_i}(\cdot | x_{it})$ and has the quantile distribution function $q_{it}(\tau_i) = \inf \{ v : F_{y_i|x_i}(v | x_{it}) \geq \tau_i \}$ for any $\tau_i \in (0, 1)$. The cross-quantilogram then measures the serial dependence between two events $\{y_{1t} \leq q_1(\tau_1)\}$ and $\{y_{2,t-k} \leq q_2(\tau_2)\}$ and with the quantile hit process denoted as $\{1[y_{it} \leq q_{it}(\cdot)]\}$. The cross-correlation of quantile hits or cross-quantilogram is estimated then as defined by (1).

$$\rho_{\tau}(k) = \frac{E[\phi_{\tau_1}(y_{1t} - q_{1,t}(\tau_1))\phi_{\tau_2}(y_{2,t-k} - q_{2,t-k}(\tau_2))]}{\sqrt{E[\phi_{\tau_1}^2(y_{1t} - q_{1,t}(\tau_1))]} \sqrt{E[\phi_{\tau_2}^2(y_{2,t-k} - q_{2,t-k}(\tau_2))]}} \quad (1)$$

where the quantile hit process is $\phi_\alpha = 1[u < 0] - \alpha$ and k is a positive integer indicating lag length. If there is no cross-dependence or directional spillover, then $\rho_\tau(k)$ will be zero, and if $\widehat{\rho}_\tau(k) = 1$, then there is likely quantile dependence or directional spillovers. We test this using the Box-Ljung (1978) significance test for autocorrelation with the null hypothesis in accordance with (2).

$$H_0: \widehat{\rho}_\tau(1) = \dots = \widehat{\rho}_\tau(k) = 0 \quad (2)$$

$$H_1: \widehat{\rho}_\tau(k) \neq 0 \text{ for one or multiple } k$$

The Box-Ljung test takes the form as presented in equation (3).

$$\widehat{Q}_\tau(p) = T(T+2) \sum_{k=1}^p \frac{\widehat{\rho}_\tau^2(k)}{T-k} \quad (3)$$

If $\widehat{\rho}_\tau(k) = 0$ we reject H_1 and assume dependence.³ To obtain information for the hypothesis testing we perform stationary bootstrap procedures with 500 iterations. Our output from the CQC will be presented as heatmaps, which make the results easy to interpret. The X- and Y-axes depict 11 different quantiles each ranging from $[q = (0.05, 0.1, 0.2, \dots, 0.95)]$. We present our results with a lag length of one.⁴ The upper and lower quantiles represent the tails of the variable distributions, which in turn represent the months with abnormal return. For our control estimations we perform panel quantile regressions based on Koenker (2004).

3. DATA AND PRELIMINARY ANALYSIS

In this study we investigate the quantile dependence between energy commodities and housing returns in the US, both on a national and regional level. We use monthly data on single-family house prices for the nine different US Census Bureau divisions and the US national prices spanning from January 1991 to May 2019. The US Census Bureau divisions are presented in Table 1. The housing data have been retrieved from the Federal Housing Finance Agency (2019) and consist of weighted repeat-sales indices, measuring average price changes in repeat sales or refinancing of the same properties. Our focus on the US is motivated first by the role played by the US housing market in the global financial crisis. Furthermore, the US represents a large share of the world energy market in terms of consumption together with large regional differences in price increases in the last few decades. The selected commodities are oil, coal, and natural gas⁵ and these were chosen based on theoretical linkages to housing prices. The relationship between oil and housing has been investigated by Killins, Egly, and Escobari (2017), Breitenfeller, Cuaresma, and Mayer (2015), Leung, Shi and Tang (2013), Khiabani (2015), and Kilian and Zhou (2018). As for coal, we choose to include it due to

