Speculative Bubble Spillovers across Regional Housing Markets

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ABSTRACT. *In this paper we determine whether speculative bubbles in one region in the United States can lead bubbles to form in others. We first apply a regime-switching model to determine whether speculative bubbles existed in the U.S. regional residential real estate markets. Our findings suggest that the housing markets in five of the nine census divisions investigated were characterized by speculative bubbles. We then examine the extent to which bubbles spill over between neighboring and more distant regions, finding that the transmission of speculative bubbles and nonfundamentals between regions is multidirectional and does not depend on contiguity or distance.* (JEL C51, R21)

I. INTRODUCTION

In the last two decades, the housing market in the United States has been a major topic of discussion mainly due to the rapid increases and subsequent falls in house prices, especially between 2000 and 2010. Following the collapse of the information technology bubble in 2000, the Federal Reserve adopted an expansionary monetary policy, reducing short-term rates by almost five percentage points in less than two years. This, coupled with a relaxation of mortgage market practices, induced an aggressive rise in real estate prices in many parts of the United States.

Beginning in the 1980s, the mortgage market in the United States changed substantially, such that while loans continued to be locally originated, securitization meant that they were packaged and distributed globally. One of the intentions of this deregulation was to minimize mismatches in supply and demand for loanable funds within regions. Localized market failures could then be absorbed nationwide or globally, thus spreading the risks. However, the resultant linkages between local markets and between previously separate whole asset classes actually caused greater instability and the inception of systemic risks that had not previously existed. Ashton (2009) discusses the recent subprime crisis that arose with the housing bubble, and its effect of increasing systemic risk. The housing market became linked, through securitization, with both the bond and the equity markets. Through a process that has been termed "glocalization" (Martin 2010), local housing market conditions became more—not less—important in their effects, since local falls in house prices or increases in foreclosure caused reductions in the values of traded assets that were widely felt and that could cause instability in economic activity a long way from the place of origin (see also Pike and Pollard 2010). Martin (2010, 20) gives the example of Michigan, where house prices did not experience any significant appreciation and where subprime lending did not take place on a large scale, but which was nevertheless hit hard by the secondary effects of the decline in manufacturing activity when housing bubbles burst in other areas. As Aalbers (2009a, 36) put it, "The old geography of local housing markets has not been replaced by a global housing market, but by a chain that starts with the local . . . turns national . . . , then global . . . then local again."

It is often presumed in the literature that real estate bubbles are widespread and occur simultaneously everywhere. However, as we will demonstrate below, there is significant regional variation in the extent to which house prices were affected by bubbles, and consid-

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erable differences in the timing of growth and subsequent collapse for those regions where bubbles arose. There exists some good discussion of this effect (see, e.g., Aalbers 2009a; Wyly, Atia, and Hammel 2004), but very little of this is backed up by formal quantitative modeling, which is where this study contributes to the debate.

While a considerable body of research has developed by way of determining whether there exist bubbles in house prices—mainly at the national level but occasionally at the regional level too—very little has been written on the extent to which bubbles can be transmitted from one region to another. Much of the terminology in recent research is either implicitly (e.g., Martin 2010, 14) or explicitly (e.g., Clapp and Tirtiroglu 1994) suggestive of a presumption that bubbles will begin in one city or region and then spatially diffuse outward, but this conjecture has rarely been subject to more formal empirical scrutiny. In this paper, we contribute to the body of literature on spatial house price interactions by examining the dynamics of the regional housing markets in the United States. The paper sets out to establish whether speculative bubbles in one region cause the inception of bubbles in other regions. We examine whether there were speculative bubbles in the property markets of each of the nine census divisions in the United States between 1991 and 2010. From this, we proceed to determine whether speculative bubbles in the regions spilled over to contiguous or noncontiguous regions. We tackle this issue in two ways. First, we examine the effect on the bubble in one region of a shock to the bubble in another via a Bayesian vector error correction model with priors set based on the inverses of the distances between key cities within each region. Second, we develop a formal multivariate bubble spillover model. Therefore, this paper builds upon previous findings that have evaluated price and volatility transmissions across regional real estate markets and provides valuable information on whether speculative bubbles are transmitted to neighboring regions or to functionally similar but possibly distant regions.

The motivation to study speculative bubble spillovers across the regional housing market in the United States is twofold. First and foremost, the existing literature has suggested that there is a strong long-run relationship between the aggregate level of consumption in a country and housing wealth. Wilkerson and Williams (2011) note that the general consumption level in an economy is more sensitive to changes in real estate–related wealth than other forms of wealth, including wealth from the stock market. Roubini (2006) demonstrates that the Federal Reserve ought to react to asset bubbles (both in the stock market and the housing market), because if left unchecked they could lead to severe economic imbalances. Therefore, it is important for policy makers to be able to understand the pattern of speculative transmission in the housing market, enabling policymakers to implement monetary policies aimed at preventing another episode of housing bubble spillovers, which if ignored could have a serious adverse effect on national income.

II. THE EXISTING LITERATURE

Regional House Price Diffusion and Ripple Effect Studies

Historically, the literature on the interlinkages and ripple effects of regional real estate markets has been dominated by research on the United Kingdom. The first notable studies to examine the long-run relationships between movements in regional house prices are those of Giussani and Hadjimatheou (1991) and MacDonald and Taylor (1993). The former show that changes in real estate prices in Greater London influence prices in other regions of the United Kingdom. However, they focus only on the ripple effect from Greater London prices and not from other regions. Using a cointegrating approach, MacDonald and Taylor, on the other hand, find linkages between several regions and conclude that long-run house price movements in one region influence changes in other regions. Also employing cointegration and causality testing methods, Alexander and Barrow (1994) assess whether there is multidirectional causality of real estate prices in the United Kingdom. They find the causal flow to be northward, such that prices in the South East affect first the neighboring East Midlands, before eventually affecting the North. Meen (1999) provides possible explanations of factors that may cause a ripple effect of house prices between regions, one of which is interregional migration. Meen states that expensive houses in the South could force people to move North, where prices are relatively low, which could subsequently lead to an increase in prices in the North. Other possible drivers of interregional house price spillovers suggested by Meen include spatial arbitrage and equity transfer. Spatial arbitrage refers to a situation in which the transmission of new information first occurs between contiguous regions before influencing other noncontiguous regions, while equity transfer simply involves moving from an expensive region to a relatively cheaper one.

Research on spillovers in the U.S. regional housing market has been relatively sparse. Tirtiroglu (1992) and Clapp and Tirtiroglu (1994) use data from Hartford, Connecticut, to analyze the diffusion of price changes throughout a Metropolitan Statistical Area (MSA). Clapp and Tirtiroglu find that house prices follow a spatial diffusion process, whereby price changes in one region initially affect the contiguous regions before diffusing to other noncontiguous regions. A broader view is taken by Pollakowski and Ray (1997), who examine the nine census divisions in the United States. Using vector autoregressive (VAR) models and Granger causality tests, they examine price diffusion patterns. Their results show diffusion patterns that are not explained by spatial factors but that might be more plausibly be attributed to demographics and political jurisdictions. More recently, Gupta and Miller (2012) examine the interregional relationships of real estate prices in eight MSAs in the southern part of California, also finding multidirectional diffusion of house prices. Other recent papers have analyzed return and volatility spillovers in the U.S. housing market, including Miao, Ramchander, and Simpson (2011) and Zhu, Füss, and Rottke (2012).[1]

Studies on Housing Market Bubbles

Following the recent surge and subsequent collapse in house prices, a different strand of research set out to establish whether speculative bubbles drove house prices in the United States. Prior to the market crash, there was some research suggesting that fundamental factors were the prime influence on the surge in prices. McCarthy and Peach (2004), for example, argue that the aggressive run up in prices could be justified by the increase in population density in many states, as well as sharp falls in mortgage rates, and concluded that prices were not driven by speculative bubbles. However, post-2005, after the boom period ended, a number of studies supported the view that speculative bubbles were important. The common hypothesis was that house prices were driven by people's excessive expectations of continued price growth. Christie, Smith, and Munro (2008) discuss the emotional impact of a rapidly rising market on buyers' mind-sets when determining the appropriate valuation to place on a property.

