Increased Real House Price Volatility Signals Break from Great Moderation: Appendix[*]

Adrienne Mack and Enrique Martínez-García
Federal Reserve Bank of Dallas

Current Draft: January 9, 2012

[*] We would like to thank Nathan Balke, Jim Dolmas, María Teresa Martínez García, Anthony Murphy, and Mark A. Wynne for comments on either the current or previous drafts. We also acknowledge the OECD for providing a description of their own house price data and the assistance of many national statistical offices and/or central banks in collecting all our series. We are also greatly indebted to the routines made available by Kim and Nelson (1999). All remaining errors are ours alone.

Appendix: Sources of house price index data

	House price definition	Source
Australia	Weighted average of 8 capital cities, new and existing detached house price index, per dwelling	Australia Bureau of Statistics 1986Q3-2010Q4
	Weighted average of 6 capital cities, new and existing dwelling price index, per dwelling	Australian Treasury 1960Q3-2010Q4
Belgium	Nationwide existing single-family house price index, per dwelling	Statistics Belgium 1973Q1-2010Q4
Canada	Nationwide average price of existing dwellings, per dwelling	Canadian Real Estate Association 1980M1-2010M12 1974-2010 (annual)
Switzerland	Nationwide new and existing single-family house price index, per dwelling	Swiss National Bank 1970Q1-2010Q4
Germany	Nationwide existing terraced house price index, per dwelling	Deutsche Bundesbank 1995-2010 (annual)
	W. Germany existing terraced house price index, per dwelling	Deutsche Bundesbank 1990-2010 (annual)
	W. Germany new terraced house price index, per dwelling	Deutsche Bundesbank 1975-2010 (annual)
Denmark	Nationwide new and existing single-family house price index, per dwelling	Statistics Denmark (BIS) 1971Q1-2010Q4
Spain	Nationwide average price of existing dwellings per square meter	Ministerio de Fomento 1995Q1-2010Q4
	Nationwide average price of new and existing dwellings, per square meter	Ministerio de Vivienda 1987Q1-2004Q4
	Madrid average price of new dwellings, per square meter	Tecnigrama 1976-1986 (annual)
Finland	Nationwide existing single-family house price index, per square meter	Statistics Finland 1985Q1-2010Q4
	Nationwide existing apartment price index, per square meter	Statistics Finland 1970Q1-2009Q4

France	Nationwide existing detached house and apartment price index, per dwelling	INSEE 1996Q1-2010Q4
	Nationwide existing apartment price index, per dwelling	CEGDD - Ministère de l'Écologie 1936-2009 (annual)
U.K	Nationwide new and existing dwelling price index, per dwelling	Department of Communities and Local Government 1968Q2-2010Q4
Ireland	Nationwide average price of existing dwellings, per dwelling	Department of Environment, Heritage and Local Government 1978Q1-2010Q4 1974-2009 (annual)
Italy	13 Main metropolitan area average price of new and existing dwellings, per square meter	Nomisma 1988S1-2010S2
	13 Main metropolitan area average price of new dwellings, per square meter	Il Consulente Immobiliare 1967-2001(bi-annual) 2002-2009(annual)
Japan	Nationwide urban residential land price index, per square meter	Japan Real Estate Institute 1955S1-2010S2
S. Korea	Nationwide new and existing dwelling price index, per dwelling	Kookmin Bank 1986M1-2010M12
	Kyung-Hwan Kim (1993) index:	
	- Nationwide quoted transactions and estimations of real estate agents	Korea Housing Bank 1982-1990 (annual)
	- Nationwide standard construction costs (excluding land)	Korea Housing Bank 1978-1981 (annual)
	- Nationwide weighted average of total factor costs for single-family house and apartment construction	Korea Housing Bank 1974-1977 (annual)
Netherlands	Nationwide existing single-family house price index, per dwelling	Statistics Netherlands 1995M1-2010M12
	Nationwide average price of existing dwellings, per dwelling	Kadaster 1976M1-2010M12

Norway	Nationwide new and existing detached house price index, per dwelling	Statistics Norway 1992Q1-2010Q4
	Norges Bank forecasting model index:	
	- Nationwide sales reports of Norges Eindomsmeglerforbund real estate agents	Norges Eindomsmeglerforbund 1987Q1-2003Q4
	- Dwelling price based on national property register	GAB Register 1984Q1-1986Q4
	- Nationwide building cost index	Statistics Norway 1979Q1-1983Q4
	- Housing rent component of the Consumer Price Index	Statistics Norway 1972Q1-1978Q4
New Zealand	Nationwide new and existing detached house price index, per dwelling	Reserve Bank of New Zealand 1962Q2-2010Q4
Sweden	Nationwide new and existing one- and two-family house price index, per dwelling	Statistics Sweden 1986Q1-2010Q4 1975-2010 (annual)
United States	Nationwide existing single-family house price index, per dwelling	FHFA 1975Q1-2010Q4

Note: Kyung-Hwan Kim (1993): "Housing Prices, Affordability, and Government Policy in Korea." Journal of Real Estate Finance and Economics 6 (1), pp. 55-71.
Note: All data used in our econometric analysis was last revised/updated during the second quarter of 2011. Most of the time series employed in our investigation correspond with the public sources made available through the Federal Reserve Bank of Dallas' international house price database. Only in the cases of Canada and Denmark, the country data used to compute the OECD-19 aggregate has been obtained from alternative national data sources.