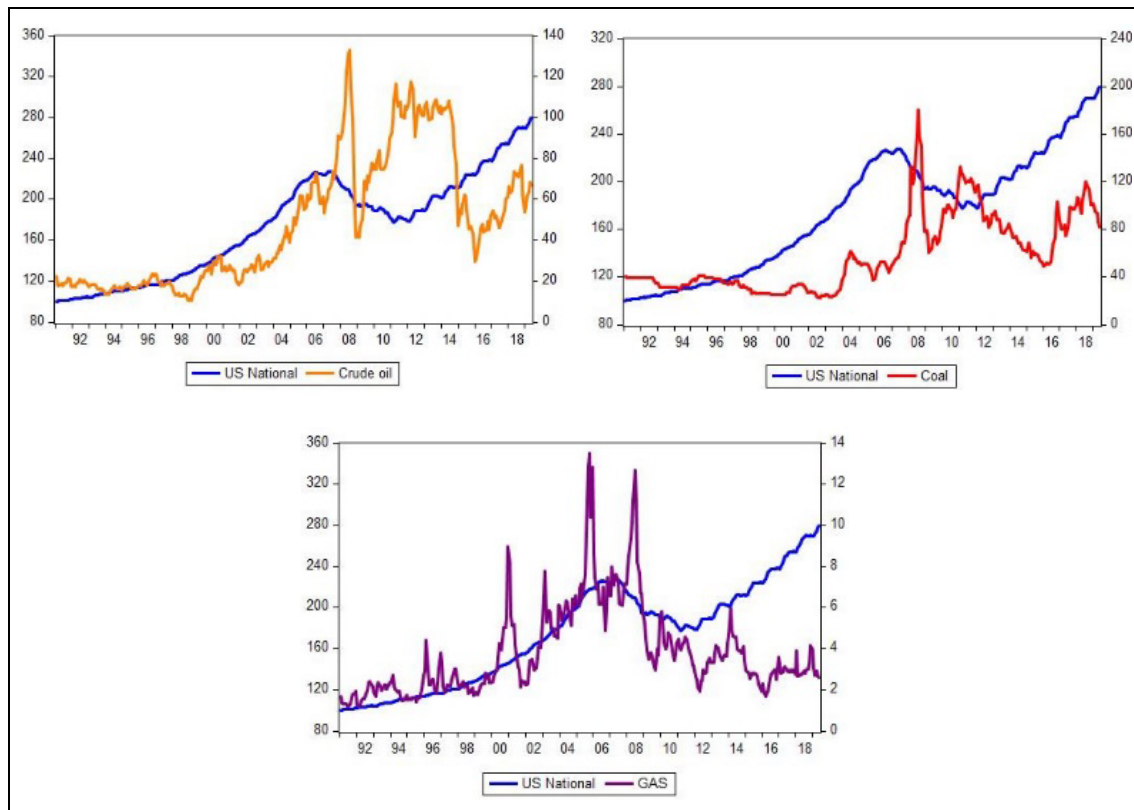
³ In addition, we incorporate the partial cross-quantilogram to test our correlations for uncertainties. The partial cross-quantilogram measures, just like the cross-quantilogram, the dependency between the two events $\{y_{1t} \leq q_1(\tau_1)\}$ and $\{y_{2t-k} \leq q_2(\tau_2)\}$, but also controls for intermediate events such as t and $t-k$. Our control variables or uncertainties are represented by the vector $\bar{z}_t = [\psi(y_{\tau_3} - q_{3t}(\tau_3)), \dots, \psi(y_{\tau_n} - q_{nt}(\tau_3))]$ and $\hat{\rho}_{\tau|z} = -\hat{\rho}_{\tau,12|z} / \sqrt{\hat{\rho}_{\tau,11}\hat{\rho}_{\tau,12}}$ is the conditional cross-correlation.

⁴ We have also performed estimations for lag 2 and 12 but due to restricted space we do not include them in the results. However, these can be distributed on demand.

⁵ We also included heating oil to highlight the difference from crude oil. As the results in large mimic those for crude oil, we do not include these estimations in the paper. However, they are available on demand.

its connection to heating prices and steel production (which in turn is an input in housing construction), along with the fact that the US historically has been a prominent producer. The inclusion of natural gas is motivated by the US progress in shale production and by the connection to heating. The data for coal, crude oil, and natural gas are retrieved from the World Bank (2019). Our data for coal consist of monthly data on Australian thermal coal, which works as a proxy for the global price of coal and is commonly used as a proxy by investors. For crude oil we use the average spot price of Brent, Dubai, and West Texas Intermediate, equally weighted. For natural gas, we include the US spot prices. For heating oil, we use the S&P GSCI Heating Oil Index retrieved from DataStream. For the estimations, we use the return series of each index, which we calculate as the logarithmic difference of the price series.

Figure 3: Time Trends of the Housing and Energy Commodities



Notes: This figure shows the time trends between the US national housing index and the OIL, COAL and GAS respectively. The data for the commodities have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019). All indices in this figure are denoted in prices. The left vertical axis represents the price of US national housing index and the right vertical axis represent the price of the commodities.

Source: The data for the commodities have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019).

Figure 3 depicts the co-movement between the commodities and the US national house index during the sample period. As depicted, the commodities exhibit higher fluctuations than housing prices and were also more affected by the financial crisis.

Table 2: Descriptive Statistics

	Mean (%)	Std. Dev.	Skewness	Kurtosis	JB	ADF _c	AD _{ct}	PP
<i>Commodity Markets</i>								
OIL	0.32	8.12	-0.84	4.48	72.41***	-14.30(0)***	-14.28(0)***	-14.24***
COAL	0.21	6.20	0.33	9.32	581.21***	-13.09(0)***	-13.07(0)***	-13.30***
GAS	0.13	13.59	0.03	4.13	18.79***	-17.28(0)***	-17.28(0)***	-17.26***
<i>Housing Market</i>								
ENC	0.25	0.78	-0.39	4.35	35.56***	-9.68(3)***	-9.70(3)***	-11.23***
ESC	0.28	0.75	-0.47	4.82	60.77***	-19.38(0)***	-19.37(0)***	-19.37***
MA	0.26	0.77	0.01	2.59	2.26	-7.96(1)***	-7.94(1)***	-14.67***
MT	0.39	0.87	-0.99	5.53	148.75***	-5.21(2)***	-5.20(2)***	-13.17***
NE	0.29	0.96	0.17	2.90	1.70	-8.84(1)***	-8.83(1)***	-15.79***
PF	0.35	1.01	-0.58	3.88	30.93***	-4.82(1)***	-4.83(1)***	-8.87***
SA	0.31	0.77	-0.84	5.00	98.83***	-7.44(1)***	-7.43(1)***	-12.78***
WNC	0.30	0.74	-0.55	5.20	88.06***	-9.78(4)***	-9.84(4)***	-14.92***
WSC	0.32	0.60	-0.15	4.48	33.60***	-16.79(0)***	-16.79(0)***	-16.95***
USA	0.30	0.61	-0.53	4.08	33.45***	-7.59(0)***	-7.58(0)***	-7.66***

Notes: Normality of the series are tested by the Jarque-Bera (JB). ADF test is the adjusted Dickey-Fuller test for unit roots where ADF(c) and ADF(ct) tests for unit-root with a constant (c) and with a constant and trend (ct) with lag length in parenthesis. The PP represent the Phillips-Perron unit-root tests. The parentheses represent the optimal lag length based on the information criteria. *, ** and *** represents the significance at 10%, 5%, and 1%.