Investigating national house prices, Belke and Wiedmann (2005) find there to be strong evidence of speculative bubbles in the real estate market that were fueled by the expansion of the credit market. Narrowing to regions, Zhou and Sornette (2006) show that of the 50 U.S. states, 22 were influenced by speculative bubbles as their real estate prices grew at a faster than exponential rate. Recent papers including that by Goodman and Thibodeau (2008) investigate house prices in 84 MSAs around the United States, finding evidence of the presence of bubbles in 25, including Los Angeles and Miami, while areas such as St. Louis and Seattle had no bubbles since house prices appreciated far less than predicted by their model.

Mikhed and Zemcik (2009) use a unit root approach to detect bubbles in MSAs. Their argument is that a bubble exists if the real estate price series is nonstationary but the rent

[1] There are several other house price diffusion studies that have focused on countries other than the United States and the United Kingdom. For example, Stevenson (2004) examines cross-border and interregional ripple effects of house prices in Ireland and Northern Ireland, and Luo, Liu, and Picken (2008) examine house price diffusion patterns in Australia. Holly, Pesaran, and Yamagata (2011), on the other hand, examine the possibility of international spillovers.

series is stationary. Other studies to have tested for the presence of speculative bubbles focused on countries other than the United States. For example, Roche (2001), Fernandez-Kranz and Hon (2006), and Hatzvi and Otto (2008) all find evidence of speculative bubbles in the Irish, Spanish, and Austrian real estate markets, respectively.

Even though there have been a number of studies that have looked at either regional house price diffusion or speculative bubbles, there have been relatively few that have examined the regional spillover of speculative bubbles in the real estate market. Costello, Fraser, and Groenewold (2011) focus on the Australian real estate market between 1984 and 2008. Their results show New South Wales to be the region most susceptible to speculation from other regions. Füss, Zhu, and Zietz (2011) and Riddel (2011) focus on the U.S. housing market. Riddel examines home prices in Las Vegas and Los Angeles only and finds evidence of the contagion of speculative activity, with house price appreciation in Los Angeles contributing to the speculative bubble in Las Vegas. Füss, Zhu, and Zietz, on the other hand, concentrate on the 20 largest MSAs between 1998 and 2008. Their results show that bubbles transmit from one geographical zone to another regardless of whether they are contiguous.

Although the paper by Füss, Zhu, and Zietz provides a concise examination of the interregional spillover of speculative bubbles in the real estate markets, we believe that our study builds upon theirs in several ways. First, the period they investigate is relatively short, and thus it excludes the tail end of the crash in the real estate market. Second, their paper does not employ a formal bubble test to determine whether the nonfundamental component of house prices is a speculative bubble. Lastly, this paper covers all regions in the United States, while Füss, Zhu, and Zietz focus on real estate markets in only selected MSAs. The present study covers the period 1991–2010, thereby accounting for the boom and bust periods in the market. We use a regime-switching model introduced by van Norden and Schaller (1993, 1999) to test formally for the presence of rational speculative bubbles in all regions, after which we proceed to analyze, using two different approaches, the diffusion process of changes in the bubble size of each region to others.

III. DATA

For this study, we use monthly data from January 1991 to February 2010. The data on house prices for the nine census divisions are retrieved from the Federal Housing Finance Agency house price index (hereafter HPI) and are adjusted for inflation.[2] These census divisions are New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Pacific, and Mountain.[3] We should note that there is very significant heterogeneity in the housing markets within the census regions. For example, the Mountain region contains low-priced MSAs such as Albuquerque and high-priced ones such as Boulder/Loveland, Colorado. It is possible that aggregation bias may be driving some of the results, but it would not be possible to implement the analysis at a lower level of aggregation since there would be too many areas to model jointly. Although it is not possible to be certain regarding the size of the impact of this aggregation bias or even the sign of its effect, we believe that it is most likely to make the tests for bubble spillovers more conservative, since the effect of any such linkages that exist between the key centers within the regions will be diluted by the effects of the much

[2] The census divisions house price index sourced by FHFA can be downloaded from http://research.stlouisfed.org/fred2/.

[3] *New England (NENG):* Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont; *Middle Atlantic (MATL):* New Jersey, New York, and Pennsylvania; *East North Central (ENC):* Illinois, Indiana, Michigan, Ohio, and Wisconsin; *West North Central (WNC):* Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, and South Dakota; *South Atlantic (SATL):* Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia; *East South Central (ESC):* Alabama, Kentucky, Mississippi, and Tennessee; *West South Central (WSC):* Arkansas, Louisiana, Oklahoma, and Texas; *Mountain (MTN):* Arizona, Colorado, Idaho, Nevada, New Mexico, Utah, and Wyoming; *Pacific (PAC):* Alaska, California, Hawaii, Oregon, and Washington.

smaller towns in the same regions that do not share the bubbly characteristics.

The HPI on each of the divisions is a weighted repeat-sales index on single-family properties. It tracks average price changes in repeat sales, also measuring mortgage transactions on properties whose mortgages have been financed by either Freddie Mac or Fannie Mae.

As there are no rental data available for the census divisions, we follow previous research by McCarthy and Peach (2004) and Himmelberg, Mayer, and Sinai (2005) in investigating the presence of speculative bubbles via the user cost of housing. The user cost of housing is a tool employed to study the demand for housing and to analyze the equilibrium value of the imputed rental income accrued to homeowners. It is effectively a proxy for the annual total cost of ownership. Numerous studies including those by Poterba (1992), Himmelberg, Mayer, and Sinai (2005), and Poterba and Sinai (2008) argue that in equilibrium, the user cost is equal to the imputed rental income per unit of housing capital divided by the price of a unit of housing capital. By rearranging this relationship, the imputed rent series can be derived by simply multiplying the price series by the corresponding user cost series. In this study, we compute the user cost series using the definition given by McCarthy and Peach (2004):

$$uc_t = (1 - \tau_t)(r_t^{\mathrm{rf}} - \omega_t) + \delta_t - g_{t+1}, \qquad [1]$$

where r_t^{rf} is the risk-free interest rate, ω_t is the one-year cost of property taxes, τ_t is the income tax rate, δ_t is maintenance cost expressed as a fraction of home value, and g_{t+1} is the expected capital gain (or loss) during the year.

The interest rate on the three-month T-bill is used as a proxy for the risk-free rate,[4] average property tax rate data for each state are obtained from Emrath (2002), income tax data are obtained from the TAXSIM model of the National Bureau of Economic Research (NBER),[5] the 30-year conventional mortgage rate data are also retrieved from NBER, and the maintenance cost is assumed to be 2.5% based on the work of Hardin, Rosenthal, and Sirmans (2007). The expected capital gain is the one-step-ahead forecast of the house price growth rate from an AR(1) model.

An alternative to using the imputed rent approach discussed above is to employ the regional consumer price index for owners' equivalent rent (OER) of primary residences provided by the Bureau of Labor Statistics as a proxy for rents.[6] The index measures the change in rental amounts that homeowners would charge to rent their primary residences if their properties were unfurnished and without utilities. In this case, we would have to use the Northeast's OER for New England and Middle Atlantic; Midwest's OER for East North Central and West North Central; South's OER for South Atlantic, East South Central, and West South Central; West's OER for Pacific and Mountain. However, the problem with this approach is that it ignores the significant heterogeneity that may exist across the regions. For example, the average cost of renting in the Pacific region may, in reality, be far higher than that of the Mountain region. Therefore, using one rental series to represent these two regions could lead to severe analytical issues, and consequently we employ the implicit rental data.