Appendix: A univariate AR(p) model with a two-state Markov-switching mean-variance of the first-difference of real house prices and real GDP (in logs)

$$
\begin{aligned}
&\left(y_t - \mu_{S_t}\right) = \sum_{k=1}^{p} \phi_k \left(y_{t-k} - \mu_{S_{t-k}}\right) + \varepsilon_t, \\
&\varepsilon_t - N\left(0, \sigma^2_{S_t}\right), \\
&\mu_{S_t} = \mu_1 S_{1t} + (\mu_1 + \mu_d) S_{2t}, \mu_d \equiv \mu_2 - \mu_1, \\
&\sigma^2_{S_t} = \sigma^2_1 S_{1t} + \left(\sigma^2_1 + \sigma_p\right) S_{2t}, \sigma_p \equiv \sigma^2_2 - \sigma^2_1, \\
&S_{jt} = 1 \text{ if } S_t = j, \ S_{jt} = 0 \text{ otherwise}, \ j = 1,2, \\
&p_{ij} = \Pr(S_t = j | S_{t-1} = i), \ \sum_{j=1}^{2} p_{ij} = 1.
\end{aligned}
$$

The first difference in logs of each series is annualized and expressed in percentages for the estimation. We do not model spillovers between the dynamics of any of the series we investigate, postulating what is essentially a univariate model specification for each one of them. The model collapses to a plain-vanilla AR(p) process with a common mean and variance whenever $\mu_d = 0$ and $\sigma_p = 0$. For each series, we consider all possible specifications with at most p=6 lags and with either one or two mean-variance states (or regimes). We select the best specification in every case using the Akaike information criterion. We report the Maximum Likelihood estimates of the preferred models for each series in Tables 1.A and 1.B—including two regimes in every case—and we compare them against their natural counterparts under the assumption of a common mean and a common variance. We summarize the selection results based on the Akaike information criterion in Table 2.

Table 1.A

Maximum Likelihood Estimates of an AR(p) Model with a Markov-Switching Mean-Variance for the First-Difference (in Logs) of Real House Prices and Real GDP (OECD-19, Quarterly: 1975Q1-2010Q4)

	OECD-19 Real House Price Growth			
Parameters	Two States		One State	
p_{11}	0.9564	(0.0389)***	--	--
p_{21}	0.0151	(0.0190)	--	--
ϕ_1	0.5698	(0.0860)***	0.6025	(0.8688)***
ϕ_2	0.1740	(0.1083)*	0.1272	(0.1016)
ϕ_3	0.2827	(0.1119)**	0.2753	(0.0999)***
ϕ_4	-0.2075	(0.0963)**	-0.1524	(0.1232)
ϕ_5	0.0737	(0.0883)	-0.0057	(0.1435)
σ_1^2	0.6412	(0.1758)***	2.9763	(0.3583)***
$\sigma_2^2 - \sigma_1^2$	3.3765	(0.6446)***	--	--
μ_1	2.3553	(1.3154)*	1.0597	(0.9621)
$\mu_2 - \mu_1$	-0.9225	(1.0651)	--	--
Log likelihood		-261.53		-271.07
Akaike (AIC) criterion		3.9498		4.0300
Expected duration of state 1		22.94 quarters	--	--
Expected duration of state 2		66.29 quarters	--	--
	OECD-19 Real GDP Growth			
Parameters	Two States		One State	
p_{11}	0.9249	(0.0368)***	--	--
p_{21}	0.0751	(0.0368)**	--	--
ϕ_1	0.3437	(0.1123)***	0.4067	(0.0839)***
ϕ_2	0.1542	(0.0909)*	0.0987	(0.0903)
ϕ_3	-0.1303	(0.0823)	-0.0475	(0.0904)
ϕ_4	0.0348	(0.0753)	0.0289	(0.0850)
σ_1^2	1.8092	(0.4401)***	5.8996	(0.7077)***
$\sigma_2^2 - \sigma_1^2$	13.6868	(4.3456)***	--	--
μ_1	3.0065	(0.2702)***	2.6431	(0.4022)***
$\mu_2 - \mu_1$	-1.1548	(1.0525)	--	--
Log likelihood		-298.27		-320.59
Akaike (AIC) criterion		4.4356		4.6991
Expected duration of state 1		13.32 quarters	--	--
Expected duration of state 2		13.32 quarters	--	--

Sources: Haver Analytics, OECD Economic Outlook 89 Database, National Sources and Authors' Calculations.

