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House Price Synchronicity, Banking Integration, and Global Financial Conditions

by Adrian Alter, Jane Dokko, Dulani Seneviratne

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Abstract

We examine the relationship between house price synchronicity and global financial conditions across 40 countries and about 70 cities over the past three decades. The role played by cross-border banking flows in residential property markets is examined as well. Looser global financial conditions are associated with greater house price synchronicity, even after controlling for bilateral financial integration. Moreover, we find that synchronicity across major cities may differ from that of their respective countries', perhaps due to the influence of global investors on local house price dynamics. Policy choices such as macroprudential tools and exchange rate flexibility appear to be relevant for mitigating the sensitivity of domestic housing markets to the rest of the world.

JEL Classification Numbers: E30, F42, F44

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ABSTRACT 2

I. INTRODUCTION 5

II. DATA AND MEASUREMENT 8
A. House Price Gap Synchronicity 8
B. Business Cycle Synchronicity 9
C. Bilateral Banking Integration 9
D. Global Financial Conditions 10
E. Other Controls 10

III. COUNTRY-LEVEL ANALYSIS 11
A. Empirical Strategy 11
B. Results 12
C. Robustness Checks 13

IV. CITY-LEVEL ANALYSIS 18
A. Network Analysis: House Price Interconnectedness at City Level 19
B. Empirical Strategy 19
C. Results 19

V. EXTENSIONS: THE IMPACT OF MACROPRUDENTIAL POLICIES 23
A. Empirical Strategy 23
B. Results 24

VI. CONCLUSIONS 26

REFERENCES 27

FIGURES
1. House Price Gap Synchronicity Across Countries and Cities 6
2. House Price Synchronicity and Transmission of External Shocks 7
3. Impact of Global Financial Conditions on House Price Synchronization 13
4. House Price Interconnectedness Among Countries vs. Cities 18
5. Average House Price Growth and Demand-side Macroprudential Policies 24
6. Impact of Macroprudential Measures on House Price Synchronicity 25

TABLES
1. House Price Gap Synchronicity at Country Level and Global Factors 15
2. House Price Gap Synchronicity at Country Level and Global Factors—Robustness Checks: Global Factors 16
3. House Price Gap Synchronicity at Country Level and Global Factors—Robustness Checks: Additional Controls 16
4. House Price Gap Synchronicity at Country Level and Global Factors—Robustness Checks: Clustering of Standard Errors 17

5. House Price Gap Synchronicity at City Level and Global Factors—Two-Way Clustering 21
6. House Price Gap Synchronicity at City Level and Global Factors—Multi-Way Clustering 22

ANNEXES

I. Data Sources, Coverage, and Summary Statistics 31
II. Alternative Measures of House Price Synchronicity 35
III. Methodology—House Price Interconnectedness Analysis 40
IV. Impact of Macroprudential Measures on House Price Synchronicity—Regression Results 41

I. INTRODUCTION

As global liquidity surged owing to accommodative financial conditions, house prices across advanced and emerging market economies have experienced greater synchronicity. IMF (2018a) finds that nearly 80 percent of countries and cities within a broad set of developed economies have experienced positive house price growth rates in the past decade, while this figure is over 60 percent for emerging market economies and cities. Moreover, over time, median synchronicity in house price gaps—measured by extracting the cyclical component of real house prices—has steadily increased over time across countries and cities (Figure 1).[2]

House price synchronicity is of particular interest given that greater comovement in house prices could amplify the propagation of external shocks. These shocks could be directly transmitted to the domestic economy through channels such as portfolio, balance sheet, and liquidity, or indirectly through risk premium and confidence channels (Allen and Gale 2000; Longstaff 2010). Simultaneous changes in mortgage rates due to global financial conditions could lead to greater house price synchronicity, thus propagating shocks to aggregate demand when financial conditions tighten sharply. At the same time, an increase in global demand for safe assets may compress sovereign spreads where risk is perceived to be low, thereby pushing down mortgage rates and supporting house price booms in those countries (Bernanke et al. 2011). For instance, foreign capital may be a driver of residential property markets in global cities such as London, New York, or Tokyo, especially during "flight to safety" episodes (Badarinza and Ramadorai 2018). In addition, as illustrated in Figure 2, asset managers may rebalance their portfolios to mitigate their losses, thus resulting in dwindling equity price returns (i.e., portfolio channel); this impact could be further amplified due to asset classes such as REITS. In addition, an exogenous shock to house prices may lead to asset fire sales and deleveraging that would result in declining collateral values and hindering the availability of credit in the economy (i.e., bank balance sheet channel). An exogenous shock could also heighten the rollover risk as investors suffering losses may find it difficult to obtain further financing opportunities, thereby affecting the aggregate demand (i.e., liquidity channel). A shock to the financial system in one country could also result in elevated risk premia in other countries, therefore affecting the aggregate demand through indirect channels (i.e., risk premium/confidence channel).

