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I know what you did during the last bubble: Determinants of housing bubbles' duration in OECD countries[1]

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[1] *Disclaimer:* The views expressed in the paper are those of the authors and do not represent those of the Banco de la Republica or its Board of Directors.

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Abstract

We use hazard models to study the determinants of housing price bubbles' duration. We answer two related questions: i). Does prolonged domestic monetary policy easing increase the duration of housing price bubbles? And, ii). Does prolonged monetary policy easing in the US influences housing bubbles' duration in other OECD countries? Our results suggest that the answer to the first question is a clear yes, while the answer to the second question is an indirect yes. Other variables that are also good predictors of the duration of bubbles are GDP growth and the degree of financial market development. Bubbles in developed financial markets tend to last longer. Other institutional variables, such as loan-to-value caps and limits to banking leverage, population growth and the consumer confidence index, have no effect on the probability of ending a bubble. Our results have relevant policy implications.
JEL Classification*:*G01; G12; C22.
Keywords*: Housing bubbles; Bubble formation; Recursive right-tailed unit root tests; Duration; Hazard function; OECD.*

1 Introduction

The study of housing markets has recently regained interest in both academic and policy circles. Particularly, effort has been exerted in determining whether prices in different countries have increased at an unsustainable pace, fueling concerns about potential real estate bubbles. As these episodes are frequently followed by financial crises, it is important to study their formation process, as per they represent a significant risk for macroeconomic stability.

Since 2007 the world has experienced a period of unprecedented monetary policy easing. Initially this policy path involved only traditional interest rate instruments, but then it stretched to central banks' considerable balance sheet expansions through the purchase of bonds and other private assets. Although these were probably effective in preventing a worldwide stagnation, they gave way to fears over a possible build-up of global macroeconomic imbalances.

These facts lead to important questions regarding the interaction between monetary policy and the behavior of housing prices. While the literature on the optimal response of central banks to the occurrence of bubbles is ample (Bernanke and Gertler, 2001; Mishkin, 2009; Gambacorta and Signoretti, 2014, among many others), less attention has been given to the role of monetary policy easing on the formation of asset price bubbles. Papers in the tradition of the risk-taking channel of monetary policy (for instance, Altunbas et al., 2012; Amador-Torres et al., 2013; and, Dell'Ariccia et al., 2016) show that prolonged periods of expansionary monetary policy favor bank risk-taking attitudes. In a recent study, Cecchetti et al. (2017) extends these findings by showing that non-financial firms undertake higher risks as well when monetary policy eases. A few recent papers have mentioned that the large influx of global liquidity created by the quantitative easing measures adopted by the worlds' major central banks are among the main causes of housing bubbles formation in different countries (see, for instance, Brunnermeier and Schnabel, 2015; Blot et al., 2017).

Papers studying housing bubbles' formation have shown that there is vast heterogeneity in their duration (Pavlidis et al., 2016; Gomez-Gonzalez et al., 2017). Importantly, they show that bubbles occurring around the recent international financial crisis lasted significantly longer than those originated in the 1980s and 1990s. Studying what makes that some bubbles last longer than others is of great importance and has considerable policy implications, specially if monetary policy plays a significant role in duration.

In this paper we use a hazards model to study the determinants of housing price bubbles' duration. Our main emphasis is on answering two related questions: First, does prolonged monetary policy easing increase the duration of housing price bubbles? And, second, does prolonged monetary policy easing in the United States (US) influences housing bubbles' duration in other OECD countries?

We show that the answer to the first question is yes. The answer to the second question, however, is not clear-cut. We find there is no significant direct effect of the monetary policy stance in the US on the duration of bubbles in other countries. However, there might be indirect effects, as in a financially globalized environment there tends to be certain degree of monetary policy synchronization among countries (see, for example, Arouri et al., 2013).