Source: The data for the commodities have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019) and Thomson Reuters International.

Table 2 presents the descriptive stats of the housing indices and the commodities reported as return. The commodities show much higher volatility than the housing indices. As these are traded on financial markets, and therefore react to information quicker, this is not unexpected. The housing markets further exhibit similar positive average returns and volatility among the regions, though with the Pacific region as an exception. The skewness values for all variables, except for natural gas, deviate from zero, which indicates that distributions are skewed. Further, we observe that most of the variables have a negative skewness, which means that their distribution is skewed to the left. All indices, except for Middle Atlantic (MA) and New England (NE), have a kurtosis higher than three, indicating that the distributions are leptokurtic. From an economic standpoint, this means that our returns are more likely to be extreme compared to the normal distribution. The results from the Jarque-Bera (1980) test also indicate nonnormality for most indices. Table 2 also presents the results of the unit root testing using the Dickey-Fuller (1979) and Phillips-Perron (1988) tests. We report the optimal lag based on AIC in parentheses. From the ADF and PP tests we can confirm that all indices are stationary.

For our control estimations we also include economic variables and uncertainties. Our economic variables consist of data for unemployment, industrial production, interest rates, stock market, and housing starts. Our aim in including the economic variables is to control whether the commodities affect the housing prices even during the presence of economic variables. For unemployment we use regional data from the four US Census regions. As a proxy for the GDP per capita that is not available on a monthly basis, we use the Industrial Production Index (IPI), which measures the real output for US manufacturing, mining, and electric and gas industries. In terms of interest rate, we include the effective federal funds rate, which is the overnight interbank rate for depository institutions. To capture changes in wealth we also include the stock market, for which we use the S&P 500. Last, we include the regional housing starts in the US Census regions to control for supply effects. The housing starts measure the number of units of new privately owned houses during a given period whose construction has been

started. The data for the unemployment, industrial production, interest rate, and housing starts are gathered from the Federal Reserve Bank of St. Louis, while data for the stock market are gathered from DataStream. Given that we use return series for the commodities and housing indices, the control variables are also included as return in the estimations.

4. EMPIRICAL RESULTS

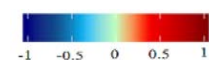
We start by analyzing the results from the cross-quantile correlations (CQC) of each commodity in the national and regional housing markets. To isolate the effects from the cross-correlations and check the robustness of our results, we control for a set of economic variables with panel quantile regression (PQR).

4.1 Cross-quantilogram

Figures 4 to 6 display our results from the CQC in heatmaps, with the quantiles of the dependent variable, in this case the housing markets, on the vertical axis and the commodities on the horizontal axis. Due to restricted space, we only report the cross-correlation of lag 1 and 2.⁶ We start by analyzing the effect of the natural gas price on the national and regional housing markets, continuing with oil and lastly coal.

The results in Figures 4 indicate that gas price does not exhibit much dependence on the housing markets, though with a few exceptions. Furthermore, the correlation structure varies among the regions and shows alternating positive and negative correlations with the housing market returns. Focusing on the natural gas in the East ESC and WSC regions displayed in Figures 4, we observe large negative correlations in the bottom left corners. This indicates that low gas returns are less prone to be succeeded by low housing returns in the following month. For ENC and ESC we find weak negative correlations in the top right corners, indicating that when gas returns are high the housing market returns are less prone to be high the following month. This could be explained by the income channel where higher natural gas prices depress the income level in the regions, leading to lower demand for housing. For some regions, such as the MT and SA, we have positive correlations in the top left corner. This indicates that housing returns more likely to be high when the gas returns are low, which could be a sign of a heating effect. In our sample, the southern regions in the US use a higher share of natural gas in their electricity production, which should make them more vulnerable to fluctuations in the gas price, and hence affect housing demand. However, the overall dependence between the gas returns and housing returns is low.

