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Bago, Jean-Louis and Akakpo, Koffi and Rherrad, Imad and Ouédraogo, Ernest

Laval University, Québec Ministry of Finances, Université Ouaga 2

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Volatility Spillover and International Contagion of Housing Bubbles*

Jean-Louis Bago † Koffi Akakpo ‡ Imad Rherrad§ Ernest Ouédraogo¶

Abstract

This paper provides new empirical evidence on housing bubbles timing, volatility spillover and bubbles contagion between Japan and its economics partners, namely, the United States, the Eurozone, and the United Kingdom. First, we apply a generalized sup ADF (GSADF) test developed by Phillips et al. (2015) to quarterly price-to-rent ratio from 1970Q1 to 2018Q4 to detect explosive behaviors in housing prices. Second, we analyze the volatility spillover in housing prices between Japan and its economic partners using the multivariate time-varying DCC-GARCH model developed by Engle (2002). Third, we assess bubbles contagion using the non-parametric model with time-varying coefficients developed by Greenaway-McGrevy and Phillips (2016). We document two historical bubble episodes from 1970 to 2018 in the Japan's housing market. Moreover, we find evidence of volatility spillover and bubbles contagion between Japan's real estate market and its most important economic partners during several periods.

Keywords: Bubble, Contagion, Real estate, Japan, DCC-GARCH

JEL codes: C12 , G12 , R31

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†Department of Economics and CRREP, Laval University, Canada,jean-louis.bago.1@ulaval.ca

‡Department of Economics and CREATE, Laval University, Canada

§Department of Finance, Government of Quebec, Canada

¶Department of Economics, Université Ouaga 2, Burkina Faso

1 Introduction

In economic literature, a real estate bubble is defined as a sustained rise in housing prices that is not fueled by the fundamentals of the economy (Garber, 1990; Flood and Hodrick, 1990; Case and Shiller, 2003; Shiller, 2015). Since the 2008 financial crisis, Japan has implemented macroprudential policies to stabilize house prices and prevent bubble episodes (Saita et al., 2016; Kobayashi, 2016). Yet, concerns have been raised recently about Japanese real estate vulnerability with respect to housing prices outpacing economic fundamentals. In fact, from 2015 to 2018, the housing price index has risen by 8.07% in Japan while the rent index has decreased by 0.85% (OECD, 2019). According to the 2018 UBS Global Real Estate Bubble Index (UBS, 2018), which gauges the risk of a property bubble on the basis of housing price patterns, Tokyo was ranked the most exuberant market in the world in 2018 with a score of 2.03, far above the critical score of 1.5[1]. Moreover, the 2019 Bloomberg report on the world's housing bubbles indicated that the housing market of Japan was moderately at risk of a bubble in the first quarter of 2019 (Bloomberg, 2019).

The aim of this paper is three-fold. First, we date-stamp housing bubbles in Japan. Second, we analyze housing prices volatility association between Japan and its economic partners, the United States, the Eurozone, and the United Kingdom. Third, we assess bubbles contagion between Japan and its economic partners[2]. From the original work of Kindleberger and Aliber (2005) to the recursive tests procedure for explosive behavior of Phillips et al. (2011, 2015), empirical methods have been developed to identify the presence of bubbles in time series. Researchers have also developed empirical models to evaluate bubble migration between real estate markets. In order to analyze the volatility of time series when the volatility varies over time and applied in several studies, he DCC-GARCH model, developed by Engle (2002) has been largely applied (Celık, 2012; Dreger and Zhang, 2013; Herwarth Kohn and Valls Pereira, 2017; Bala and Takimoto, 2017; Panda and Nanda, 2018; Corbet et al., 2019; Akkoc and Civcir, 2019). For bubbles contagion, the most popular approaches used to assess is the non-parametric model with time-varying coefficient developed by Greenaway-McGrevy and Phillips (2016) and applied by Hu and

[1] Any city with a Real Estate Bubble Index over 1.5 is considered at "Bubble Risk" according to UBS (2018)

[2] China is not included in our analysis because of insufficient data.

Oxley (2018).

In this paper, we apply the generalized sup ADF (GSADF) test developed by Phillips et al. (2015) to the quarterly price-to-rent ratio from 1970Q1 to 2018Q4 to detect explosive behaviors in housing prices. Subsequently, we analyze the volatility spillover between Japan and its economic partners using the multivariate time-varying DCC-GARCH model. This method has been developed by Engle (2002). Third, we estimate real estate bubbles contagion using Greenaway-McGrevy and Phillips (2016)'s non-parametric model with time-varying coefficients. Our methodology is related to previous studies in the literature that have documented the existence and migration of episodic bubbles (Case and Shiller, 2003; Fraser et al., 2008; Schwartz, 2009; Gelain and Lansing, 2014; Engsted and Pedersen, 2015; Engsted et al., 2016; Greenaway-McGrevy and Phillips, 2016; Caspi, 2017; Hu and Oxley, 2018; Rherrad et al., 2019).