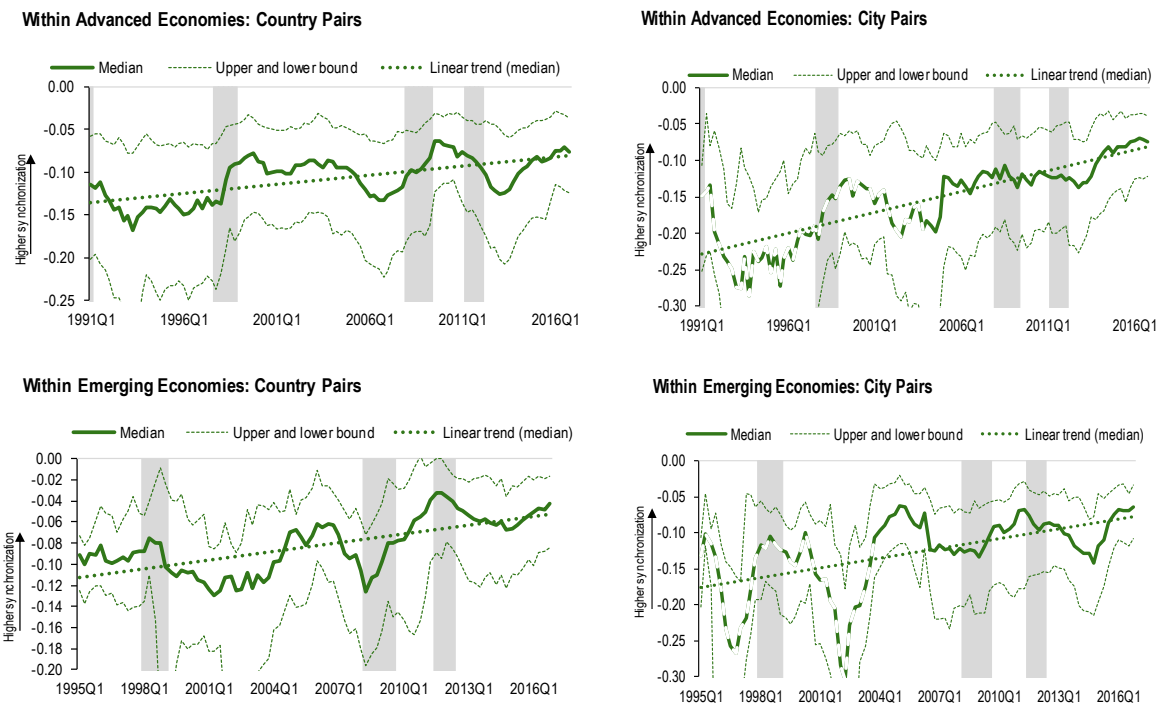
Even though housing is a non-tradable asset, Claessens et al. (2011a)—echoing past research such as Terrones (2004)—points out the presence of high synchronicity in their sample of countries, partially reflecting the importance of global factors such as global interest rates,

[2] See IMF (2018a) for a detailed discussion on trends in house prices across countries and cities. House price synchronicity measures are presented in detail in section II and Annex II.

U.S. business cycles, and global commodity prices. In the same spirit, Hirata et al. (2012) allude to the role of global integration of housing markets across advanced and emerging market economies as a determinant of house price synchronicity.[3]

Nevertheless, house price synchronicity may also be reflective of the co-movement in economic cycles (in other words, due to business cycle synchronicity). Claessens et al (2011b) notes that business cycles are highly synchronized with house price cycles. Indeed, past research has identified bilateral financial and trade linkages as two possible determinants of business cycle synchronicity between countries (IMF 2013; Kalemli-Ozcan et al. 2013a, 2013b; Duval et al 2016).