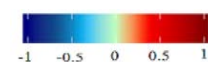
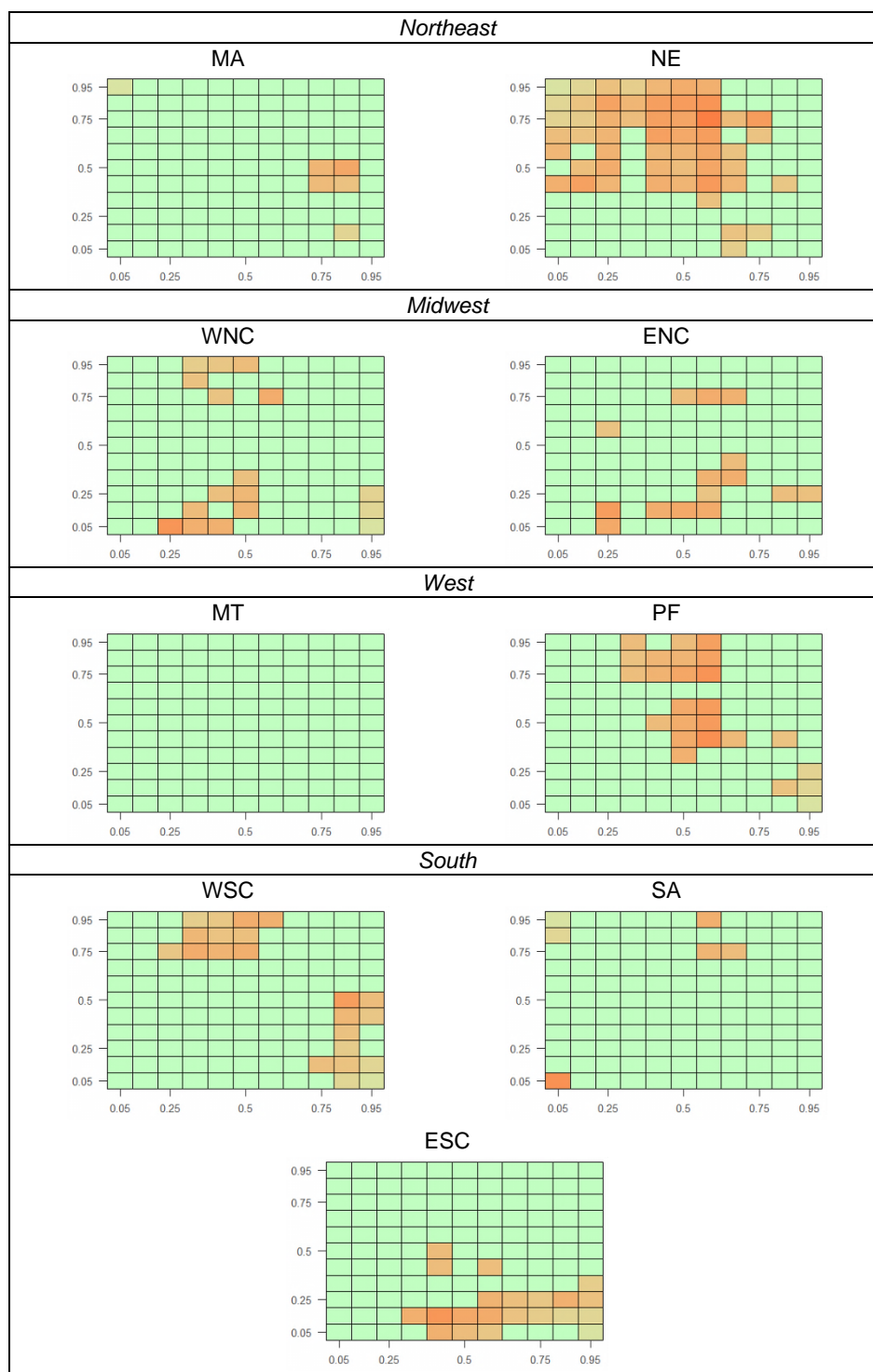
⁶ Our estimations have also been conducted at lag 2 and 12, which are available on demand.

Figure 4: CQC-estimations from GAS to Regional Housing Markets

Notes: Cross-quantilogram estimations. Notes: This figure displays the cross-quantilogram correlations with a lag length of 1. In the heatmaps, the colored areas are quantiles where the Box-Ljung test statistics is statistically significant (5% significance level). The horizontal axis represents the quantiles of the commodities and the vertical axis represents the housing return.