Our contributions to the literature are two-fold. First, up to our knowledge this is the first paper to study the determinants of housing price bubbles' duration. In this sense, we provide important evidence identifying the main macroeconomic variables predicting the time of collapse of housing price bubbles. And second, our findings add to those of previous studies showing that monetary policy is not neutral to the building of financial and macroeconomic vulnerabilities. Particularly, the longer prices are propelled by monetary expansion, the longer the bubble will endure. This result is key for policy matters, as usually longer bubbles lead to larger macroeconomic imbalances and to harsher adverse effects after they burst (Cogley, 1999).

Section 2 describes the data used in the empirical analysis. Section 3 is methodological. Section 4 presents our main findings and the last section concludes.

2 Description of the data

Our main interest in this paper is to identify the determinants of the duration of housing price bubbles and to evaluate the role of monetary policy easing on duration. For doing so, we gather information on housing price bubbles occurring in a set of 20 OECD countries between 1970 and 2015, and on various macroeconomic variables that have been suggested in the literature as potentially related with the development of asset price bubbles, such as the growth rate of GDP, inflation and the cumulative current account balance as a proportion of GDP.

We also include a variable measuring the difference between the market short-term interest rate and the interest rate that should have prevailed if a conventional Taylor rule have been followed by each country's central bank (Taylor gap). A positive quantity in this variable indicates that monetary policy is being tighter than what it should have been according to a Taylor rule, while a negative quantity is indicative of monetary policy looseness.

We also incorporate the financial markets index obtained from the International Monetary Fund (IMF), considering access, depth and efficiency indicators of each country's financial market. We further include each country's stock price index, its population growth rate, its consumer confidence index and a proxy bank leverage. Finally, we add a set of institutional and house financial characteristics proposed by Cerutti, et al. (2015). In particular we use the maximum loan-to-value and the legal right index. We collect quarterly data on all the included variables.

Given our emphasis is not in detecting housing bubbles but rather in finding the determinants of their duration, we take as given those bubbles encountered by Pavlidis et al. (2016) and Gomez-Gonzalez et al. (2017) for a set of OECD countries. Both follow the recently developed bubble detection method of Phillips et al. (2011) and Phillips et al. (2015), which is arguably the most adequate and certainly the most frequently used by recent papers identifying asset price bubbles. Tables 1 and 2 show descriptive statistics for the data used in our empirical analysis. The former presents information on individual bubble duration. The latter presents descriptive statistics on the included covariates. Some interesting facts can be highlighted. First, note that all the countries included in our sample experienced at least one housing bubble between 1970.Q1 and 2015.Q4. Second, most countries present multiple bubbles. For instance, three countries (France, the Netherlands and Norway) present five housing bubbles each. All the other countries register at most three bubbles. Third, while only two housing bubbles are detected for the US, their duration is longer than those happening in other countries. Fourth, housing bubbles last longer around the recent international financial crisis than in other periods of time. Fifth, positive bubbles are more frequent than negative bubbles.[1] Finally, on average non-US countries have had short-term interest rates above those predicted by Taylor rules. On the contrary, short-term interest rate in the US have been on average lower that those corresponding to a simple Taylor rule.