IV. METHODOLOGY

The Speculative Bubble Test

Using the sample obtained, we test for the presence of speculative bubbles in each region's real estate market using a regime-switching model introduced by van Norden and Schaller (1993, 1999). This model is based on rational speculative bubbles, which can occur when investors include expectations of future prices in their information sets. As a result, it is rational for investors to purchase

[4] The 3-month T-bill and the 30-year conventional mortgage rate can also be downloaded from http://research.stlouisfed.org/fred2/.

[5] The income tax data from TAXSIM can be found at http://users.nber.org/~taxsim/.

[6] The Owners' Equivalent Rent data from the Bureau of Labor Statistics that can be found at http://www.bls.gov/data/.

houses even when they are overpriced, as they still expect to be able to sell them for even greater sums in the future. As we will discuss below, this can also lead to regional spillovers of bubbles when investors purchase houses in one area because they believe prices will rise there following prior rises in other regions. To understand van Norden and Schaller's model fully, we discuss the original bubble model introduced by Blanchard and Watson (1982), as the van Norden–Schaller model is an extension. Blanchard and Watson decompose stock prices P_t into two components, namely, the fundamental P_t^{f} and bubble component B_t:

$$P_t = P_t^{\mathrm{f}} + B_t, \qquad [2]$$

where

$$E_t(B_{t+1}) = B_t(1+r). \qquad [3]$$

Equation [2] implies that the bubble is expected to grow at the same rate as observed prices. This satisfies the asset-pricing no-arbitrage condition for the asset in [4], where investors who are risk-neutral choose between investing in a risky asset or one that yields the rate of return that is equivalent to the discount rate in equilibrium, $1+r$:

$$P_t = \frac{(E_t(P_{t+1}) + D_t)}{(1+r)}, \qquad [4]$$

where D_t refers to the asset's income stream, that is dividends for equity and rents for real estate. Blanchard and Watson propose a specification where the bubble either survives or collapses, with the bubble following the stochastic processes:

$$E_t(B_{t+1} \mid S) = B_t \frac{(1+r)}{q} \quad \text{with probability } q,$$
$$E_t(B_{t+1} \mid C) = 0 \quad \text{with probability } 1-q. \qquad [5]$$

Here, the bubble in the next period could either survive (S) with probability q or collapse (C) with probability $1-q$. Van Norden and Schaller improve this model by allowing the probability of a bubble surviving or collapsing to depend on the size of the bubble relative to the asset price, denoted b_t ($=B_t/P_t$). Therefore, as the bubble size increases relative to its price, the probability of the bubble collapsing in the next period increases. This is mathematically represented in [6]:

$$q = q(b_t), \qquad [6]$$

where

$$\frac{dq(b_t)}{d|b_t|} < 0.$$

The bubble component relative to price in the denominator of the inequality above is a modulus, implying that the bubble term could be either positive or negative. Given these alterations to the original model, van Norden and Schaller show that the stochastic process in [5] would be rewritten as

$$E_t(B_{t+1} \mid S) = B_t \frac{(1+r)}{q(b_t)} - \frac{1-q(b_t)}{q(b_t)} u(b_t) P_t \quad \text{with probability } q(b_t),$$

$$E_t(B_{t+1} \mid C) = u(b_t) P_t \quad \text{with probability } 1-q(b_t), \qquad [7]$$

where $u(b_t)$ is a continuous and everywhere differentiable function:

$$0 \le \frac{\partial u(b_t)}{\partial b_t} \le 1.$$

Van Norden and Schaller note that under this bubble specification model, returns to an asset driven by speculative bubbles must be state dependent, implying that periodically collapsing bubbles induce regime switches in asset returns:

$$R_{t+1}^{\mathrm{s}} = \beta_{\mathrm{s},0} + \beta_{\mathrm{s},1} b_t + \varepsilon_{\mathrm{s},t+1},$$
$$R_{t+1}^{\mathrm{c}} = \beta_{\mathrm{c},0} + \beta_{\mathrm{c},1} b_t + \varepsilon_{\mathrm{c},t+1}, \qquad [8]$$

where the probability of being in the surviving regime is represented as

$$q(b_t) = \Phi(\beta_{\mathrm{q},0} + \beta_{\mathrm{q},1} |b_t|). \qquad [9]$$

The parameters $\beta_{s,0}$ and $\beta_{c,0}$ represent the mean returns in the surviving and collapsing bubble regimes, respectively, while $\beta_{s,1}$ and $\beta_{c,1}$ are the coefficients on the bubble term, thus providing information on how returns react to changes in the relative size of the bubble component in the two regimes. The standard deviations of the error terms in the surviving and collapsing regimes are represented by σ_s and σ_c, respectively, and the ε values are error terms. A standard normal cumulative distribution function Φ is used to ensure that the probability is bounded between zero and one. In [9], $\beta_{q,1}$ measures the sensitivity of the probability to changes in the relative size of the bubble. The parameters are estimated by maximum likelihood; see Brooks and Katsaris (2005a, 2005b) for details.

Van Norden and Schaller (1999) argue that a test for bubbles can be conducted via four conditions, with more of these being met constituting stronger evidence for the presence of periodic, partially collapsing speculative bubbles. First, the mean returns in the two regimes, $\beta_{s,0}$ and $\beta_{c,0}$, should differ, with expected returns in the surviving regime greater than in the collapsing regime. Second, we expect the coefficient of the relative bubble component in the surviving regime, $\beta_{s,1}$, to be greater than that of the collapsing regime, $\beta_{c,1}$. Third, we would expect $\beta_{c,1}$ to be less than zero, thus implying that the bubble in the collapsing regime has a negative impact on the asset returns. Lastly, $\beta_{q,1}$ should be negative, meaning that the probability of being in the surviving regime reduces as the relative size of the bubble increases.

We also test the bubble specifications for each region against three simpler models that are all nested within the more general model outlined above via a set of likelihood ratio tests. The first such restricted approach is the fads model, whereby investors exhibit an irrational and excessive liking for certain stocks or asset classes. The fads model will result in protracted (but nonetheless temporary) swings in prices (see van Norden and Schaller 2002), and implies that returns are linearly predictable, although mean returns do not differ across regimes. Furthermore, the deviation of actual prices from the fundamentals has no predictive ability for the probability of switching regimes, and the returns in the two regimes are characterized by different variances of residuals but are the same linear functions of bubble deviations. The fads model incorporates the restrictions $\beta_{c,0} = \beta_{s,0}$; $\beta_{s,1} = \beta_{c,1}$; $\beta_{q,1} = 0$. The second restricted model is the mixture of normals, under which all of the parameters attached to a bubble term are jointly set to zero. Finally, the volatility regimes model implies two regimes each with their own volatility and no bubble effects, implying the restrictions $\beta_{c,0} = \beta_{s,0}$; $\beta_{s,1} = \beta_{c,1} = \beta_{q,1} = 0$.

A Bayesian Vector Error Correction (BVEC) Model with Priors from the Distances between Key Cities

One of the first papers to apply a Bayesian vector autoregression (BVAR) in the context of regional studies is by Pan and LeSage (1995), who construct weights matrices and prior specifications ("priors") based on first-order contiguity. This is done to emphasize the effect of neighboring states in forecasting agricultural output. In forecasting employment, Krivelyova and LeSage (1999) also define their weight matrix based on contiguity. In their approach, they assign prior means of zero to noncontiguous states and one to neighboring states to emphasize the relatively stronger effect of the employment levels in neighboring states. They standardize their weight matrix to produce rows that sum to unity, in line with the literature on spatial econometrics.