More specifically, our paper is close to Hu and Oxley (2018) who provided the first empirical evidence about the timeline of the Japan's housing market bubble. Hu and Oxley (2018) find evidence that bubble in the stock market migrates to the real estate market. Previous papers such as Ito and Iwaisako (1995) and Lee (1995) have also indicated that the Japan real estate market were overheated. However, none of these papers investigated the possibility volatility spillover and bubbles contagion of real estate prices between the Japan real estate ant its economics partners. Thus, we contribute to the literature by (i) testing for volatility spillover of housing prices between the Japan real estate and United states, Eurozone and United Kingdom, (ii) testing for international bubbles transmission.

Our results indicate that Japan has experienced two historical bubble episodes for the period from 1970 to 2018. We found that Japan has experienced two bubbles from 1989Q1 to 1990Q4 and 2000Q2 to 2006Q4. Moreover, we find evidence of volatility spillover and bubbles migration between the real estate markets of Japan and its the most important economic partners during several periods.

The rest of the paper is organized as follows. Section 2 presents the data used in this paper. Section 3 presents our empirical models for detecting the episodes of bubbles, investigating volatility spillover and bubbles migration. Section 4 shows and discusses our empirical results, and Section 5 concludes.

2 Data

In this paper, we use quarterly real estate price-to-rent ratios from 1970Q1 to 2018Q4. The housing price data were retrieved from OECD stats OECD (2019)[3]. Our database included the real price indexes and the price-to-rent ratios for Japan, the United States, the Eurozone, and the United Kingdom.

Figure (1a) gives an observational view of the evolution of the price-to-rent ratios and the real price indexes in Japan. We also present the real estate prices in the main partners of Japan, the United States (Figure (1b)), the Eurozone (Figure (1c)), and the United Kingdom (Figure (1d)). Figure (1a) indicates that Japan has experienced non-monotonous housing price increase between 1980 and 2002. However, since 2003, housing real price and price-to-rent ratio have started a decreasing path.

The picture is different for the real estate markets of the United States, the Eurozone, and the United Kingdom. Figure (1b), Figure (1c), and Figure (1d) suggest that housing price-to-rent ratios (and real prices) have registered a substantial increased in different periods in the United States, the Eurozone, and the United Kingdom, respectively.

(Insert Figure (1) here)

Table (1) presents the descriptive statistics for the price-to-rent ratios in Japan and its main partners: the United states, the Eurozone, and the United Kingdom. On average, the price-to-rent ratio in Japan appears to be roughly higher (127.9) compared to its partners, the United States, (98.42), the Eurozone (), and the United Kingdom (74.57).

(Insert Table 1 here)

In Table (2), we analyze the stationarity of price-to-rent series. The results of the three stationarity tests (ADF, KPSS, and PP) clearly indicate that the price-to-rent ratios contain unit roots.

(Insert Table 2 here)

[3]The OECD real estate price indexes measure the rate at which the prices of residential properties (flats, detached houses, terraced houses, etc.) purchased by households are changing over time. The data cover both new and existing dwellings, independently of their final use and their previous owners. Only market prices are considered. OECD also includes the price of the land on which residential buildings are located in the housing price index.

3 Methodology

3.1 Test for explosive behavior and bubble episodes

We rely on the generalized sup ADF (GSADF) test developed by Phillips et al. (2015) to analyze the explosive behavior of housing prices in Japan. The method consists in performing a unit root test on the following equation:

$$\Delta y_t = \alpha + \beta y_{t-1} + \sum_{i=1}^{K} \gamma_i \Delta y_{t-i} + \epsilon_t \tag{1}$$

where y_t is the property price at period t, α is the intercept, K is the optimal lag order, and $\epsilon_{c,t}$ is the error term. If $\beta = 0$, the time series is considered to have a normal unit root, while $\beta > 0$ implies an explosive behavior for the time series. The generalized sup ADF (GSADF) consists of repeated estimation of equation1 on subsamples of data in a recursive fashion and is based on global backwards supremum ADF statistics of the form:

$$GSADF(r_0) = \sup_{r_2 \in [r_0,1] r_1 \in [0, r_2 - r_0]} ADF_{r_1}^{r_2} \tag{2}$$

The backward SADF (BSADF) statistic, which is used for determining the origination and collapse of each bubble, was defined by Phillips et al. (2015) as the sup value of the ADF statistic sequence:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} ADF_{r_1}^{r_2} \tag{3}$$

where r_0 is the minimum window size; r_1 is the starting point, which varies from 0 to $r_2 - r_0$; and r_2 is the ending point, which varies from r_0 to 1. The minimum window size r_0 is determined according to the formula $0.01 + \frac{1.8}{\sqrt{T}}$ proposed by Phillips et al. (2015).