Table 1. Bubbles and their duration

Country	Period	Number of Bubbles	Average Duration (Quarters)	Dates of Bubbles
United States	1970Q1-2015Q2	2	22	1981Q1 - 1982Q4, 1998Q2 - 2007Q1
Japan	1970Q1-2015Q2	2	16	2006Q2 - 2009Q1, 2010Q3 - 2015Q2
Germany	1970Q1-2015Q2	4	12.3	1989Q3 - 1990Q4, 2000Q2 - 2002Q1 (negative), 2006Q3 - 2009Q1 (negative), 2009Q3 - 2015Q2
France	1970Q1-2015Q2	5	9.8	1986Q3 - 1988Q3, 1991Q2 - 1992Q3 (negative), 1998Q4 - 2001Q4, 2003Q1 - 2006Q2, 2008Q1 - 2009Q3
Italy	1970Q1-2015Q2	3	10.3	1988Q3 - 1991Q1, 1993Q2 - 1994Q4, 2006Q4 - 2009Q4
United Kingdom	1970Q1-2015Q2	2	12	1988Q1 - 1989Q2, 1999Q2 - 2000Q3
Canada	1970Q1-2015Q2	1	30	2001Q4 - 2009Q1
Australia	1972Q1-2015Q2	2	10	1980Q1 - 1981Q2, 2000Q4 - 2004Q1
Belgium	1976Q2-2014Q4	3	20.7	1989Q1 - 1990Q4, 1998Q4 - 2001Q3, 2003Q2 - 2009Q3
Denmark	1970Q1-2015Q2	2	9.5	1981Q2 - 1982Q4, 2004Q3 - 2007Q2
Finland	1970Q1-2015Q2	3	8.7	1982Q4 - 1984Q4, 1987Q3 - 1989Q3, 2007Q3 - 2009Q2
Greece	1997Q1-2015Q2	1	9	2011Q3 - 2013Q3 (negative)
Ireland	1970Q1-2015Q2	2	10	Before 1975Q4, 1998Q2 - 2000Q3
Israel	1994Q1-2015Q2	3	16	2006Q2 - 2008Q4, 2009Q2 - 2011Q3
Netherlands	1970Q1-2015Q2	5	13.5	1976Q2 -1978Q1, 1984Q1 - 1987Q4, 1996Q4 - 2002Q2, 2008Q4 - 2010Q1, 2011Q4 - 2013Q4
Norway	1979Q1-2015Q2	4	14.7	1985Q3 - 1986Q4, 1989Q2 - 1991Q1 (negative), 1993Q2 - 2000Q3, 2006Q1 - 2008Q2
New Zealand	1970Q1-2015Q2	3	14.3	1981Q1 - 1982Q3, 1995Q4 - 1997Q3, 2002Q2 - 2009Q1
Spain	1971Q1-2015Q2	3	17.3	1986Q3 - 1988Q1, 1991Q4 - 1993Q4, 2000Q4 - 2009Q3
Sweden	1980Q1-2015Q2	3	7.3	1992Q1 - 1993Q2, 1999Q1 - 2001Q2, 2006Q3 - 2007Q4
Switzerland	1970Q1-2015Q2	4	8.5	1988Q2 - 1989Q3, 2001Q4 - 2004Q4, 2010Q2 - 2012Q1, 2012Q3 - 2014Q1
		Total	**Average Duration**	
		57	14	

[1] Negative bubbles refer to periods of an explosive behavior in the house price-to-rent ratio in moments in which this ratio is decreasing. Most negative bubbles occur after the subprime financial crisis of the US and are shorter than positive bubbles.

Table 2. Summary statistics for included covariates

	Mean	Max.	Min.	1st quartile	Median	3rd quartile	S.D.
GDP Growth (%)	4.89	23.74	-8.75	3.13	5.07	6.88	4.21
Inflation (%)	2.89	16.98	-1.22	1.55	2.37	3.46	2.47
Overnight Interest Rate (%)	4.22	19.10	-0.12	2.02	3.67	5.34	3.46
Taylor Rule Interest Rate (%)	3.59	16.89	-1.84	2.19	3.30	4.70	2.59
Taylor Gap (%)	0.31	10.33	-5.34	-1.36	0.16	1.75	2.42
U.S. Taylor Gap (%)	-0.27	5.49	-12.30	-1.98	-0.16	1.53	2.34
Government Debt to GDP Ratio (%)	67.46	249.11	11.89	39.40	58.16	74.59	45.49
Current Account to GDP Ratio (%)	0.37	5.54	-1.95	-0.62	0.28	0.99	1.29
Financial market index	59.86	100.00	10.22	40.79	64.01	80.01	24.09
Household debt to GNI (%)	131.18	324.64	35.91	95.20	124.62	153.67	55.36
Consumer confidence index	100.24	105.03	95.32	99.44	100.36	101.24	1.52
Banking leverage (%)	15.16	68.35	3.47	8.51	13.13	19.71	9.46
Legal rights index	7.19	10.00	3.00	6.00	7.00	9.00	1.68
Maximun LTV (%)	94.07	125.00	80.00	80.00	95.00	100.00	12.87
Time to maturity of mortgage debt (years)	24.18	45.00	15.00	20.00	20.00	30.00	6.53
Stock price index (2000Q1=100)	80.93	309.78	1.95	44.00	79.86	102.91	49.91
Population growth (%)	0.65	2.42	-1.79	0.34	0.56	0.96	0.58

Source: Authors' calculations.