To understand the long-term impacts of spillovers in bubbles and nonfundamental components of house prices between regions, we use an impulse response function from a BVAR/BVEC model. We employ a BVAR/BVEC model to circumvent the issue of overparameterization in standard VAR/VEC models with many lags and small samples. The problem of overparameterization may cause the model to produce imprecise and inaccurate parameter estimates. To tackle this problem, the BVAR/BVEC amalgamates prior information and the standard VAR model. With this approach, we are able to examine the propagation of shocks and market interdependences. Rather than base our priors on contiguity, we specify the weights matrix

TABLE 1
The Inverse Distance Matrix Used as Priors in the Bayesian Vector Error Correction (BVEC) Model

	PAC	MTN	WSC	WNC	ESC	ENC	SATL	MATL	NENG
PAC	0	0.546	0.075	0.082	0.069	0.071	0.058	0.051	0.048
MTN	0.518	0	0.078	0.091	0.073	0.078	0.060	0.053	0.049
WSC	0.059	0.066	0	0.082	0.318	0.119	0.198	0.085	0.073
WNC	0.073	0.086	0.092	0	0.130	0.315	0.094	0.110	0.100
ESC	0.049	0.056	0.102	0.239	0	0.147	0.228	0.099	0.081
ENC	0.050	0.056	0.288	0.104	0.156	0	0.115	0.126	0.106
SATL	0.064	0.070	0.274	0.116	—	0.176	0	0.165	0.135
MATL	0.031	0.034	0.065	0.074	0.202	0.106	0.090	0	0.398
NENG	0.035	0.038	0.067	0.081	0.105	0.107	0.089	0.478	0

Note: This table provides inverse distances for use as priors in the BVEC model. The cell entries have been normalized so that each row sums to unity. ENC, East North Central; ESC, East South Central; MATL, Middle Atlantic; MTN, Mountain; NENG, New England; PAC, Pacific; SATL, South Atlantic; WNC, West North Central; and WSC, West South Central.

as a function of the geographical distances between the regions. In each of the nine census divisions, we select the state that witnessed the greatest jump in house prices in the nationwide house price boom period of 2000 to 2005.[7] We use the coordinates of the largest cities in each of these states[8] to calculate the geographical distance between these cities, thereby acting as a proxy for the distance between the regions.[9] In other words, these selected cities are taken to represent the whole region.

We take the distances between the regions in kilometers and compute the weights matrix by simply calculating the inverses of these distances, which allows us to assign greater prior means to coefficients of nearer regions and lesser means to those of farther regions. This is logical because one might expect that in the long run, the spillover of bubbles/nonfundamentals would be due to the closeness of regions.[10] Therefore, a region like the Pacific is only 348 km from the Mountain region, and so the long-term effect of house prices in the Pacific region may have a stronger effect on house prices in the Mountain region than prices in more distant regions such as the South Atlantic, which is 3,179 km away. This weighting approach is used by Vansteenkiste (2007) in a global vector autoregressive context for evaluating regional housing spillovers. In line with previous research, the weights matrix is standardized to produce row-sums of unity, and these become the prior means, as shown in Table 1.

Before employing the model, it is important to test for stationarity of the series, because if series in the BVAR system are nonstationary and cointegrated, this could lead to spurious results. Using Johansen's test, we find evidence of cointegration among the series, and therefore we augment the BVAR model to incorporate cointegrating vectors and the model becomes a BVEC model. The number of lags used in this model is one in order to allow for consistency with that of the multivariate bubble spillover model below.

[7] In the PAC, MTN, WSC, WNC, ESC, ENC, SATL, MATL, and NENG regions, California, Nevada, Louisiana, Minnesota, Alabama, Illinois, Florida, New York, and Massachusetts, respectively, had the largest growth in house prices between 2000 and 2005.

[8] Provided by Geonames (www.geonames.org).

[9] The largest cities in California, Nevada, Louisiana, Minnesota, Alabama, Illinois, Florida, New York, and Massachusetts are Los Angeles, Las Vegas, New Orleans, Minneapolis, Birmingham, Chicago, Jacksonville, New York City, and Boston, respectively.

[10] We also employ, in a separate estimation, priors constructed using a spatial contiguity matrix instead of one based on distances. The key findings are less strong than those reported here, suggesting that distance is more important than contiguity in determining how bubbles spread, but the conclusions are qualitatively unaltered.

The Multivariate Bubble Spillover Model

Following the test for speculative bubbles in the census divisions and an examination of bubble or nonfundamental spillovers via the BVEC model, we proceed to investigate the possibility of contagion from one region to another by extending van Norden and Schaller's model. We allow the return in one region's real estate market to be dependent not only on its bubble component but also on that of the other eight regions (refer to equation [10]). We also allow the probability of being in the surviving or collapsing regime in one region to be dependent on its lagged bubble component and on that of other regions', as seen in [11]. A similar approach has been adopted by Anderson, Brooks, and Katsaris (2010), who use it to test for speculative bubble spillovers among sectors in U.S. stocks, but the model has not been previously employed in the context of the real estate market. The returns in the surviving and collapsing regimes for the multivariate model are thus,

$$R^{\mathrm{s}}_{t+1,k} = \beta_{\mathrm{s},0,k} + \sum_{k=1}^{9} \beta_{\mathrm{s},1,k} b_{t,k} + u_{\mathrm{s},t+1,k},$$
$$R^{\mathrm{c}}_{t+1,k} = \beta_{\mathrm{c},0,k} + \sum_{k=1}^{9} \beta_{\mathrm{c},1,k} b_{t,k} + u_{\mathrm{c},t+1,k}, \qquad [10]$$

with the probability of being in the collapsing regime represented as

$$q(b_{t,k}) = \Phi\left(\beta_{\mathrm{q},0} + \sum_{k=1}^{9} \beta_{\mathrm{q},1,k} |b_{t,k}|\right). \qquad [11]$$

Note that k (= 1, . . . , 9) represents the regions. Also, note that [10] and [11] are extensions to [8] and [9] respectively, as they now allow for more than one bubble as explanatory variables. Like van Norden and Schaller's model, we estimate the parameters using a maximum likelihood procedure; see Anderson, Brooks, and Katsaris (2010) for details.

Once we estimate the parameters, a block-exogeneity test is employed to determine whether one region's lagged bubble component influences the returns or the probabilities of survival/collapse in other regions. This provides information on the bubble components from each region that Granger cause both returns and the probability of a collapse in other regions. Therefore, we are able to test for multidirectional spillovers of speculative bubbles among the regions with this multivariate bubble spillover model.

The models employed in this section are econometrically robust and have been successfully implemented in various asset markets, as described above. However, before considering the results we should note several limitations of this approach. First, because the models are nonlinear and estimated by maximum likelihood, it is possible that they will suffer from estimation issues including local optima and instability—and it is particularly challenging in the real estate context where only quarterly (as opposed to monthly or even higher frequency) observations are available. Second, despite its apparent sophistication, the model still makes a number of assumptions of the data and markets to ensure tractability, for example, that the errors are normally distributed within a regime and that there are only two regimes.

Constructing a Measure of Fundamentals

Before applying the test for speculative bubbles in each region, the model requires us to estimate the fundamental component of the real estate price. We calculate the nonfundamental or bubble component by regressing the price series on the user cost series. The fitted values from the regression represent the proportion of real estate prices that are justified by the fundamental drivers of the real estate market, that is, the components of the user cost of housing (as discussed in Section III). The residuals, on the other hand, represent the proportion of real estate prices that are not fundamentally driven. These are the nonfundamental or bubble component of prices. A similar regression approach has been used in previous studies to back out the fundamental values of real estate prices, including those by Roche (2001) and Nneji, Brooks, and Ward (2013).