Phillips et al. (2015)'s procedure consists in estimating the equation (1) and then calculating repeatedly the ADF statistics on a sequence of backward expanding subsamples. Then, it computes the critical values with a monte carlo simulation and takes the maximum value of the ADF statistics (BSADF) to determing if there is a bubble in each subperiod. The maximum of these BSADF statistics is the GSADF.

3.2 Multivariate DCC-GARCH model for volatility spillover

First, we use the multivariate DCC-GARCH model developed by Engle (2002) to analyze the degree of connectedness between the markets. The estimation of Engle (2002)'s GARCH-DCC model involves two steps: the first step estimates a univariate garch model for each price, while the second estimates the time-varying conditional correlations between the pairs of markets. The procedure reads as follows. Let us consider two markets, A and B. In the first step, the bivariate DCC-GARCH model can be written as follows:

$$Y_t = \mu_t + \Omega_t^{1/2}\varepsilon_t$$
$$\begin{cases} \Omega_t = D_t R_t D_t \\ R_t = (\mathrm{diag}\,(Q_t))^{-1/2}\, Q_t\, (\mathrm{diag}\,(Q_t))^{-1/2} \\ D_t = \mathrm{diag}\left(\sqrt{\omega_{AA,t}}, \sqrt{\omega_{BB,t}}\right) \end{cases} \tag{4}$$

where $Y_t = (\Delta y_{A,t}, \Delta y_{B,t})$ is the vector of past observations of the property price-to-rent ratio, Ω_t is the bivariate conditional variance, $\mu_t = (\mu_{A,t}, \mu_{B,t})$ is the vector of conditional means, $\varepsilon_t = (\varepsilon_{A,t}, \varepsilon_{B,t})$ is the vector of standardized residuals, R_t is a 2×2 symmetric dynamic correlations matrix, and D_t is a diagonal matrix of conditional standard deviations for mean series, obtained from estimating a univariate GARCH model with $\sqrt{\omega_{ii}}$ on the ith diagonal, $i \in \{A, B\}$.

In the second step, the DCC representation focuses on the dynamic evolution of the correlations matrix R_t in Eq. 4, which is defined as follows:

$$\begin{aligned} Q_t &= (1 - \phi - \gamma)\overline{Q} + \gamma Q_{t-1} + \phi \eta_{i,t-1}\eta_{j,t-1} \\ R_t &= Q_t^{*-1} Q_t Q_t^{*-1} \end{aligned} \tag{5}$$

where $Q_t = [q_{ij,t}]$ is a 2×2 time-varying covariance matrix of standardized residuals $\eta_{i,t} = \dfrac{\varepsilon_{i,t}}{\sqrt{\omega_{i,t}}}$, $\overline{Q}$ is the unconditional correlations of $\eta_{i,t}\eta_{j,t}$, ϕ and γ are non-negative scalar parameters that satisfy a stability constraint of the form $\phi + \gamma < 1$. $Q_t^{*-1} = [q*_{ii,t}] = \sqrt{q_{ii,t}}$, and $i \in \{A, B\}$ is a diagonal matrix with the square root of the diagonal element of Q_t.

For a pair of markets A and B, the conditional correlation at time t, which captures the connection between the two markets, is computed as follows:

$$\rho_{AB,t} = \frac{(1-\phi-\gamma)\overline{q}_{AB} + \gamma q_{AB,t-1} + \phi\eta_{A,t-1}\eta_{B,t-1}}{\left[(1-\phi-\gamma)\overline{q}_{AA} + \phi\eta^2_{A,t-1} + \gamma q_{AA,t-1}\right]^{1/2}\left[(1-\phi-\gamma)\overline{q}_{BB} + \phi\eta^2_{B,t-1} + \gamma q_{BB,t-1}\right]^{1/2}} \tag{6}$$

The parameters are estimated using the quasi-maximum likelihood method (QMLE) under the Gaussian assumption (Bollerslev and Engle, 1992). If $\rho_{AB,t} > 0$ during a period t, the real estates markets A and B are positively associated in terms of prices volatility. Although, the DCC-GARCH allows for detecting price volatility, it does not allow bubbles contagion consistently Orskaug (2009). This leads researchers to focus on a more recent non-parametric method using local kernel regressions developed by Greenaway-McGrevy and Phillips (2016).

3.3 Non-parametric model with time-varying coefficient for bubbles contagion

In order to analyse bubbles migration between Japan and its economic partners, we used the non-parametric regression with time-varying coefficient developed by Greenaway-McGrevy and Phillips (2016). Let us consider two markets, A and B. The non-parametric regression specified by Greenaway-McGrevy and Phillips (2016) is [4]:

$$\widetilde{\beta}_{B,t} = \delta_{t,T}\widetilde{\beta}_{A,t-d} + \epsilon_t \tag{7}$$

where $\widetilde{\beta}_{k,t} = \hat{\beta}_{k,t} - \frac{1}{T-w+1}\sum_{t=w}^{T}\hat{\beta}_{k,t}$.