3 Duration models for studying the duration of bubbles and non-parametric analysis

We use a hazard function model to study the duration of housing bubbles, from the moment they begin until the time in which they end. This approach generalizes the more common binary response (e.g., logit or probit) models by modelling not only if the bubble ended but also its duration - allowing a finer measurement of the effect of different variables on its rupture. Thus, duration models applied to this problem can provide answers to questions that are relevant both for macroeconomic and prudential policy, such as: how do macroeconomic variables relate with the duration of housing bubbles? Or, how does monetary policy affect the duration of bubbles? A model capable of answering those questions at a low cost can be very useful as an early warning model to identify potential vulnerabilities.

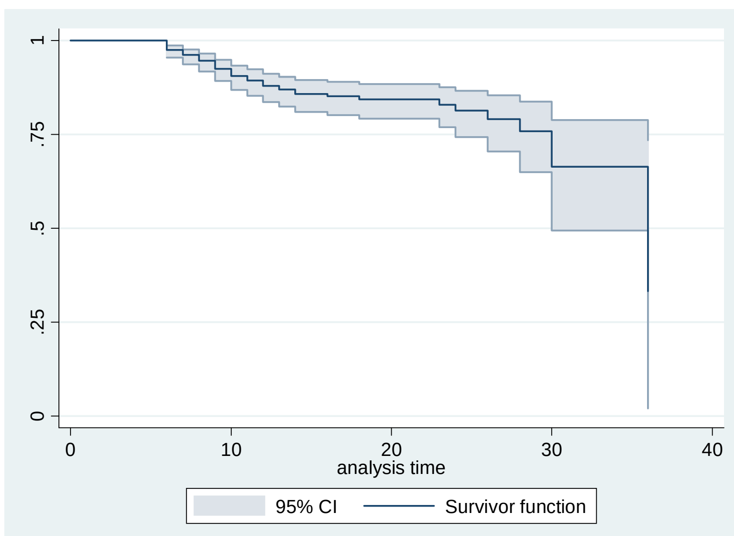
In duration models, the dependent variable is duration, the time that takes a system to change from one state to another. In our case, duration is the time that it takes for a bubble to end after it has been detected by the methodology described in Phillips et al. (2011) and Phillips et al. (2015).

In theory, duration T is a non-negative, continuous random variable. However, in practice, it is usually represented by an integer number of time periods, in our case quarters. When T can take a large number of integer values, it is conventional to model duration as being continuous.

Duration can be represented by its density function $f(t)$ or its cumulative distribution function $F(t)$, where $F(t) = Pr(T \leq t)$, for a given t. The survival function, which is an alternative way of representing duration, is given by $S(t) = 1 - F(t) = Pr(T > t)$. In words, the survival function represents the probability that the duration of an event is larger than a given t.

Figure 1 shows the Kaplan-Meier non-parametric estimated survival function for our data. Some interesting facts are observed. All bubbles last more than seven periods. Hence, the estimated probability of survival for $t\epsilon\{1, ..., 6\}$ is 1. There is high dispersion in durations, but ties can be observed in the data. For instance, various bubbles last exactly 30 periods. And, no bubble endures more than 9 years. Hence, the probability of survival drops to zero after 36 quarters.