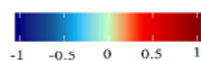
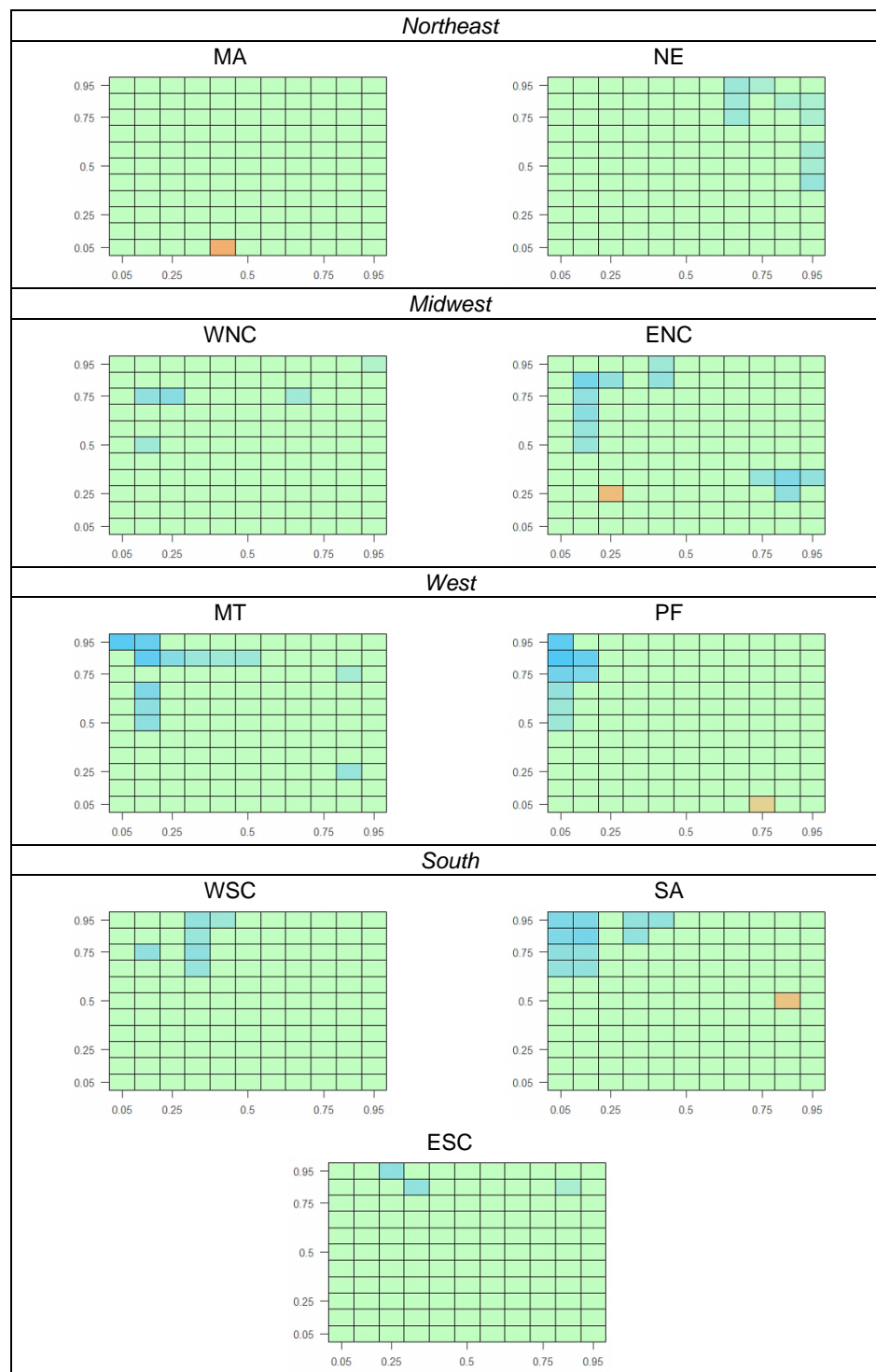
Source: The data for the commodities have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019).

Looking instead at the directional predictability from the oil market to the housing returns depicted by Figures 5, we can in general observe large positive dependence, both on a national and regional level. The dependence is spread over a large part of the quantiles, indicating that the oil price correlates with the housing returns during different states of the oil return and in different parts of the housing return distribution. Dependence is found in the lower right corners in more than half of the estimated regions, indicating that when the oil returns are high, the likelihood of the housing return being in its lower quantiles is higher. Another interesting finding is that, just like our estimations for natural gas and housing, there is a lot of regional heterogeneity in terms of the size of the dependence as well as the impact on different quantiles. Our results are at odds with Antonakakis, Gupta, and Muteba Mwamba (2016) who found a consistently negative relationship between oil and housing prices in the US since the mid-19th century. However, in this study, Antonakakis, Gupta, and Muteba Mwamba (2016) use a long-ranging annual national data set with a DCC-GARCH approach, in contrast to our relatively short but monthly data for US regions with CQC. Previous works such as Kilian and Zhou (2018), however, have found that oil price shocks may raise the housing demand not only in oil-producing regions but also in other areas through government redistribution of oil incomes. In line with these findings, Khiabani (2015) found that oil price shocks affect the housing prices in Iran positively. While Kilian and Zhou (2018) and Khiabani (2015) use data for Canada and Iran, which are net oil exporters, the US is a net importer of oil. Killins, Egly, and Escobari (2017), however, in line with our result, discover that some oil-specific demand shocks (“precautionary demand”) influence the housing prices in the US positively in the short term. With our data set, we are unfortunately not able to separate the demand from the supply effect of increased oil prices. Given that the US is a net importer of oil, rising prices should, according to this theory, reduce household incomes due to higher energy prices, thereby reducing the demand for housing. The positive dependence in the lower right corners (right tail of the oil returns and left tail of the housing return) is in line with these findings. However, we also find positive dependence during periods when both the oil and housing prices are booming (mid to higher quantiles of the variables). From a theoretical standpoint, the income channel therefore seems unlikely in explaining those dependence structures. Another explanation might therefore be that higher oil prices influence the housing prices positively due to increasing production costs, such as costs for transportation or input goods. Other factors could also be due to both variables being affected by changes in macroeconomic variables. The regional differences might be explained, however, by the differences in production and export intensity of the goods (net importer or net exporter of commodities), as suggested by previous literature.

Figure 5: CQC-estimations from OIL to Regional Housing Markets

Cross-quantilogram estimations. Notes: This figure displays the cross-quantilogram correlations with a lag length of 1. In the heatmaps, the colored areas are quantiles where the Box-Ljung test statistics is statistically significant (5% significance level). The horizontal axis represents the quantiles of the commodities and the vertical axis represents the housing return.

Source: The data for the commodities have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019).