The time-varying coefficient δ is estimated by local kernel regression such that:

$$\hat{\delta}(r;h,d) = \frac{\sum_{j=w+d}^{T} K_{hj}(r)\widetilde{\beta}_{B,j}\widetilde{\beta}_{A,j-d}}{\sum_{j=w+d}^{T} K_{hj}(r)\widetilde{\beta}^2_{A,j-d}} \tag{8}$$

where $K_{hj}(r) = \frac{1}{h}K(\frac{j/T-r}{h})$, $K(.) = (2\pi)^{-1/2}e^{-\dfrac{1}{2}(.)^2}$ is a Gaussian kernel, h is the bandwidth,

[4] Deng et al. (2017) notation.

r is the fraction date, and d is the lag.

4 Empirical Results

4.1 Bubble detection

The results of the GSADF test for price exuberance are presented in Table (3) for Japan, the United States, the Eurozone, and the United Kingdom. The test revealed an overall explosive behavior during the period 1970-2018 for all the markets. Bubble timelines are presented in Figures (2a), (2b), (2c) and (2d) for Japan, the United States, the Eurozone, and the United Kingdom, respectively. Figure (2a) shows that Japan experienced two bubbles from 1989Q1 to 1990Q4 and 2000Q2 to 2006Q4, with a peak at 2003Q4. For the markets of the United states, the Eurozone, and the United Kingdom, episodes of speculative bubbles have been observed as well. The results in Figure (2b) suggest that the real estate market of the United States contained bubbles during the periods of 1981Q2-1989Q3 and 1999Q2-2006Q2. The market of the Eurozone (Figure (2b)) also experienced three bubbles during the periods of 1988Q4-1990Q1, 1995Q3-1997Q4 and 2003Q1 to 2006Q4. In the United Kingdom, two bubble episodes have been observed from 1987Q4 to 1989Q3 and 1999Q3 to 2007Q4. For recent years, our results indicate that, the United States and the Eurozone are also entering bubble territory since 2017Q4 and 2018Q2 respectively, while the United Kingdom and Japan remains cool.

4.2 DCC-GARCH estimates

In this section, we present the DCC-Garch estimates of housing price volatility transmission between Japan and its partners. The DCC-GARCH correlations for pairs of markets are presented in Figure (3a) for Japan-Eurozone, Figure (3b) for Japan-United Kingdom, and Figure (3c) for Japan-United States.

Figure (3a) indicates that, the real estate markets of Japan and the United States exhibit a positive relationship among the prices volatilities before 1998Q2 except for the period 1988Q1 to 1991Q4. This implies that implies that increase in volatility in one price leads to increase in volatility of the other price during that period. The relationship has been negative between Japan and United State during the period 1998Q3 to 2007Q1. After 2007Q1, the connection varied over time with the larger part in the positive area. Overall, for most of the period studied except 1988Q1 to 1991Q4, We observed a positive association between the markets of Japan and USA in terms of housing prices volatility. The same picture is observed between Japan and the Eurozone (see Figure (3b)), where the prices volatility in the two markets have been positively correlated between 1983Q4 and 1999Q1. Since 2009Q2, the connection has fluctuated between positive and negative. For the pair Japan-United Kingdom (Figure (3c)) we observe that the correlation has been fluctuating between positive and negative, with a larger part in the positive area. Overall, the DCC-GARCH results suggest that prices volatility in the market of Japan were strongly connected to the markets of United States, the Eurozone, and the United Kingdom before the 2000s. In fact, this period corresponds with the economic rise of China, which has since become one of Japan's main economic partners. However, data on China were not sufficient to test for a connection between China and Japan. More data will be needed to test for this connection precisely.

4.3 Non-parametric model with time-varying coefficient estimates

In this section, we report the non-parametric time-varying coefficients of real estate bubbles contagion estimated from Greenaway-McGrevy and Phillips (2016) in Figure (4). Figure (4a) presents the housing price transmission between Japan and United States. We observe that the markets of Japan and the United States have been connected for the periods of 1970Q1 to 1994Q4, 1997Q1 to 2007Q4, and 2016Q2 to 2018Q4. The connection between Japan and the Eurozone (see Figure (4b)) presents an "M-shape". The two markets have been connected during the periods of 1989Q2 to 1996Q1 and 2001Q3 to 2010Q3, indicating that housing prices were transmitted during this period. In Figure (4c), the results indicate that the real estate markets of Japan and the United Kingdom are strongly connected over the entire period, suggesting housing price contagion between these markets over the period 1970-2018. Overall, these results suggest that the real estate market of Japan were connected to the markets of the United states, the Eurozone and the United

Kingdom over several periods.