Figure 1: Estimated Survival Function of Housing Bubbles



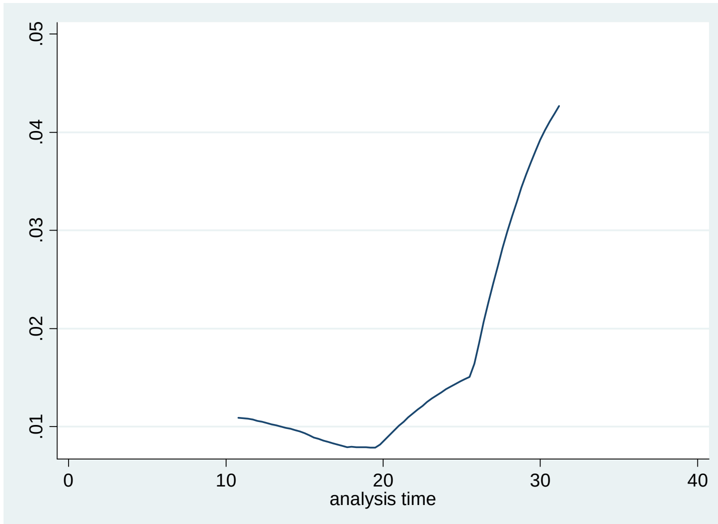
Now, the probability that a state ends between period t and $t + \Delta t$, given that it has lasted up to time t , is given by

$$\Pr\left(t < T \leq t + \Delta T > t\right) = \frac{(F(t+\Delta t) - F(t))}{S(t)} \tag{1}$$

This is the conditional probability that the state ends in a short time after t, provided it has reached time t. For example, in our case it is the probability that a bubble ends shortly after t. The hazard function $\lambda(t)$, which is another way of characterizing the distribution of T, results from considering the limit when $\Delta t \rightarrow 0$ of equation (1). This function gives the instantaneous probability rate that a change of state occurs, given that it has not happened up to moment t.

Fully parametric and semi-parametric models can be used for modeling the hazard function. The literature suggests using either simple parametric functions (e.g., exponential, Weibull or Gompertz) or easily interpretable semi-parametric (e.g., proportional hazards or accelerated life-time) models. Non-parametric analysis is useful in determining which way to follow. Figure 2 presents the estimated smoothed non-parametric hazard function for the duration of housing bubbles. An asymmetric Epanechnikov kernel function is used, and the bandwidth corresponds to the one that minimizes the mean quadratic error under our kernel choice. Note that it exhibits a non-monotonic behavior. However, as for most of the time the graph is monotonically increasing, we perform our estimations using two different modeling strategies. In the first we use a semi-parametric proportional hazards model and in the second we use a Weibull distribution with positive time-dependence.

Figure 2: Non-parametric smoothed hazard function



4 Estimation results

According to the non-parametric estimations reported above, we perform two alternative specifications of the hazard function. In the first a Weibull model is fitted and under the second a proportional hazards model is used. Under the first model, the hazard function takes the following representation:

$$\lambda(t) = \alpha\theta t^{\alpha-1}, \ \ (\alpha,\theta) >> 0 \tag{2}$$

where α is a parameter representing time-dependence,[2] and θ is parameterized exponentially ($\theta = \exp(X'\beta)$), with X standing for a matrix of individual characteristics and β being the corresponding vector of parameters. Table 3 presents estimation results for this empirical model. Six different estimations are reported. Each one of them includes a different combination of covariates. Some variables, however, are included in all six cases, namely GDP growth, inflation and the Taylor

[2] If $\alpha = 1$ the Weibull distribution collapses to the exponential distribution; if $\alpha < 1$ duration exhibits a negative time-dependence, and $\alpha > 1$ corresponds to positive time-dependence.

gap.