Figure 1. House Price Gap Synchronicity Across Countries and Cities
(Closer to zero denotes higher synchronicity)



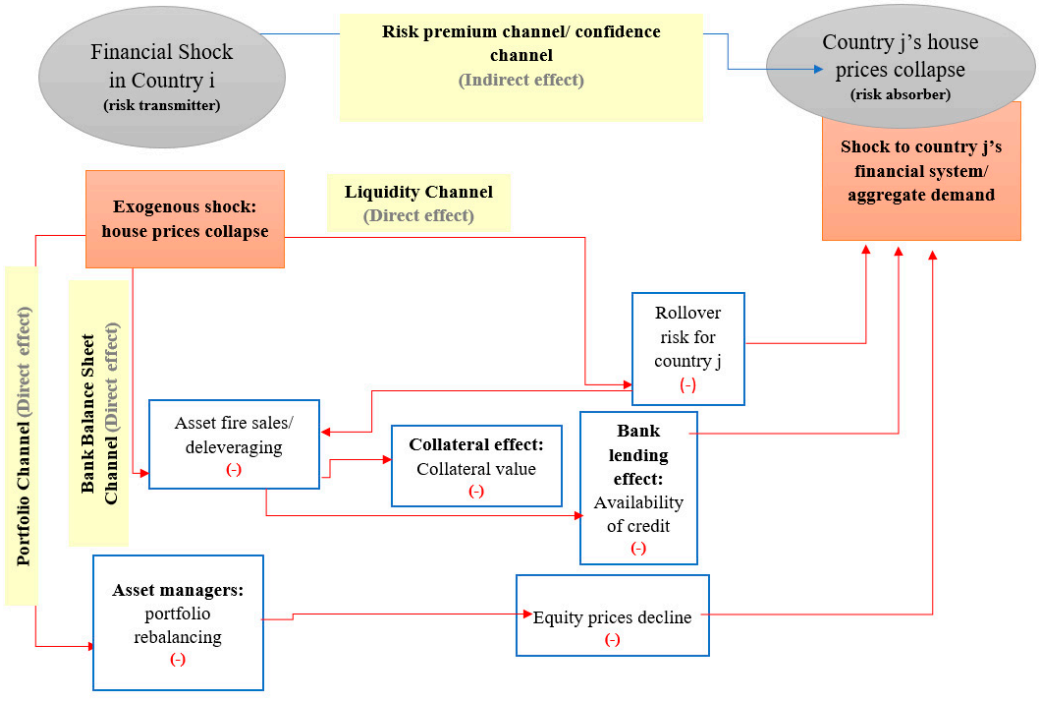
Source: Authors' estimates.
Note: The Synch1 measure capturing the negative of the absolute difference between the house price gaps between two countries is used (see Annex II for further details). Upper and lower bounds are the 75th and 25th percentiles of the samples respectively. Solid median lines in city-pair panels denote the time span with significantly higher city-sample coverage. Shaded areas correspond to U.S. recession periods.

[3] Several papers focus on house price co-movement within a country. For instance, Landier, Sraer, and Thesmar (2017) find evidence for increased correlation of U.S. housing market across states owing to the rise of large banks.

In this paper, building upon the literature on global financial conditions and house prices, we analyze the role of bilateral financial linkages and global financial conditions above-and-beyond that of business cycle synchronicity as a driver of house price synchronicity. We perform bilateral panel data analyses at country-pair level with nearly 50,000 observations and at major city-pair level with nearly 70,000 observations for a broader set of advanced and emerging economies (over 40 economies) and cities (over 70 cities) than previously analyzed. In particular, we aim to address the following questions: (1) Do global financial conditions amplify the house price synchronicity controlling for bilateral macro-financial linkages? (2) Is there an association between bilateral bank linkages and house price synchronicity above-and-beyond that of business cycle synchronicity? (3) What is the role of various institutional factors in either mitigating or amplifying the impact of global financial conditions on house price synchronicity? (4) Do policy tools such as macroprudential policies still turn out to be effective in addressing domestic vulnerabilities in the presence of heightened house price synchronicity?