5 Conclusion

In this paper, we used nationally representative housing price-to-rent ratios to identify episodic bubbles in the real estate market of Japan. We applied Phillips et al. (2015)'s GSADF test for explosive behavior detection. The results indicate that, overall, Japan's real estate market has been exuberant during the period 1970-2018. Analyzing the bubble timeline, we found that Japan has experienced two historical bubbles from 1989Q1 to 1990Q4 and 2000Q2 to 2006Q4, with a peak at 2003Q4. This result is consistent with the Bloomberg (2019) report, which indicates that Japan is currently at risk of a bubble. We also analyzed the housing price volatility and bubbles contagion between Japan and the United States, the Eurozone, and the United Kingdom using Engle (2002)'s DCC-GARCH model and Greenaway-McGrevy and Phillips (2016)'s non-parametric model with time-varying coefficient. Overall, the results suggest that the market of Japan has been connected to the United States, the Eurozone, and the United Kingdom during several periods from 1970 to 2018 in terms of housing price transmission. However, the intensity of the contagion has decreased after the 2000's. This period corresponds to the economic boom of China, which has become one of Japan's main economic partners. Unfortunately, due to lack of data, price contagion between the real estate markets of Japan and China were not addressed in this paper. For future research, more data will be needed to analyze the connection between these two markets, especially as Chinese interest in Japanese real estate market rises dramatically.

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Country	Minimum	Maximum	Mean	Sd	Kurtosis	Skewness
Japan	90,983	187,226	127,943	25,608	-0,929	0,274
United States	87,242	126,724	98,452	9,156	1,131	1,194
United Kingdom	48,394	115,279	74,570	20,337	-1,202	0,481

Table 1: *Descriptive statistics*

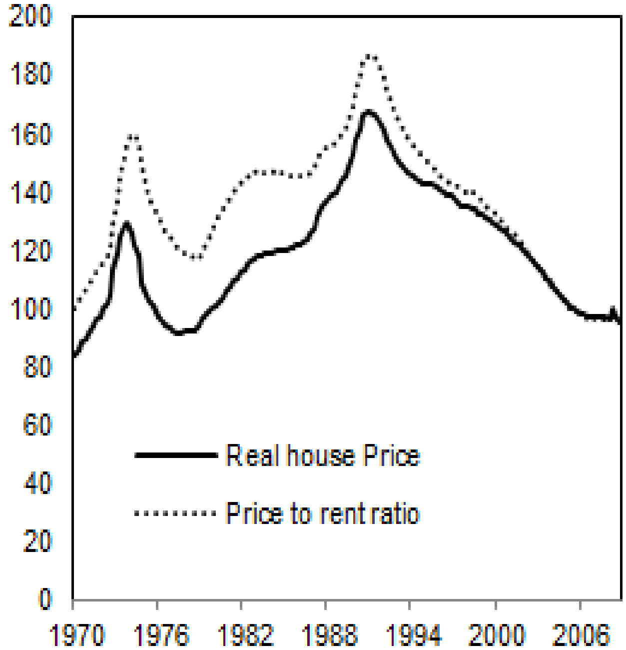
	ADF		PP		KPSS	
	statistic	p-value	statistic	p-value	statistic	p-value
Japan	-1,7165	0,4184	-2,4688	0,3799	0,6384	0,0191
United States	-0,7566	0,7749	-2,2639	0,4657	0,248	0,1
United Kingdom	0,0544	0,9591	-1,9695	0,5889	0,9359	0,01

Table 2: *Unit root and stationary test*

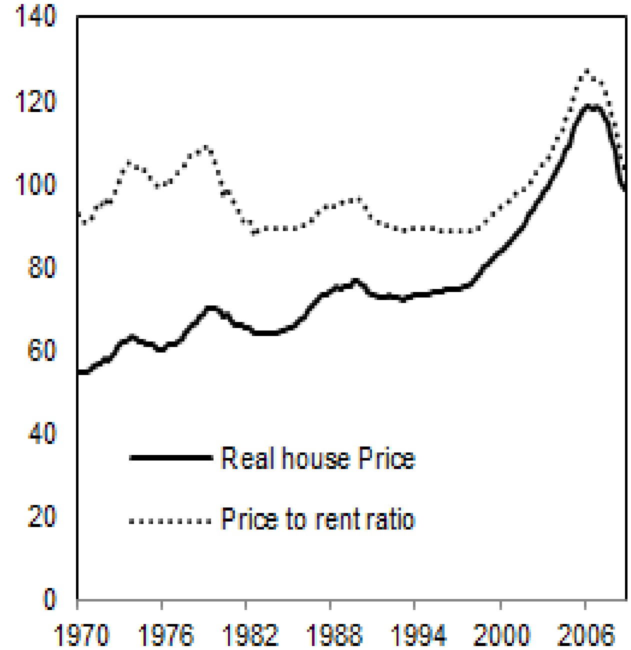
Country	Period	Optimal lags	GSADF	Interpretation
Japan	1970Q1-2018Q4	1	10,982***	Presence of bubble
United States	1970Q1-2018Q4	3	7,373***	Presence of bubble
Eurozone	1970Q1-2018Q4	5	3.346***	Presence of bubble
United Kingdom	1970Q1-2018Q4	1	3,83***	Presence of bubble