Table 3: Estimation results under Weibull model

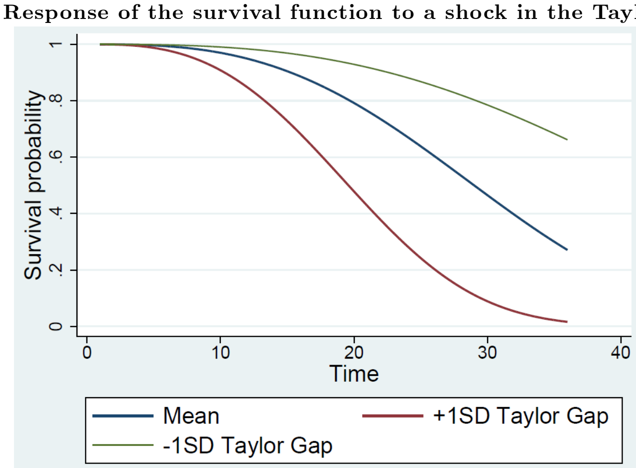
Variable	(1)	(2)	(3)	(4)	(5)	(6)
GDP growth	-0.263***	-0.259***	-0.219***	-0.175***	-0.232***	-0.144**
	(0.044)	(0.048)	(0.052)	(0.050)	(0.049)	(0.058)
Inflation	0.488***	0.495***	0.473***	0.317	0.384***	0.256**
	(0.114)	(0.111)	(0.146)	(0.192)	(0.129)	(0.125)
Taylor gap	0.475***	0.483***	0.404***		0.396***	0.359***
	(0.078)	(0.087)	(0.072)		(0.074)	(0.081)
US Taylor gap	-0.004	-0.005	0.068	0.231**	0.009	-0.013
	(0.076)	(0.075)	(0.084)	(0.118)	(0.078)	(0.083)
$\frac{\text{Current account}}{\text{GDP}}$	0.858***	0.857***	0.878***	0.766	0.956***	0.925***
	(0.126)	(0.127)	(0.127)	(0.148)	(0.150)	(0.115)
$\frac{\text{Government debt}}{\text{GDP}}$		0.001				
		(0.005)				
Negative bubble dummy			1.431**			
			(0.590)			
Financial Market Index					-0.029**	
					(0.013)	
Stock price						-0.022***
						(0.008)
Constant	-10.830***	-10.994***	-11.670***	-9.330	-9.090***	-8.948***
	(1.002)	(1.246)	(1.168)	(0.901)	(1.282)	(1.145)
α	2.932***	2.947***	3.168***	2.520***	3.106***	3.176***
	(0.275)	(0.289)	(0.319)	(0.239)	(0.314)	(0.301)
Wald test	79.18***	81.30***	99.09***	39.41***	83.87***	110.84***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Newey and West (1987) robust standard errors in parentheses. *, **, *** indicate statistical significance at 10%, 5% and 1%, respectively.

The value of α is greater than 2.5 in all cases. This implies that our Weibull distri-

bution exhibits positive time dependence; i.e., after controlling for the adequate set of covariates, the probability that a bubble ends increases over time.
Importantly, the monetary policy stance appears to influence the duration of bubbles. The tightening of monetary policy increases substantially the probability of ending a bubble at all times. Specifically, a one percent increase in the Taylor gap (100 basis points increase in the difference between the observed short-term interest rate and the one prescribed by the Taylor rule) increases in more than 40% the probability the bubble ends. Symmetrically, relaxation of the monetary policy has the effect of increasing the duration of bubbles. This effect is significant at the 1% level in all four specifications in which this covariate is included.
Figure 3 shows results of a sensitivity exercise in which the Taylore rule gap is changed in one standard deviation for the average positive bubble. It shows how the survival function changes as a shock to this variable happens. Note that a one standard deviation decrease in the gap reduces the probability of ending the bubble in approximately 50 percent after 35 time-periods. Also note that the effect is asymmetrical, as the response of the bubble duration to an increase in the Taylor gap is different than the response to a decrease in this variable.

Figure 3: Response of the survival function to a shock in the Taylor rule gap



Models (1), (2), (3), (5) and (6) include both the US Taylor gap and each countries' own gap. In these five models, the former appears to be statistically insignificant in explaining duration. However, when the own countries' gap is excluded from the regression (Model (4)), it matters statistically. The sign of this covariate is positive and statistically significant at the 1% level. This result shows that the US policy stance may matter for other countries, as in a financially globalized environment there tends to be certain degree of monetary policy synchronization (see Cecchetti et al., 2017).