Our main findings are fourfold. First, the importance of global factors in house price synchronicity as documented in past research still holds when a broader sample of countries and cities with coverage spanning through end-2016 is used. Notably, we find that abundant global liquidity as well as loose financial conditions (in addition to other global factors such as global interest rates) are positively associated with house price synchronicity across country-pairs as well as across major city-pairs. Thus, this paper sheds light on the important

Figure 2. House Price Synchronicity and Transmission of External Shocks



Source: Authors' illustration.

role played by mounting financial integration on housing markets across the globe. Second, we find that greater exchange rate flexibility attenuates the positive impact of global factors on house price synchronicity. Third, bilateral relationships such as past co-movement in business cycles and bilateral bank linkages are also positively associated with house price synchronicity. Finally, we find that the macroprudential policies aimed at tackling domestic vulnerabilities may have the additional impact of reducing countries' house price synchronicity with the rest of the region and the world.

The rest of the paper is structured as follows. Section II describes the data and the construction of the main indicators used in the empirical analyses. Section III presents the main country-level empirical analysis and additional robustness checks. Section IV presents the city-level analysis where we first provide a network analysis on city-level interconnectedness dynamics followed by the empirical analysis. Section V extends the analysis further, looking at the impact of macroprudential policies on house price synchronicity. Section VI concludes.

II. DATA AND MEASUREMENT

This section presents a brief description of the construction of the main variables used in our regression analyses. Further information on underlying data sources, descriptions, and the economies and cities covered in this paper are presented in Annex I.

A. House Price Gap Synchronicity

We employ a measure of house price synchronicity that can be computed at any point in time (in other words at time-series level) rather than as period-wise computations; this measure also provides the additional advantage of not being bound between -1 and 1.

Synchronicity is calculated using the instantaneous quasi-correlation, originally presented by Morgan, Rime, and Strahan (2004) and used in recent business cycle literature (such as Duval et al. 2016; IMF 2013; Kalemli-Ozcan et al. 2013a, 2013b).[4] House price synchronicity ($HPsynch_{ijt}$) between country *i* and *j* at time *t* is measured as follows:

$$HPsynch_{ijt} = \frac{(HPgap_{it} - \overline{HPgap_i})(HPgap_{jt} - \overline{HPgap_j})}{\sigma_i^{gap}\sigma_j^{gap}}, \qquad (1)$$

where $HPgap_{it}$ and $HPgap_{jt}$ stand for house price gap of country i and j respectively at quarter *t* and the gaps are measured as explained above. $\overline{HPgap_i}$ and $\overline{HPgap_j}$ are the

[4] For robustness purposes, alternative measures of house price synchronicity are considered in Annex II.

average house price gaps of countries *i* and *j* respectively, while $\sigma_i^{gap}, \sigma_j^{gap}$ are the standard deviations of house piece gaps of countries *i* and *j* respectively.

House price gaps are measured by extracting the cyclical component of real house prices using the band-pass filter of Christiano and Fitzgerald (2003), with the maximum length of 30 years to capture medium-term financial cycles[5]. The above cyclical components of house prices are then taken as a ratio of the house price levels to obtain house price gaps[6].

B. Business Cycle Synchronicity

Business cycle synchronicity (BCS) is analogous to the house price synchronicity measure presented above.

$$BCS_{ijt} = \frac{(Ygap_{it} - \overline{Ygap_i})(Ygap_{jt} - \overline{Ygap_j})}{\sigma_i^{gap}\sigma_j^{gap}} \quad , \qquad (2)$$

where $Ygap_{it}$ and $Ygap_{jt}$ represent output gaps of countries *i* and *j* respectively at quarter *t* and the gaps and measured using Christiano and Fitzgerald band-pass filter (2003), with the maximum length adjusted for business cycles instead of financial cycles. $\overline{Ygap_i}$ and $\overline{Ygap_j}$ are the average output gaps of countries *i* and *j* respectively, while $\sigma_i^{gap}, \sigma_j^{gap}$ are the standard deviations of output gaps of countries *i* and *j* respectively.