Table 3: *GSADF test for exuberance detection in Japan, United States, Eurozone, and United Kingdom*

Figure 1: *Real house price and price-to-rent ratios*



(a) *Japan*



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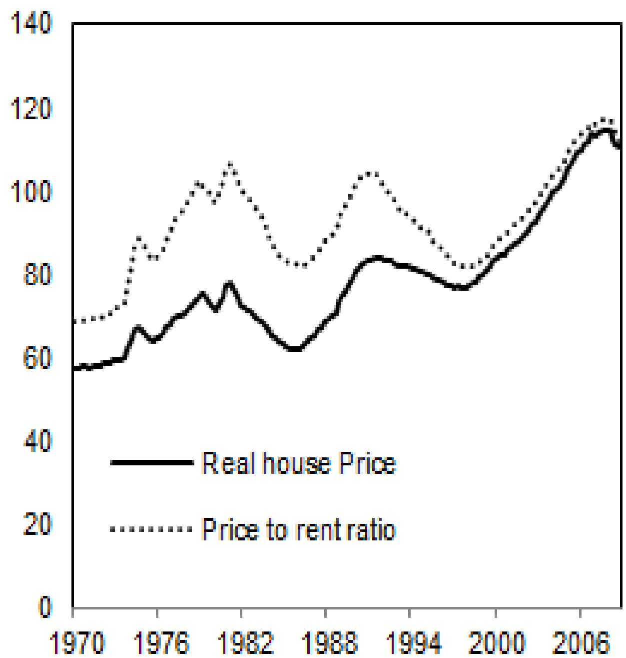

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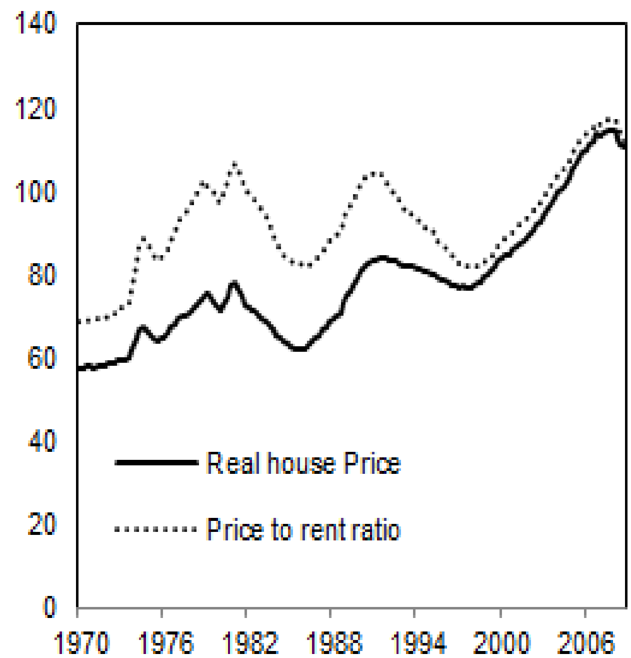
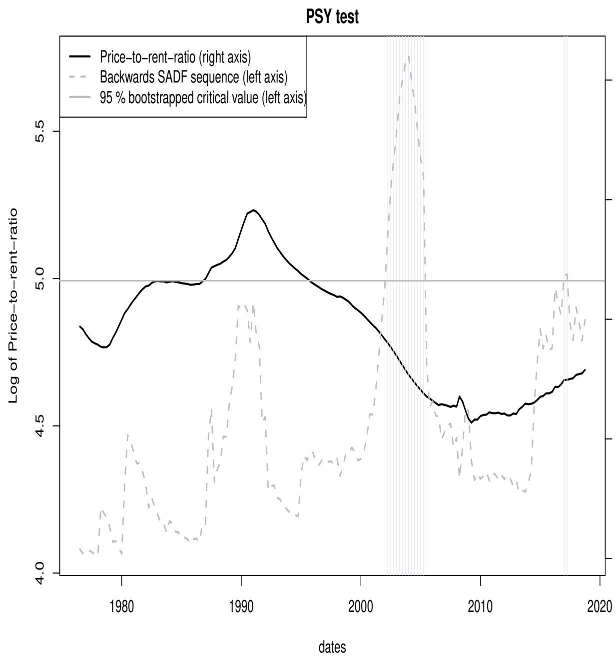
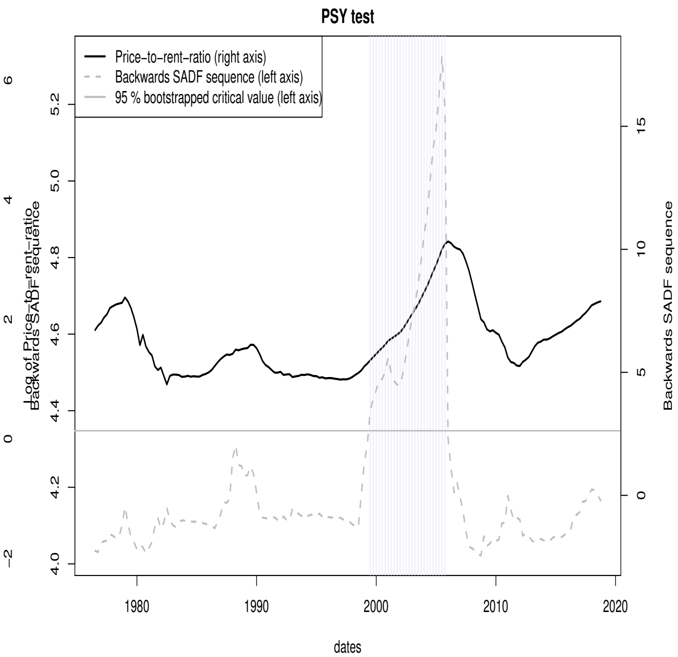