Note: The individual country sources are detailed in the Table "sources of house price index data" and the Federal Reserve Bank of Dallas International House Price Database. The first-differences in logs are annualized for our estimation. Standard errors are in parentheses. One asterisk indicates the point estimate is significant at the 90% confidence level. Two asterisks indicate it is significant at the 95% confidence level. Three asterisks indicate it is significant at the 99% confidence level. The expected duration of each state is computed from the point estimates of the transition probabilities as $\frac{1}{1-p_{jj}}$ for each j=1,2.

Table 1.B
Maximum Likelihood Estimates of an AR(p) Model with a Markov-Switching Mean-Variance for the First-Difference (in Logs) of Real House Prices and Real GDP (U.S., Quarterly: 1975Q1-2010Q4)

	U.S. Real House Price Growth			
Parameters	Two States		One State	
p_{11}	0.9787	(0.0180)***	--	--
p_{21}	0.0165	(0.0213)	--	--
ϕ_1	0.5355	(0.0851)***	0.5409	(0.0864)***
ϕ_2	-0.0586	(0.0936)	-0.1670	(0.1001)*
ϕ_3	0.3297	(0.1026)***	0.4083	(0.0993)***
ϕ_4	-0.2184	(0.1167)*	-0.1690	(0.1006)*
ϕ_5	0.0014	(0.0774)	0.0723	(0.1001)
ϕ_6	0.2454	(0.0779)***	0.1727	(0.0886)*
σ_1^2	3.4025	(0.6217)***	10.1554	(1.2270)***
$\sigma_2^2 - \sigma_1^2$	16.6403	(4.0297)***	--	--
μ_1	2.3553	(1.3154)*	0.5062	(2.1134)
$\mu_2 - \mu_1$	-1.3396	(2.0588)	--	--
Log likelihood		-336.93		-353.18
Akaike (AIC) criterion		5.0939		5.2727
Expected duration of state 1		46.99 quarters	--	--
Expected duration of state 2		60.66 quarters	--	--
	U.S. Real GDP Growth			
Parameters	Two States		One State	
p_{11}	0.9682	(0.0246)***	--	--
p_{21}	0.0318	(0.0246)	--	--
ϕ_1	0.2346	(0.0903)***	0.3246	(0.0832)***
ϕ_2	0.2471	(0.0890)***	0.1176	(0.0832)
σ_1^2	3.3890	(0.6031)***	8.7483	(1.0419)***
$\sigma_2^2 - \sigma_1^2$	20.055	(6.2097)***	--	--
μ_1	3.1378	(0.3730)***	2.8231	(0.4466)***
$\mu_2 - \mu_1$	-1.9506	(1.6534)	--	--
Log likelihood		-333.08		-320.59
Akaike (AIC) criterion		4.8380		5.0635
Expected duration of state 1		31.48 quarters	--	--
Expected duration of state 2		31.48 quarters	--	--

Sources: Haver Analytics, OECD Economic Outlook 89 Database, National Sources and Authors' Calculations.
Note: The individual country sources are detailed in the Table "sources of house price index data" and the Federal Reserve Bank of Dallas International House Price Database. The first-differences in logs are annualized for our estimation. Standard errors are in parentheses. One asterisk indicates the point estimate is significant at the 90% confidence level. Two asterisks indicate it is significant at the 95% confidence level. Three asterisks indicate it is significant at the 99% confidence level. The expected duration of each state is computed from the point estimates of the transition probabilities as $\frac{1}{1-p_{jj}}$ for each j=1,2.

Table 2
Akaike Statistics for Model Selection of an AR(p) Model with a Markov-Switching Mean-Variance for the First-Difference (in Logs) of Real House Prices and Real GDP (OECD-19 & U.S., Quarterly: 1975Q1-2010Q4)

OECD-19 Real House Price Growth						
	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	AR(6)
One State	4.0634	4.037	4.0279	4.0229	4.0300	4.0524
Two States	4.0329	3.9736	3.9596	3.9498	3.9498••	3.9704
OECD-19 Real GDP Growth						
	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	AR(6)
One State	4.6802	4.6816	4.7004	4.6991	4.7161	4.7363
Two States	4.4602	4.4502	4.4489	4.4356••	4.4417	4.4622
U.S. Real House Price Growth						
	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	AR(6)
One State	5.4492	5.4497	5.3162	5.3289	5.2791	5.2727
Two States	5.254	5.2496	5.1634	5.1652	5.1213	5.0939••
U.S. Real GDP Growth						
	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	AR(6)
One State	5.0676	5.0635	5.084	5.0844	5.1032	5.1223
Two States	4.8719	4.8380••	4.842	4.8385	4.8531	4.8677

Sources: Haver Analytics, OECD Economic Outlook 89 Database, National Sources and Authors' Calculations.
Note: The individual country sources are detailed in the Appendix Table "sources of house price index data" and the Federal Reserve Bank of Dallas International House Price Database. We use a pair of bullets to indicate the model selected for each variable given that it attains the lowest Akaike (AIC) criterion value among all the specifications considered.