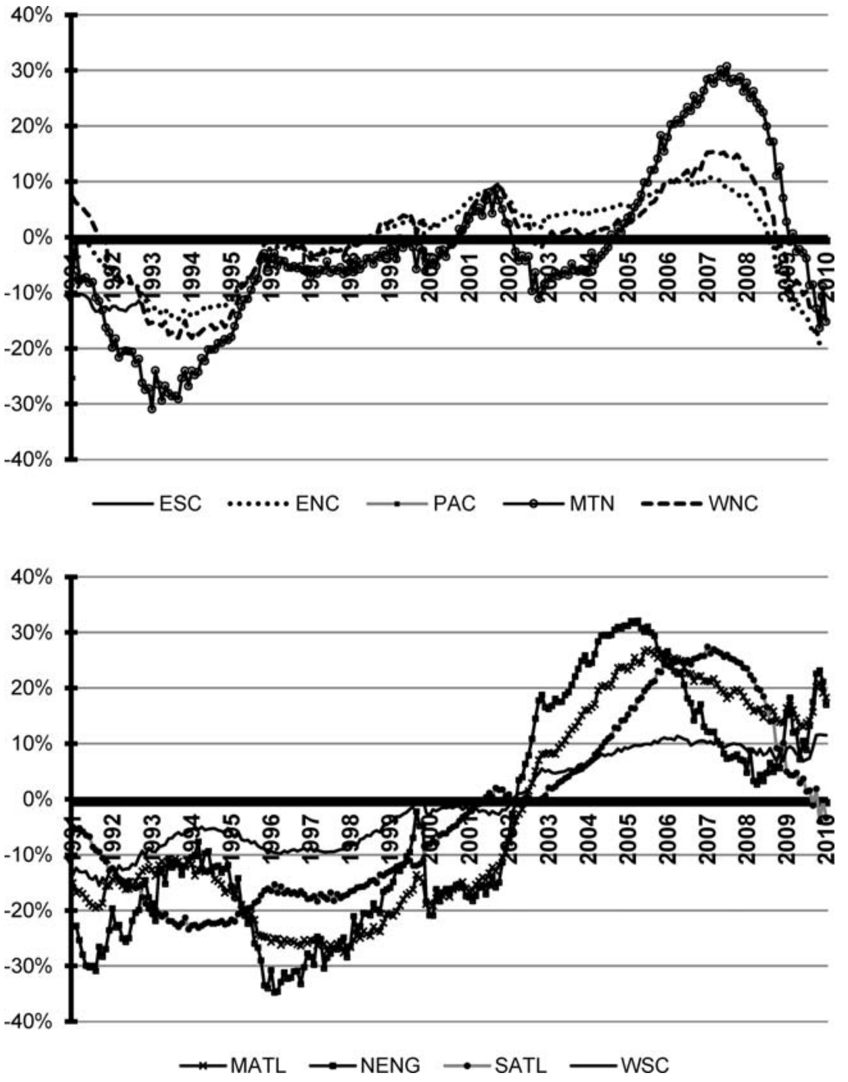

FIGURE 1
Bubble and Nonfundamental Components Relative to Prices, 1991–2010 (See Table 1 for Abbreviations)

V. RESULTS AND FINDINGS

A Summary of the Bubble Characteristics of Each Region

Figure 1 is a graphical representation of the bubble component relative to price levels (b_t) in all nine regions. This is a measure of the level of under-/overvaluation in real estate prices. From the graph, it is clear that all the regions were undervalued at some point in the period 1991–2000. This is not surprising as the United States had officially just come out of a recessionary phase in the first quarter of 1991, according to the National Bureau of Economic Research. From then until 1999, the real values of houses in the Middle Atlantic, New England, and Pacific regions fell by 10%, 1.7%, and 6.6% respectively, while the South Atlantic witnessed a growth rate of just

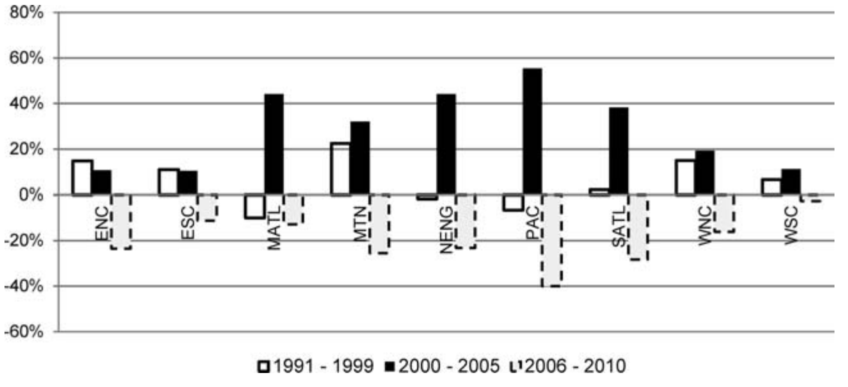

FIGURE 2
Growth Rates of Regional House Prices (See Table 1 for Abbreviations)

2.2% (refer to Figure 2). However, following the collapse of the information technology bubble in 2000, the Federal Reserve reacted by making sharp cuts to the federal funds rate, causing it to fall from 6.5% in the fourth quarter of 2000 to roughly 1% by the first quarter of 2004. At the same time, the number of mortgage brokerages in the United States increased from 30,000 in 2000 to 53,000 in 2004, according to Wholesale Access Data from the Mortgage Bankers Association of America, which also showed that the number of mortgage originations across the United States increased from around \$1.1 trillion to \$3.8 trillion between 2000 and 2003. This increased access to credit consequently induced demand-pull inflationary pressures in the real estate markets in many regions.

Referring to Figure 2, the biggest jumps in house prices were in the Pacific area, where valuations grew by 55.4% between 2000 and 2005, and so, by December 2005, its real estate market was overvalued by about 40% relative to rent-based fundamentals. Similarly, the real estate markets in regions with megacities, such as New England, South Atlantic, and Middle Atlantic, also saw prices considerably exceed their intrinsic values. East South Central and West South Central, however, witnessed very modest price changes over that same period.

At the city level, those most susceptible to bubbles were supply constrained, such as New York or Los Angeles, alongside other cities that have high house price elasticities to incomes, such as large cities in Florida, for example, Miami. Other cities, where there were neither significant constraints on new house building nor cyclical variation in activity, were less likely to see bubble formation (see also Martin 2010).

The rise in house prices was accompanied by a corresponding rise in the general level of inflation in the economy from a trough of 1% in 2002 to almost 5% in late 2005. This prompted the Federal Reserve to adopt aggressive contractionary monetary policy measures, increasing the effective federal funds rate by 425 basis points in just 10 quarters following the first quarter of 2004. This sharp rise in rates had an adverse impact on one-year adjustable rate mortgage holders, and a wave of mortgage defaults followed. According to the Federal Reserve, the delinquency rate on single-family residential mortgages grew from 1.6% in 2006 to 11.2% in 2010. Unsurprisingly, mortgage origination in this period fell from \$2.7 trillion to \$1.6 trillion, thus causing an abrupt drop in house prices. Bubble collapses, perhaps unsurprisingly, occurred in precisely the reverse formation of their growth: those regions that had previously experienced the fastest and most extreme growth of prices relative to fundamentals and where subprime mortgage lending was most prevalent (e.g., Pacific, Mountain, and South Atlantic) exhibited the largest and fastest relative falls in real estate valuations.

By 2010, prices in many regions were close to their fundamental values. However, the real estate markets in East North Central and Pacific had fallen below their fundamental values by that time, according to our calculations.

Results from the Speculative Bubble Test

In this subsection, we formally test for whether the deviations of each region's real estate prices from their fundamental values are as a result of the existence of speculative bubbles, by applying the van Norden–Schaller model. The results are given in Table 2.

Although there is a large number of parameters in the table, interpreting the results is straightforward. For example, referring to the real estate market in the Pacific, the mean monthly returns in the surviving ($\beta_{s,0}$) and collapsing ($\beta_{c,0}$) regimes are 0.26% and –0.56%, respectively. For all regions, the return is greater in the surviving than the collapsing regime, as expected. In the surviving regime, the bubble yields a higher return than in the collapsing regime, as the coefficient of $\beta_{s,1}$ is greater than that of $\beta_{c,1}$, as expected for four of the nine regions, although only for three of them is $\beta_{c,1}$ actually negative. It is not usually required that all four restrictions described above be present for a conclusion of the presence of a speculative bubble to be drawn, and it is worth noting that the parameters $\beta_{s,0}$, $\beta_{c,0}$, $\beta_{q,0}$, and $\beta_{q,1}$ have the expected signs and sizes in all cases. The terms σ_s and σ_c represent the volatility of returns in the surviving and collapsing regimes, respectively. As expected, returns are more volatile in the collapsing regime than the surviving regime for seven of the nine regions.