(d) *United Kingdom*

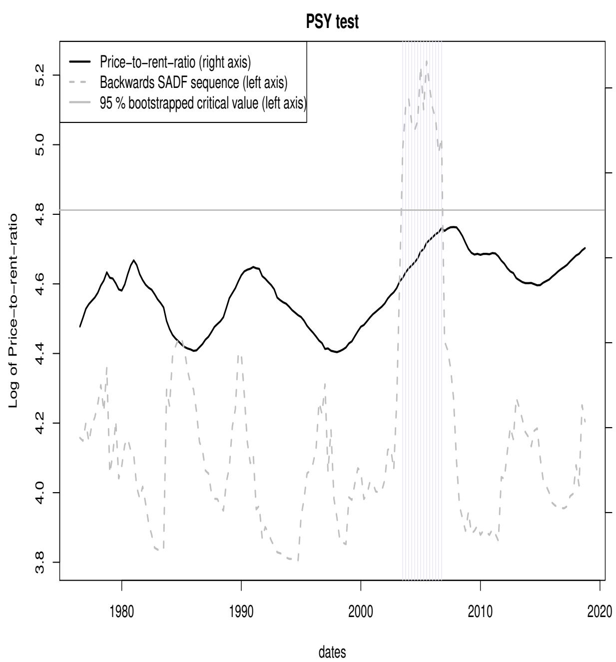
Figure 2: *Real estate bubble detection using GSADF*