Figure 6: CQC-estimations from COAL to Regional Housing Markets

Cross-quantilogram estimations. Notes: This figure displays the cross-quantilogram correlations with a lag length of 1. In the heatmaps, the colored areas are quantiles where the Box-Ljung test statistics is statistically significant (5% significance level). The horizontal axis represents the quantiles of the commodities and the vertical axis represents the housing return.

Source: The data for the commodities have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019).

In regard to directional predictability from the coal price to the housing markets, in Figure 6, we observe some heterogeneity between the regions in the size of the spillovers, however they are consistently negative in all cases. In most regions, the dependence tends to gather around the upper left corner and in the upper half of the heatmap. This indicates that when the returns of the coal are low or modest, it is unlikely that the housing returns will be in their highest quantiles. One possible explanation for this might be that both variables are influenced by macroeconomic variables, hence, when the economy is bad and coal returns low, the demand for housing may be dampened. Some regions, such as the Pacific, for instance, show dependence with the coal market despite the fact that their share of coal in the energy consumption is close to zero. Various regions might, however, have different sensitivity to macroeconomic trends depending on their form of economic structure. Given that we do not find any positive correlation between housing and coal returns, our results do not suggest that the housing-coal correlation may be influenced by a construction channel.⁷

4.2 Panel Quantile Regression

In this section, we present the results from the panel quantile regressions where we estimated the effect of the commodities on the regional housing markets while controlling for economic variables. As we measure the returns in the CQC, all of our included variables in the PQR are in first difference. Although the PQR only shows the effect in quantiles of the dependent variable and the results from the PQR will not be directly interpretable with those from the CQC, we still expect to find correlations that we want to control for these variables. In the CQC we could not find any large dependence or directional predictability to the US national housing market from the returns of natural gas, but we did however find significant dependence in some of the regions. Given that the PQR shows average effects of the regions, we would not be able to investigate the effect of commodities on these quantiles of the housing returns after controlling for the economic variables. We have for those reasons estimated the PQR using both the national house price index and subsamples of the data. The subsamples were divided from the results of the CQC. Those regions with most dependence on each individual commodity were group together. These estimations are presented in Table 3, with the subsamples of oil (b), natural gas (c), and coal (d). After controlling for VIF value among the commodities we exclude heating oil from the PQR estimations.

⁷ We also control our CQC correlations with some uncertainty variables such as VIX and oil price uncertainty (i.e., the conditional volatility was derived from a GARCH (1,1) process). In general, these control estimations do not alter our primary correlations between the commodity and housing markets and are therefore not presented in the paper. These estimations are, however, available on demand.

Table 3A–B: Fixed Effect Panel Quantile Regressions

Table 3A: Dependent Variable: House Price Index for All Regions					
Quantiles:	10th	20th	30th	40th	50th
Unemployment	–0.017 (0.017)	–0.014 (0.011)	–0.009 (0.010)	–0.009 (0.010)	–0.011* (0.006)
Industrial production	0.125** (0.053)	0.073** (0.033)	0.011 (0.024)	–0.002 (0.028)	–0.025 (0.029)
Interest rate	0.010*** (0.002)	0.009*** (0.002)	0.008*** (0.002)	0.008*** (0.001)	0.009*** (0.001)
Stock market	0.031*** (0.01)	0.015** (0.007)	0.007 (0.004)	0.004 (0.004)	–0.001 (0.004)
Housing starts	0.000 (0.001)	0.002*** (0.001)	0.002*** (0.001)	0.002** (0.001)	0.001 (0.001)
OIL	0.005 (0.003)	0.009*** (0.003)	0.007*** (0.002)	0.008*** (0.002)	0.007*** (0.001)
COAL	–0.008 (0.006)	–0.006 (0.004)	–0.001 (0.003)	–0.003* (0.002)	–0.004* (0.002)
GAS	0.001 (0.002)	0.001 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.000)
Number of observations	3,060				
Table 3B: Dependent Variable: House Price Index for ESC, NE, PF and WSC					
Unemployment	–0.019 (0.028)	–0.018 (0.021)	–0.014 (0.021)	–0.010 (0.018)	–0.017 (0.015)
Industrial production	0.056 (0.072)	–0.001 (0.033)	–0.040 (0.040)	–0.067** (0.037)	–0.079 (0.055)
Interest rate	0.008*** (0.003)	0.009*** (0.002)	0.008*** (0.002)	0.008*** (0.001)	0.009*** (0.001)
Stock market	0.025 (0.018)	0.025** (0.012)	0.008 (0.007)	0.007** (0.004)	–0.001 (0.007)
Housing starts	0.001 (0.003)	0.001 (0.003)	0.002 (0.002)	0.001 (0.002)	0.000 (0.003)
OIL	0.002 (0.005)	0.003 (0.003)	0.003** (0.001)	0.006** (0.002)	0.006** (0.003)
Table 3A: Dependent Variable: House Price Index for All Regions					
Quantiles:	60th	70th	80th	90th	95th
Unemployment	–0.013* (0.007)	–0.018** (0.008)	–0.022*** (0.007)	–0.024** (0.011)	–0.019 (0.013)
Industrial production	–0.051** (0.024)	–0.102*** (0.030)	–0.125*** (0.027)	–0.182*** (0.040)	0.207*** (0.044)
Interest rate	0.011*** (0.001)	0.011*** (0.002)	0.010*** (0.002)	0.011*** (0.002)	0.009*** (0.001)
Stock market	0.003 (0.005)	0.008 (0.006)	0.004 (0.006)	0.005 (0.006)	0.001 (0.009)
Housing starts	0.001 (0.001)	0.001 (0.001)	0.000 (0.001)	–0.001 (0.001)	0.003*** (0.001)
OIL	0.008*** (0.002)	0.007*** (0.002)	0.010*** (0.002)	0.007** (0.003)	0.009* (0.006)
COAL	–0.003 (0.002)	–0.007** (0.002)	–0.010*** (0.002)	–0.008** (0.003)	–0.010* (0.005)
GAS	–0.001 (0.001)	0.000 (0.001)	0.001 (0.001)	0.003 (0.001)	0.004 (0.003)
Number of observations					
Table 3B: Dependent Variable: House Price Index for ESC, NE, PF and WSC					
Unemployment	–0.024** (0.011)	–0.028** (0.013)	–0.024* (0.014)	–0.037** (0.017)	–0.016 (0.028)
Industrial production	–0.096** (0.047)	–0.107*** (0.030)	–0.150*** (0.043)	–0.141*** (0.029)	0.193*** (0.057)
Interest rate	0.012*** (0.002)	0.010*** (0.003)	0.011*** (0.003)	0.008** (0.003)	0.009*** (0.002)
Stock market	0.000 (0.008)	0.006 (0.010)	0.002 (0.012)	0.006 (0.014)	0.000 (0.015)
Housing starts	–0.001 (0.002)	–0.001 (0.002)	0.000 (0.002)	–0.002 (0.002)	–0.003* (0.002)
OIL	0.004 (0.003)	0.004 (0.003)	0.006* (0.004)	0.005 (0.004)	0.007* (0.004)