The bubble model is tested against other stylized alternative models of returns, namely, the mixture-normal, fads, and volatility regimes models, and these results are presented in the second panel of Table 2. For the East South Central and Mid Atlantic regions, the tests against stylized alternative models provide little evidence in support of the bubble model, although we find that the simpler models are resoundingly rejected in favor of the bubble specification for the other series. Hence, we conclude that housing markets in these three regions were not subject to speculative bubbles, perhaps due to the low growth in residential population. According to the U.S. Department of Commerce Census Bureau, the East South Central population grew by only 20% between 1991 and 2010, compared to 58% in the Mountain region.

Results from the BVEC Model

In Table 3, the effect of an unexpected one-unit increase in the size of the bubble/nonfundamental component relative to house price is documented. From this table, it is possible to quantify the degree of spillover over a 12-month period. For example, a 1% unexpected increase in the Pacific region's bubble size relative to average house prices increases the bubble in the neighboring Mountain region by 0.28% over the 12 months succeeding this shock. This implies that the contagion of the housing bubble from the Pacific region is most felt by the Mountain region. Interestingly, this effect is not seen to the same degree in the reverse, that is, an unexpected increase in housing market speculation in the Mountain region has a much smaller effect on the Pacific region's bubble. The column entitled "Total" shows the absolute aggregate effect of an unexpected increase in one region's speculative component on nationwide housing market over the 12 months succeeding the shock. Here, it is clear that a shock in the East North Central region has the greatest effect, perhaps due to the fact that it is centrally located and has close proximity to many other regions. Other than this region, bubble shocks in the East South Central and West North Central regions have the most impact on nationwide prices with a one-unit shock in the bubble component relative to prices in these regions leading to 0.77% and 0.75% nationwide rises in the bubble/nonfundamental components relative to price, respectively. This shows that the effects of the bubbles in these regions' housing markets are not only contagious in the short term, as shown in the multivariate regime-switching bubble spillover model, but there are also significant spillovers in the long run.

TABLE 2
Results from the Regime-Switching Speculative Bubble Model for All Nine Census Divisions' Residential Real Estate Markets

	ESC	ENC	MATL	NENG	PAC	SATL	MTN	WNC	WSC
Coefficients									
$\beta_{s,0}$	1.0004***	1.0011*	1.0009***	1.0020***	1.0026***	1.0020***	1.0023***	1.0016***	1.0012***
	(0.0000)	(0.0760)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$\beta_{s,1}$	0.0123***	0.0045*	0.0066	−0.0012***	−0.0121	0.0014***	0.0226***	0.0058	0.3551
	(0.0011)	(0.0760)	(0.1071)	(0.0066)	(0.1071)	(0.7965)	(0.0000)	(0.2949)	(0.3551)
$\beta_{c,0}$	0.9953***	0.9968***	0.9566***	0.9811***	0.9944***	0.9969***	0.9958***	0.9973***	0.9976***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$\beta_{c,1}$	−0.0536***	0.0183*	0.1421*	0.0057	0.0657***	0.0300**	0.0196	0.0104	0.0271
	(0.0000)	(0.0581)	(0.0984)	(0.7879)	(0.0000)	(0.0124)	(0.2617)	(0.5556)	(0.2281)
$\beta_{q,0}$	9.4152***	0.9342***	5.4824***	2.0519***	1.2549***	0.9965**	1.2307***	0.9696*	0.9327**
	(0.0039)	(0.0081)	(0.0000)	(0.0031)	(0.0015)	(0.0179)	(0.0004)	(0.0952)	(0.0403)
$\beta_{q,1}$	−44.5897**	−3.4817	−1.5828	−4.0639	−9.2530***	−6.3288**	−4.0060	−1.4402	1.5231
	(0.0111)	(0.1367)	(0.1155)	(0.2739)	(0.0014)	(0.0137)	(0.1198)	(0.7470)	(0.6299)
σ_s	0.0057***	0.0030***	0.0068***	0.0077***	0.0058***	0.0036***	0.0041***	0.0041***	0.0037***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
σ_c	0.0010	0.0081***	0.0109	0.0067*	0.0111***	0.0106***	0.0110***	0.0094***	0.0091***
	(0.5373)	(0.0000)	(0.4984)	(0.0749)	(0.0000)	(0.0000)	(0.0000)	(0.0006)	(0.0000)
Restrictions									
Fads	0.0000	12.0906***	0.0000	12.1743***	49.5902***	11.7036***	11.8833***	3.9704	4.1708
	(1.0000)	(0.0071)	(1.0000)	(0.0068)	(0.0000)	(0.0085)	(0.0078)	(0.2647)	(0.2436)
Normal-Mixture	0.0000	9.3718**	2.5083	0.0247	37.2381***	16.6236***	45.2337***	4.1980	3.6458
	(1.0000)	(0.0247)	(0.4738)	(0.7161)	(0.0000)	(0.0008)	(0.0000)	(0.2409)	(0.3023)
Volatility	0.0000	10.4673**	0.0000	2.2046	42.8127***	13.3197***	51.4624***	1.2102	3.3214
	(1.0000)	(0.0333)	(1.0000)	(0.6982)	(0.0000)	(0.0098)	(0.0000)	(0.8764)	(0.5055)

Note: The model is $R^{s}_{t+1} = \beta_{s,0} + \beta_{s,1} b_t + u_{s,t+1}$; $R^{c}_{t+1} = \beta_{c,0} + \beta_{c,1} b_t + u_{c,t+1}$; $q(b_t) = \Phi(\beta_{q,0} + \beta_{q,1} |b_t|)$. This table provides results from the tests for speculative bubbles in the residential real estate market of all nine census divisions in the United States. The figures in parentheses represent the *p*-values of the parameter estimates, which are computed by taking the inverse of the Hessian matrix (first panel). The test statics presented in the second panel are for restrictions to simpler specifications, with *p*-values in parentheses; see Brooks and Katsaris (2005a) for further details. See Table 1 for abbreviations.

*, **, *** Significance at the 10%, 5%, and 1% levels, respectively.

TABLE 3

Impulse Responses from a Bayesian Vector Error Correction Model after 12 Months Using Inverse Distance-Based Priors

Shocked Variable	PAC	MTN	WSC	WNC	ESC	ENC	SATL	MATL	NENG	Absolute Total
PAC	0.090	0.282	− 0.007	0.032	0.034	0.020	0.046	0.055	0.084	0.635
MTN	0.114	− 0.013	0.039	0.032	0.024	0.034	0.050	0.019	0.025	0.324
WSC	0.059	0.041	− 0.006	0.042	0.143	0.039	0.112	0.051	0.068	0.548
WNC	0.001	− 0.040	0.033	0.023	0.118	0.167	0.076	0.120	0.173	0.671
ESC	0.003	0.009	− 0.029	0.085	0.035	0.046	0.156	0.106	0.300	0.711
ENC	0.040	0.145	0.150	0.290	0.181	0.195	0.184	0.185	0.261	1.633
SATL	0.003	0.007	− 0.030	0.035	− 0.010	0.029	− 0.001	− 0.087	0.162	0.107
MATL	− 0.011	− 0.031	− 0.088	0.029	0.153	0.011	0.139	0.050	0.270	0.522
NENG	− 0.020	− 0.098	− 0.228	− 0.016	− 0.112	− 0.010	− 0.007	0.006	− 0.010	− 0.496

Note: Cell entries present the impact of a unit shock to the bubble, b_t, as a proportion of the average house price, on the regions after 12 months. The final column presents the sums of the absolute impacts of a shock to a given region on all other regions. See Table 1 for abbreviations.