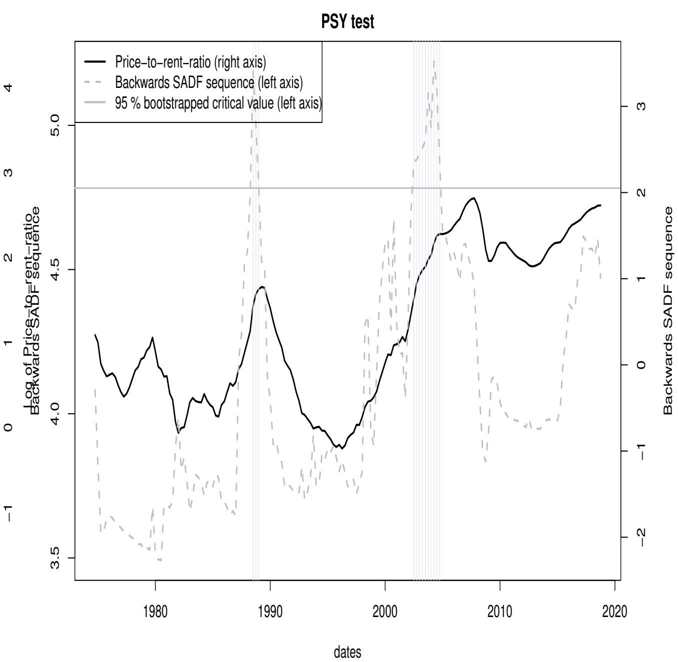
(a) *Japan*



(b) *United States*

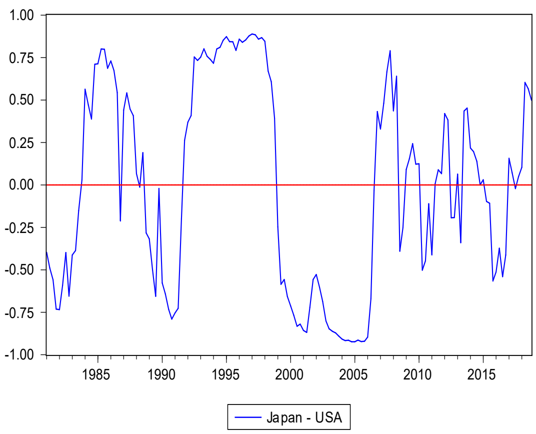


(c) *Eurozone*

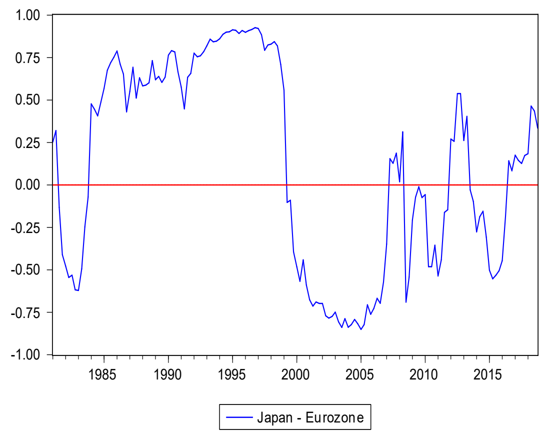


(d) *United Kingdom*

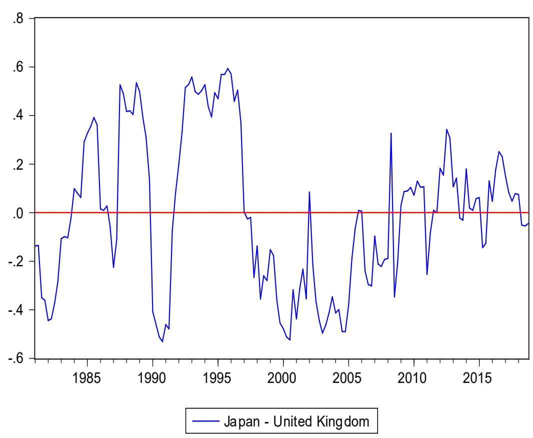
Figure 3: *Housing prices volatility spillover using DCC- GARCH model*



(a) *Japan - United States*

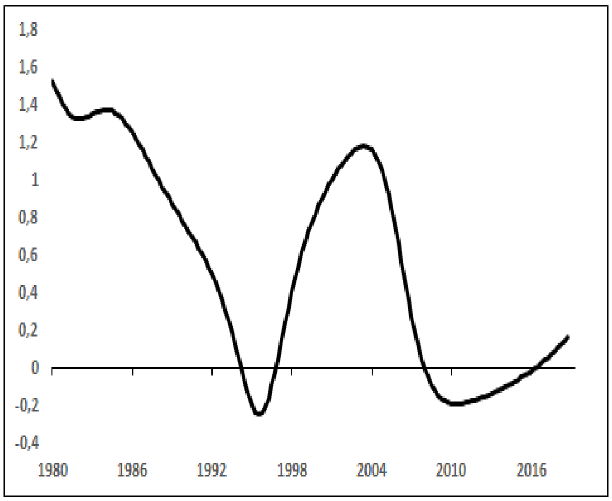


(b) *Japan - Eurozone*

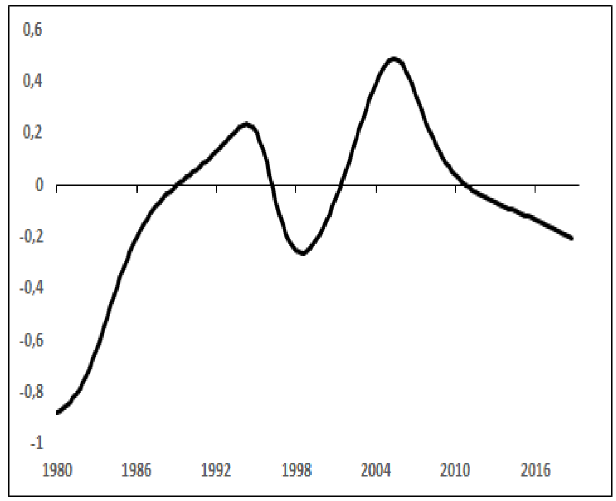


(c) *Japan - United Kingdom*

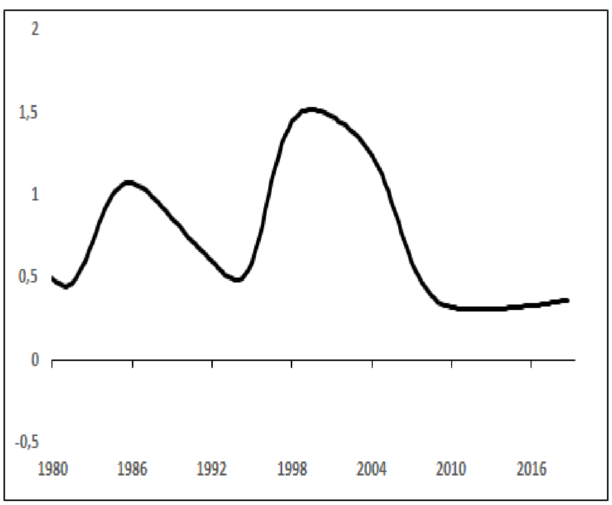
Figure 4: *Bubble contagion between Japan and its economic partners using non-parametric model*



(a) *Japan - United States*



(b) *Japan - Eurozone*



(c) *Japan - United Kingdom*