Notes: This figure displays the panel–quantile regressions. *, **, and *** indicates significance at 10%, 5%, and 1%.

Bootstrapped standard errors in parenthesis with an iteration of 500.

Source: The data for the commodities have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019) and Thomson Reuters International.

Table 3C–D: Fixed Effect Panel Quantile Regressions

Table 3C: Dependent Variable: House Price Index for ESC, SA and WSC					
Quantiles:	10th	20th	30th	40th	50th
Unemployment	−0.070* (0.036)	−0.033*** (0.008)	−0.034*** (0.013)	−0.026* (0.014)	0.001 (0.018)
Industrial production	0.128 (0.078)	0.044 (0.058)	−0.026 (0.0499)	−0.010 (0.019)	−0.003 (0.022)
Interest rate	0.013*** (0.002)	0.013*** (0.002)	0.009*** (0.001)	0.010*** (0.001)	0.013*** (0.001)
Stock market	0.020*** (0.006)	0.015*** (0.003)	0.012*** (0.003)	0.007*** (0.002)	0.006* (0.004)
Housing starts	−0.004 (0.007)	0.000 (0.005)	−0.003 (0.004)	−0.002 (0.003)	−0.002 (0.002)
GAS	0.001 (0.002)	0.000 (0.001)	0.002*** (0.001)	0.001 (0.001)	0.001** (0.000)
Number of observations	1,020				
Table 3D: Dependent Variable: House Price Index for MT, SA, ENC and PF					
Unemployment	−0.132*** (0.049)	−0.122** (0.050)	−0.088*** (0.032)	−0.073*** (0.027)	−0.060** (0.029)
Industrial production	0.137** (0.066)	0.071* (0.039)	−0.015 (0.037)	−0.043 (0.036)	−0.046 (0.045)
Interest rate	0.010*** (0.002)	0.009*** (0.003)	0.008*** (0.002)	0.009*** (0.002)	0.011*** (0.001)
Stock market	0.024** (0.011)	0.031*** (0.005)	0.014*** (0.004)	0.009*** (0.003)	−0.002 (0.003)
Housing starts	0.005** (0.002)	0.003 (0.001)	0.005*** (0.0019)	0.002*** (0.001)	0.003*** (0.001)
COAL	−0.012 (0.007)	−0.008** (0.005)	0.001 (0.005)	−0.001 (0.004)	−0.004 (0.003)
Table 3C: Dependent Variable: House Price Index for ESC, SA and WSC					
Quantiles:	60th	70th	80th	90th	95th
Unemployment	−0.019* (0.011)	−0.022 (0.014)	−0.026** (0.013)	−0.041 (0.019)	−0.040*** (0.015)
Industrial production	−0.049*** (0.017)	−0.057*** (0.020)	−0.116*** (0.032)	−0.080** (0.048)	−0.154** (0.060)
Interest rate	0.012*** (0.003)	0.011*** (0.002)	0.010*** (0.004)	0.007** (0.003)	0.006*** (0.002)
Stock market	0.008 (0.006)	0.017*** (0.005)	0.013 (0.010)	0.020 (0.017)	0.039** (0.016)
Housing starts	−0.003 (0.003)	−0.001 (0.002)	−0.003 (0.002)	−0.009*** (0.002)	−0.010*** (0.002)
GAS	0.001 (0.001)	−0.002 (0.001)	0.000 (0.001)	0.000 (0.002)	0.000 (0.004)
Number of observations					
Table 3D: Dependent Variable: House Price Index for MT, SA, ENC and PF					
Unemployment	−0.043 (0.034)	−0.073*** (0.024)	−0.093*** (0.026)	−0.121*** (0.036)	−0.133*** (0.036)
Industrial production	−0.120*** (0.042)	−0.173*** (0.0299)	−0.228*** (0.027)	−0.254*** (0.048)	−0.256*** (0.049)
Interest rate	0.015*** (0.002)	0.015*** (0.001)	0.014*** (0.002)	0.012*** (0.002)	0.008*** (0.002)
Stock market	0.001 (0.006)	0.005 (0.005)	0.005 (0.007)	−0.013 (0.012)	−0.002 (0.013)
Housing starts	0.003*** (0.001)	0.002 (0.001)	0.000 (0.001)	−0.002 (0.002)	−0.008*** (0.002)
COAL	−0.002 (0.003)	−0.007** (0.003)	−0.009*** (0.002)	−0.006 (0.005)	−0.012** (0.006)