Our results support that GDP growth affects bubble duration negatively. In other words, an increase in the rate of economic activity reduces the probability the bubble ends. Inflation risings increase the duration of bubbles. Additionally, Model (5) shows that the more developed the financial market, the lower the probability that a bubble bursts. Model (6) also accounts for synchronization between housing and stock markets, as it shows that increases in the financial markets index reduce the probability of ending the bubble. In other words, when the financial system is growing as a whole the conditions are set to inflating asset prices further. Interestingly, our results indicate that, all else equal, negative bubbles are shorter than positive bubble. It is important to highlight that institutional variables, such as loan-to-value caps and limits to banking leverage, population growth and consumer confidence index, have no effects on bubbles' termination. These results indicate that once a bubble begins, differences in the institutional environment do not make difference in the observed times to collapse.

Regarding the semiparametric model, Table 4 reports estimation results when using the proportional hazards model of Cox (1972). Econometric results are qualitatively identical to those reported above. Hence, they show that our main findings are quite robust to different specifications of the hazard rate.

Table 4: Estimation results under Cox proportional hazard model

Variable	(1)	(2)	(3)	(4)	(5)	(6)
GDP growth	-0.257***	-0.259***	-0.220***	-0.176***	-0.225***	-0.150***
	(0.037)	(0.044)	(0.045)	(0.043)	(0.041)	(0.046)
Inflation	0.521***	0.519***	0.499***	0.378*	0.384***	0.294***
	(0.099)	(0.097)	(0.111)	(0.175)	(0.113)	(0.099)
Taylor gap	0.458***	0.455***	0.405***		0.349***	0.341***
	(0.086)	(0.093)	(0.079)		(0.074)	(0.087)
US Taylor gap	0.026	0.026	0.076	0.251**	0.035	0.033
	(0.073)	(0.074)	(0.077)	(0.104)	(0.070)	(0.082)
$\frac{\text{Current account}}{\text{GDP}}$	0.815***	0.817***	0.810***	0.778***	0.970***	0.883***
	(0.116)	(0.119)	(0.118)	(0.155)	(0.158)	(0.105)
$\frac{\text{Government debt}}{\text{GDP}}$		-0.001				
		(0.005)				
Negative bubble dummy			0.973**			
			(0.538)			
Financial Market Index					-0.039***	
					(0.015)	
Stock price						-0.024***
						(0.006)
Wald test	91.61***	92.18***	91.60***	38.88***	75.38***	113.1***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Newey and West (1987) robust standard errors in parentheses. *, **, *** indicate statistical significance at 10%, 5% and 1%, respectively.

5 Conclusions

In this paper we use hazard models to study the determinants of housing price bubbles' duration. Our main goal is answering two related, policy-relevant, questions: First, does prolonged domestic monetary policy easing increase the duration of housing price bubbles? And, second, does prolonged monetary policy easing in

the US influence housing bubbles' duration in other OECD countries?
Our results suggest that the answer to the first question is a clear yes, while the answer to the second question is an indirect yes. On the one hand, increases in the gap between the policy rate and the interest rate implied by a simple Taylor-type rule lead to higher chances of ending a housing bubble. This result holds both for sensible parametric and semiparametric specifications of the hazard function and are robust to different control variables. On the other hand, while in general the US Taylor rule gap does not dignificantly influence the probability of ending a bubble in other OECD countries after controling for their own Taylor rule gap, it matters in specifications in which the latter is excluded. This result suggests that in a financially globalized environment certain degree of monetary policy synchronization is observed among countries (see, for example, Arouri et al., 2013).
Other variables are also good predictors for the duration of bubbles. For instance, GDP growth affects bubble duration negatively. Similarly, bubbles in more developed financial markets tend to last longer. Negative bubbles, i.e. exponential decreases in the price-to-rent ratio, are on average shorter than positive bubble. Institutional variables, such as loan-to-value caps and limits to banking leverage, population growth and consumer confidence index, have no effects on bubbles' termination. These results indicate that once a bubble begins, differences in the institutional environment do not make difference in the observed times to collapse.

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