C. Bilateral Banking Integration[7]

Banking integration is measured using bilateral locational banking statistics on residency basis obtained from BIS IBS restricted databases, to be conceptually consistent with balance of payments, national accounts, and external debt statistics. Bilateral banking integration is measured as the logarithm of the sum of bilateral claims of country *i* vis-à-vis country *j* and bilateral claims of country *j* vis-à-vis country *i* as a ratio of the sum of GDPs of country *i* and *j*[8]:

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[5] For emerging market economies, we use 20 years as the maximum length instead.

[6] As a robustness check, we also constructed house price gaps using Hodrick and Prescott (1997) filter with a lambda of 400,000 which is commonly used as the lambda relevant for financial cycles. We obtain house price gaps broadly consistent to that of the Christiano and Fitzgerald (CF) filter. CF filter is chosen for our analysis as it computes the cyclical component for all observations without being prone to tail bias.

[7] Additional forms of bilateral financial integration measures such as bilateral portfolio linkages and bilateral direct investment linkages are not used in our analysis due to their lower frequency and shorter time span.

[8] To address the issue of mirror data asymmetry, following Kalemli-Ozcan et al. (2013a; 2013b), we take the average of country *i*'s assets vis-à-vis country *j* and county *j*'s liabilities vis-à-vis country *i* as the assets of country *i* vis-à-vis country *j* and vice versa.

$$FININT_{ijt} = \ln\left(\left(\frac{A_{ijt}+A_{jit}}{GDP_{it}+GDP_{jt}}\right) * 100\right) \quad (3)$$

where A_{ijt} is the bilateral claims of country *i* vis-à-vis country *j* at quarter *t*, A_{jit} is bilateral claims of country *j* vis-à-vis country *i*, GDP_{it} is the nominal GDP of country *i* at time *t*, and GDP_{jt} is the nominal GDP of country *j* at time *t*.

D. Global Financial Conditions

We control for the effect of global financial conditions on house price gap synchronicity as common shocks could propagate through global financial stability-related risks. In our main analyses, we focus on changes in Bank of International Settlements' (BIS) global liquidity to capture global financial conditions. This measure captures the changes in banks' cross-border claims denominated in all currencies plus local claims in foreign currency in percent of global GDP. In addition to global liquidity, as robustness checks, we also use global financial conditions index (FCI) and the U.S. FCI estimated in line with IMF (2017).[9] We also use Chicago Board Options Exchange volatility index (VIX), as well as Wu and Xia (2016) and Krippner (2013) U.S. shadow interest rates to capture global financial conditions in robustness specifications.

E. Other Controls

To further assess the impact of global financial conditions and bilateral bank linkages when countries have stronger institutions or when they are at different stages of economic development, we use several institutional characteristics and advanced/emerging market economy dummy variables. In particular, we use indicators for high capital account openness (measured using the Chinn-Ito index which is a *de jure* measure of financial openness), high exchange rate regime (measured using *de facto* exchange rate regime indices by Ilzetzki, Reinhart, and Rogoff 2017), and high financial openness (measured using the index developed by Lane and Milesi-Ferretti (2007), which is a *de facto* measure of financial openness) separately in specifications, where high is defined as a dummy variable that equals 1 when both countries in the country-pair are in the top fifth of the institutional characteristic during a given quarter. Dummy variables for advanced economies, emerging market economies, and advanced-emerging market economies take the value of 1 if both countries in the country-pair are either advanced economies, emerging market economies, or advanced-emerging market economies.

[9] See Annex 3.2 of the IMF's October 2017 GFSR (Chapter 3) for FCI construction methodology.

III. COUNTRY-LEVEL ANALYSIS

A. Empirical Strategy

This paper employs bilateral country-pair panel data analysis to estimate the impact of business cycle synchronicity, bilateral financial linkages, and global financial conditions on house price synchronicity at country-level[10]. Our baseline econometric specification presented below is estimated at quarterly frequency from 1990 to 2016, for 40 countries: [11]

$$HPsynch_{ijt} = \alpha_{ij} + \beta_1 BCS_{ijt-1} + \beta_2 FININT_{ijt-1} + \beta_3 GLOBAL_{t-1} + \beta_4 INST_{ijt-1} \text{ x } GLOBAL_{t-1} + \beta_5 INST_{ijt-1} + tr + \varepsilon_{ijt} \quad (4)$$