Notes: This figure displays the panel-quantile regressions. *, **, and *** indicates significance at 10%, 5%, and 1%.

Bootstrapped standard errors in parenthesis with an iteration of 500.

Source: The data for the commodities have been retrieved from the World Bank (2019) and for the housing index from Federal Housing Finance Agency (2019) and Thomson Reuters International.

Table 3a presents the result for the average effect of the commodities and economic variables on the US regions. Starting with the economic variables, not unexpectedly, the regional unemployment affects the housing prices negatively with a significant effect in medium to higher quantiles of the housing return distribution. This correlation will most likely be an income effect where higher unemployment leads to lower incomes and reduced demand for housing. Interestingly we find that the industrial production is significantly negative in higher quantiles of the return distribution but positive in lower quantiles. This finding may relate to the turbulence during the financial crisis, where the housing market crashed before the rest of the economy, including the industrial production, and recovered much later but with a sharper increase, during a time period when the changes in industrial production were quite modest. The positive correlation in lower return distribution would in that case be a result of the outbreak years of the crisis 2008–2009 when the housing market and the rest of the economy crashed together. We also found a significantly positive correlation between the housing returns and the interest rate. Through the income channel, we could expect the relationship to be negative as lower interest rates would lead to lower mortgage rates, thereby increasing the demand for housing. However, the positive relationship might be a result of the fact that housing returns tend to be high when the economy is booming, which in turn might lead to inflation and an increased policy rate. Another explanation may be that higher interest rates lead to higher production costs and thus higher prices. The weak value of the coefficient could therefore be a result of the income channel working in the other direction, decreasing the total effect. Further, the stock market has a significantly positive impact on the lower quantiles of the housing return, probably due to a wealth effect, thereby increasing the demand for housing. Last, housing starts have a significantly positive effect on the housing returns in the lower quantiles, indicating that when supply increases, the housing prices also increases. In the higher quantiles, however, the housing starts have a positive effect on the housing return, indicating the opposite relationship.

For the energy commodities our results largely correspond to the CQC. As can be seen in Table 3A, the oil returns have a positively significant impact on the housing returns in lower, middle, and higher parts of the housing return distribution. In contrast, the returns of coal have a negative impact on the housing returns, especially in the higher parts of the distribution. The returns of natural gas, on the other hand, do not influence the housing returns in any quantiles. This, however, is not contradictory to the CQC result given that Table 3A displays an average effect of the aggregated regions and we could not see any dependence or directional predictability from the gas returns in the CQC on the national level. If we look instead at a subsample of the regions that displayed the largest dependence on the housing returns (Table 3d), some significant correlation is found in the lower to middle quantiles, even though the effect is weak. Subsamples of the regions with the largest oil and coal spillovers, shown in Table 3B and Table 3D, respectively, also confirm our findings from the full sample. Our results from the PQR stand in contrast to the results in Leung, Shi and Tang (2013), who found that the energy commodities only influence the housing prices in New Zealand and Australia through the macroeconomic variables. Their study, however, did not separate the effect of different energy commodities on the housing prices, which might explain the contrasting findings. Our results of the PQR therefore indicate that the effects of energy commodities on housing returns are robust, even after controlling for macroeconomic variables.

5. CONCLUSION AND POLICY IMPLICATIONS

This paper examines the quantile dependence and directional predictability between energy commodities, natural gas, oil, and coal, and the national and regional housing markets in the US during the period 1991–2019. By using a cross-quantilogram approach and panel quantile regressions we capture dependence in the full return distribution of the housing market from any quantile of the commodity return. Our main finding is that housing returns are dependent on the returns of the oil market with a positive correlation in a large part of the distribution, but that the housing returns are more likely to be low after extremely high returns on the oil market. Furthermore, we find a heterogeneous response for the housing market in different regions with regard to all commodities. This appears in terms of the size of the dependence, but also for the sign of the dependence on the commodities. The findings in this study are robust to controls of economic state variables. Our results provide information for government and monetary policy agencies that can be of importance in decisions related to macroprudential policy. Furthermore, our findings have implications for financial markets and portfolio performance. Although direct investments in housing are not common in investment portfolios, they do affect the return of real estate companies in the longer run. The suggested dependence between energy investments and housing is therefore of importance for the hedging or diversification possibilities of portfolios.

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