TABLE 4

Results from the Block Exogeneity Bubble/Nonfundamental Spillover Test

Dependent Variable	Explanatory Variable								
	ESC	ENC	MATL	NENG	PAC	SATL	MTN	WNC	WSC
ESC		10.2266**	0.0000	10.4835**	10.2029**	12.4888***	7.9123**	53.5715***	5.9998
		(0.0167)	(1.0000)	(0.0149)	(0.0169)	(0.0059)	(0.0479)	(0.0000)	(0.1116)
ENC	5.2010		19.6313***	8.6378**	48.8523***	22.3603***	0.0000	24.0841***	0.0000
	(0.1577)		(0.0002)	(0.0345)	(0.0000)	(0.0001)	(1.0000)	(0.0000)	(1.0000)
MATL	9.2073**	3.3879		3.1186	2.0713	8.9630**	0.0000	7.8622**	7.5572*
	(0.0267)	(0.3356)		(0.3737)	(0.5578)	(0.0298)	(1.0000)	(0.0489)	(0.0561)
NENG	4.6865	8.9554**	0.0000		12.9731***	7.2768*	1.7685	50.1832***	3.6454
	(0.1962)	(0.0299)	(1.0000)		(0.0047)	(0.0636)	(0.6218)	(0.0000)	(0.3024)
PAC	0.0000	22.9257***	0.0000	4.6752		3.9363	0.0000	10.8073**	1.5954
	(1.0000)	(0.0000)	(1.0000)	(0.1972)		(0.2684)	(1.0000)	(0.0128)	(0.6604)
SATL	17.2469***	8.2227**	0.0000	8.0217**	28.0158***		0.0000	0.0000	1.9415
	(0.0006)	(0.0416)	(1.0000)	(0.0456)	(0.0000)		(1.0000)	(1.0000)	(0.5846)
MTN	32.9326***	8.8141**	0.0000	2.5608	2.9393	0.0000		18.1380***	7.7792*
	(0.0000)	(0.0319)	(1.0000)	(0.4644)	(0.4011)	(1.0000)		(0.0004)	(0.0508)
WNC	13.7042***	14.3679***	0.0000	14.9916***	12.5341***	11.6584***	0.0000		0.0000
	(0.0033)	(0.0024)	(1.0000)	(0.0018)	(0.0058)	(0.0086)	(1.0000)		(1.0000)
WSC	1.6149	6.0871	0.0000	2.1434	0.3764	0.0000	0.0860	19.5067***	
	(0.6560)	(0.1075)	(1.0000)	(0.5432)	(0.9451)	(1.0000)	(0.9935)	(0.0002)	

Note: The block exogeneity tests on the estimates from the multivariate bubble spillover model provide evidence of whether there are bubble spillovers from one region to another. The dependent variable in this case refers to the real estate market returns in a census division, while the explanatory variable refers to the size of the bubble/nonfundamental component relative to price. Note that the figures in parentheses are the p-values and the other numbers are the chi-squared test statistics. See Table 1 for abbreviations.

*, **, *** Significance at the 10%, 5%, and 1% levels, respectively.

Results from the Multivariate Bubble Spillover Model

We now proceed to model more formally how speculative bubbles or nonfundamentals spill over from one region to another. This is achieved by applying the methods introduced in equations [10] and [11], where spillovers are determined by examining whether the bubble component in one region jointly influences the returns and the probability of a bubble collapsing in another.[11] Table 4 provides the key information on the spillover directions of speculative bubbles and nonfundamentals

[11] We do not present the results from this model due to space constraints.

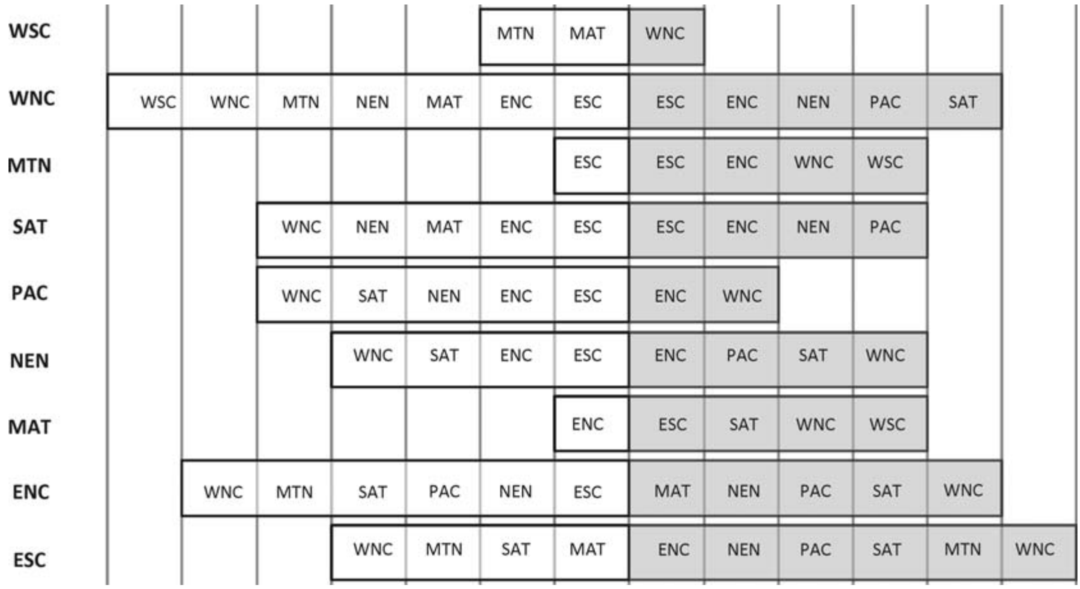

FIGURE 3
Regions and Their Speculative Bubble/Nonfundamental Spillover Directions (See Table 1 for Abbreviations)

between regions as we test for the combined impact of regions' bubbles on both returns and the probability of survival. These tests are based on the joint restriction that all of the bubble parameters for one region are zero in the regression for another. Here, we conclude that one region's bubble or nonfundamentals affect another region's if the block exogeneity test null hypothesis is rejected. For example, if we refer to the column MTN, we are examining the effect on other regions of the bubble in the Mountain region. In this case, there is evidence that the nonfundamental component in the East South Central region spilled over only to the Mountain region.[12]

A simplified graphical summary of Table 4 is given in Figure 3. Each bar in the graph represents a particular region. The darker shaded part of the bar on the left represents the regions that influence the region under study (e.g., WSC is under study in the first row, WNC in the second, etc.), while the lighter shaded part on the right represents those regions that are affected by bubbles from the region under study. From the graph, it is clear that there are multidirectional spillovers of speculative bubbles and nonfundamentals between the regions. Like the results of Füss, Zhu, and Zietz (2011), our results show that the direction of speculative bubble spillovers does not depend on geographic locations, and so therefore, the spillover of speculative activities is not dependent on contiguity. Similar to the findings from the aforementioned BVEC model, we find that the centrally located East South Central, East North Central, and West North Central regions are most influential. These regions are also susceptible to bubbles in other census divisions perhaps due to the fact that these regions are centrally located. Rather unsurprisingly, other than these centrally located regions, the Mountain, South Atlantic, Pacific, and New England regions are highly susceptible to speculative bubbles in other regions. A reasonable explanation for this phenomenon is that investors in other regions were keen to profit from the surge in prices in the four regions. Figure 2, discussed earlier, showed that average house prices in the four

[12] Note that we do not use the term "speculative bubbles," as Table 2 provides no evidence of bubbles in some of the regions; instead we refer to them as "nonfundamental components."

regions jumped by over 40% between 2000 and 2005 compared to the relatively modest growth in other regions. With such aggressive growth in house prices, it is possible that demand for properties in these four regions by investors from other regions may have increased, thus causing bubbles to spillover to these four regions.