where $HPsynch_{ijt}$ is the synchronicity of house price gaps between country-pair *i* and *j* at quarter *t*. BSC_{ij} denotes business cycle synchronicity between country *i* and *j*. $FININT_{ij}$ refers to bilateral financial integration between country *i* and *j*.[12] $GLOBAL_t$ is the global factor proxied by the changes in global liquidity. $INST_{ij}$ denote dummies which equal 1 if both countries have a high level of an institutional characteristic (i.e., economic development level, *de jure* capital account openness, exchange rate flexibility, or *de facto* financial account openness).[13] All regressors are lagged by one quarter. In addition, linear and quadratic time trends (tr) are included. α_{ij} is the country-pair fixed effects capturing unobservable time-invariant idiosyncratic factors common to country-pair *i* and *j* such as geographic proximity. ε_{ijt} is the error term.[14] Importantly, country-pair fixed effects capture time-invariant supply-side and regulatory considerations that influence house price synchronicity between two countries.

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[10] See Annex II for the analysis on the impact of Bilateral Linkages on House Price Gap Synchronicity.

[11] Although our house price time series, particularly for advanced economies, start several decades prior to 1990, we restrict our econometric analysis to begin in 1990 as the availability of data on bilateral banking linkages significantly improves starting from 1990. We exclude four EMs out of our original sample of 44 countries in the econometric analysis due to the short length of their house price time series.

[12] Financial integration is measured using bilateral locational banking statistics on residency basis obtained from BIS IBS restricted databases. Bilateral banking integration is measured as the logarithm of the sum of bilateral claims of country *i* vis-à-vis country *j* and bilateral claims of country *j* vis-à-vis country *i* as a ratio of the sum of GDPs of country *i* and *j*. Additional forms of bilateral financial integration measures such as bilateral portfolio linkages and bilateral direct investment linkages are not used in our analysis due to their lower frequency and much shorter time span.

[13] High level is defined based on the top 1/5 of the distribution of institutional characteristics, at any point in time. In addition, robustness checks were performed by defining the institutional factors as high using 75th or 66th percentile instead of the 80th percentile as cutoff rates.

[14] To account for serial correlation, following Cameron et al. (2011), standard errors are multi-way clustered (at country *i*, country *j*, and time level, where appropriate).

B. Results

Impact of Global Financial Conditions on House Price Gap Synchronicity

In our main analyses, we estimate the impact of global financial conditions (also referred to as the global factor) on house price gap synchronicity using the changes in BIS' global liquidity variable mentioned in the preceding section as the proxy for the global factor[15] and instantaneous quasi-correlation (also mentioned in the previous section)[16] as the synchronicity measure for house price and business cycle synchronicity. The results presented in Table 1 show that the global financial conditions are positively associated with house price synchronicity even when controlling for bilateral macro financial conditions including business cycle synchronicity and banking integration (column 4). This impact is also robust across various specifications, including where we control for different institutional characteristics and various error clustering methods are considered (see Tables 2–4 for robustness checks). This result could provide preliminary evidence for the positive association between the abundance of global liquidity and short-term co-movements in house price gaps.

Moreover, the impact of the global financial conditions on house price synchronicity appears to be higher between advanced economies than in country-pairs that are emerging market economies (column 5). While the impact of the global financial conditions in advanced economies is statistically significant and positive, neither emerging market economies' nor advanced-emerging market economy-pairs' impact is statistically significant at conventional levels when standard errors are clustered in the most stringent manner.