There are several other possible reasons for the regional spillover of speculative bubbles. Building on Pollakowski and Ray's (1997) conclusion that the media fosters noncontiguous house price interactions, the widespread news coverage on the growing real estate market in regions across the United States may have caused investors in already "bubbly" regions to seek housing in other regions that were not as overvalued as theirs. For example, house owners in other regions may have invested in the Pacific or Middle Atlantic regions, as media reports may have led them to believe that prices would continue to rise in these regions. If this were the case, demand for homes in these target regions would increase, real estate prices would then rise and might exceed fundamental values, which could then lead to speculative buying in those target regions. Therefore, in this case, the speculative bubble in the Pacific region, for example, could further fuel speculative bubbles in the New England and South Atlantic regions. This view is fairly similar to that of Shiller, writing in the *New York Times,*[13] who highlights the importance of the National Association of Realtors and other related agencies' nationwide public relations campaigns on the virtues of investing in real estate, in contributing to the creation of a housing bubble.

Another possible explanation for the spillover of speculative bubbles from one region to another could be due to herding effects. When there is uncertainty and asymmetric information in a market, individuals might be more likely to be influenced by other people's decisions because these individuals believe that the crowd is better informed than they are and there is also "safety in numbers." Therefore, any new information is likely to cascade, making rational investors reliant on others' judgments (Bikhchandani, Hirshleifer, and Welch 1992). This may have been the case in the real estate market, especially in the boom period of 2000–2005, thus promoting nationwide speculation. Information about rising prices in other regions may have caused individuals who had already invested in bubbly states to invest elsewhere, which may in turn have caused prices to exceed their fundamental values, subsequently leading to the inception of speculative bubbles. This may have also been the case but in reverse during the collapsing bubble period of 2006–2010, where uncertainty about economic conditions and the increasing delinquency and foreclosure figures in one region may have led to a decline in transactions in other regions. The herd, in this case, would begin to view the real estate market as unattractive and local transactions may decrease, putting downward pressure on prices. This view is also shared by Baddeley (2005), who shows that herding and information asymmetry may be a source of upward and downward frenzies in the real estate market.

Lastly, regional spillovers of speculative bubbles may be explained by the migrating "equity transfer" argument propounded by Meen (1999). In his study, Meen argues that regional ripple effects in house prices could be explained by people moving from a more expensive region to a cheaper one, as they would then have stronger buying power. Therefore, in this case, as a speculative bubble existed in the South Atlantic region, some of its residents might have decided to move to the relatively cheaper East North Central because they could acquire the same type of property for less, thus providing them with spare cash. Increased demand in the East North Central region might then cause the region's speculative bubble to grow, which would subsequently lead to further speculation and a potential subsequent collapse.

VI. CONCLUSIONS

The paper investigates the interlinkages between the regional housing markets in the

[13] This article was published in the *New York Times* on March 2, 2008, and it can be accessed online at http://pages.stern.nyu.edu/~cedmond/ge08/Shiller%20on%20bubbles.pdf.

United States by examining how speculation in one region transmits to other regions. The study focuses on a period of two significant decades in the real estate market, 1991–2010, thus covering the recent boom and bust periods. Before conducting the analysis on possible spillovers of speculative bubbles between regions, we first apply a regime-switching model to test for the presence of collapsing speculative bubbles in each of the nine census divisions. We then proceed to investigate the possibility of bubble/nonfundamental component spillovers (a proxy for the transmission of speculative activities) across the regional housing markets using two approaches. First, we employ a BVEC to examine the extent to which geographical distances between regions influence the spread of bubbles. Second, we implement block exogeneity tests on the estimates from a multivariate regime-switching spillover model.

The results show evidence of speculative bubbles in five of the nine regions. We find the housing market in the Pacific region to be the most overvalued, where prices exceeded their estimated fundamental values by almost 40% at their peak in 2007. Prices in the Mountain and West South Central regions, on the other hand, remained fairly close to their fundamental values over the sample period examined even though all nine regions' real estate markets were overvalued from 2000 onward. These results agree with findings in previous research by Zhou and Sornette (2006), Goodman and Thibodeau (2008), and Mikhed and Zemcik (2009), who have all shown the existence of regional bubbles in U.S. housing markets.

Further tests reveal that there are multidirectional spillovers of speculative bubbles and nonfundamental components of prices across contiguous and noncontiguous regions. Like Füss, Zhu, and Zietz (2011), we find that speculation in one region could spread to others. Speculation in the northern central regions is most likely to lead to a nationwide buying frenzy. However, the limited speculation that does arise in the East and West South Central regions has the least influence on other regions. Our research demonstrates that while house price dynamics had important regional variations across the United States, the bubble interactions between regions did not spread outward from those areas that experienced the earliest or largest bubbles, like the impact of an explosion. Rather, prices collapsed most spectacularly in those regions where the bubbles had grown the fastest and the furthest, driven by limited supply and high house price elasticities to incomes. We show that bubble spillovers did not occur predominantly between the geographically closest regions but were caused by other factors. Future research could usefully investigate why these connections occur, for example, is it because the regions have strong economic connections such as trade flows or migration patterns?

There are policy implications arising from these findings.[14] First, states in regions that are prone to speculation may consider reviewing their tax policies on home purchases, in line with Texas, which could possibly reduce the level of speculation. Emrath (2002) shows that the average residential property tax paid in Texas in 2000 was 1.7% compared to the 0.7% and 0.8% paid in bubbly regions California and Nevada, respectively. They may also want to adopt stricter policies on home refinancing in order to curb the emergence of nationwide speculative activities. According to the Office of Consumer Credit Commissioner in Texas, Texans using home equity loans cannot borrow more than 80% of their home values. They are also prohibited from obtaining more than one home equity loan at a time. This limit on borrowing is much stricter than in many other contagious states such as California and Florida. The Office claims that these policies were introduced to prevent overleveraging. Similar policies were introduced in Canada; for example, since July 2012, federal mortgage indemnity insurance, which is required for all buyers holding a less than 20% deposit, has been restricted. The amount that can be borrowed when refinancing homes has also been reduced. Such strin-

[14] It is fairly easy to come up with a set of policy measures that might, with the benefit of perfect hindsight, have prevented a previous bubble from forming. However, the evidence suggests that many bubbles share the same characteristics and causes and in that sense are cyclical and repetitive through time. To the extent that history could repeat itself if no contrary measures are taken, we believe that these policy ideas are still relevant for the future.

gent measures may also deter homeowners from using home equity loans to buy second homes, thus reducing the chances of speculation that may fuel the growth of bubbles. More recently in February 2014, the Canadian government scrapped its investor visa scheme, which had enabled wealthy foreigners to invest in Canadian assets, including real estate, in exchange for a visa.

Some states, including North Carolina and Massachusetts, provide stricter regulations that try to reduce the incidence of some of the worst effects of predatory lending practices that can increase the likelihood of foreclosure (see Wyly et al. 2009). But state government powers to act are severely restricted by federal opposition and vested interests in allowing the continuation of current practices by banks (Aalbers 2009a, 38). Aalbers (2009b) argues that it was not in fact the housing bubble that caused a crisis in the mortgage market, but rather the other way around: the structure, incentives, and lack of regulation of the mortgage market caused the real estate bubble to both arise and then to subsequently collapse. This suggests that policy actions should focus on banks and securities firms, combined with a framework of support for homeowners experiencing repayment difficulties, rather than being directed at the housing market per se.

Second, policy makers should endeavor to follow the real estate markets of dominant coastal regions such as the Pacific more closely, as these effectively act as leading indicators for subsequent price changes in other areas. Our research indicates that evidence of bubble formation in regions that are most likely to experience them at an early stage in the housing cycle can be used as early warning indicators that can trigger policy responses before the bubble develops nationally, as also suggested by Agnello and Schuknecht (2011).

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