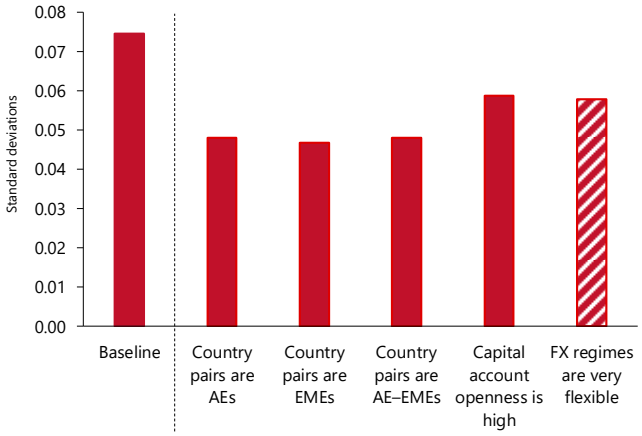
Institutional characteristics such as higher exchange rate flexibility appear to be attenuating the positive association between global financial conditions and house price synchronicity (column 7). This impact is statistically significant at 1 percent confidence interval. Moreover, it is robust to various controls, as presented in Tables 2–5. We also find an attenuating effect of de jure financial openness (i.e., Chinn-Ito index of capital account openness) on the global financial conditions' impact on house price synchronicity, but the impact of this interaction term is not statistically significant at conventional levels (column 6). Results in columns 4 to 6 are also presented in figure 3, where we have standardized the coefficients for comparability across specifications.

[15] See Table 2 in the robustness checks section for results using additional proxies for global factors.

[16] Given global financial conditions index is more of a short-term indicator, we believe instantaneous quasi-correlation (that purges the mean house price gap) as the synchronicity measure is better suited for this analysis.

Furthermore, the positive impact of global liquidity on house price synchronicity was substantially higher prior to the global financial crisis (GFC). This may provide evidence to the association between the global house price boom that occurred preceding the GFC and the abundance of global liquidity accumulated during that period.

Figure 3. Impact of Global Financial Conditions on House Price Synchronization



Source: Authors' estimates.
Note: Global financial conditions are proxied by the BIS global liquidity variable mentioned in the previous section. Synchronicity is measured by the quasi correlation of gaps. Shaded bars denote joint significance of the F-test at or above 90 percent. Patterned bars denote interaction terms that are statistically significant. Coefficients are standardized. Standard deviation of the country-level dependent variable is approximately 0.85 (see Annex Table 1.3). AEs = advanced economies; EMEs = emerging market economies; FX = exchange rate.

The analysis concerning the impact of bilateral linkages on house price gap synchronicity is presented in Annex II. Using an alternative measure of house price synchronicity, which captures the medium-term dynamics through differences in house price gaps, we find evidence that both business cycle synchronicity and bilateral banking integration are positively and robustly associated with house price synchronicity.

C. Robustness Checks

In addition to the results presented above, various robustness checks were performed, with the main findings broadly unchanged. For instance, alternative proxies for global financial conditions including the U.S. financial conditions index (FCI), Global FCI, CBOE volatility index (VIX), U.S. shadow interest rates (Wu and Xia 2016; Krippner 2013) are used, where the global financial conditions and the high exchange rate regime interaction terms are still found to be statistically significant with the coefficient sign and the size broadly unchanged (Table 2).[17] Specifications above were also estimated by replacing BCS with interest rate synchronicity to investigate the role of synchronized monetary policies in contributing to house price synchronicity. We find interest rate synchronicity to be a statistically significant driver of house price synchronicity on its own when either synchronicity measure is used (either synch1 or quasi correlation). However, the statistical significance of interest rate synchronicity above and beyond other financial factors such as the global liquidity and

[17] While results are robust to these alternative proxies for the global factor, the level of statistical significance declines, especially when the most stringent manner of standard error clustering is considered.

bilateral banking linkages is only robust to less stringent manners of standard error clustering (Table 3, columns 3-6). At the same time, trade integration was included as an additional control, but found not to be statistically significant (Table 3, columns 7-8). When equity price synchronicity is included as an additional control, the main results presented in the previous section remain broadly unchanged (Table 3, columns 9-10). However, equity price synchronicity itself does not consistently have a statistically significant relationship with house price synchronicity.

Various clustering alternatives were employed (clustering at country-pair level, two-way at country *i* and country *j*, two-way at country-pair and time level, and without clustering, Huber/White/sandwich estimator), and as expected, the level of significance improves under less restrictive clustering options (Table 4). Additional time controls, such as year fixed effects and linear time trends, were also considered with little changes to the main conclusions. Finally, further robustness checks were employed by dropping one country-pair at a time as well.

Table 1. House Price Gap Synchronicity at Country Level and Global Factors

Dependent Variable: House Price Gap Synchronization of Country Pair i and j (quasi correlation)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Business Cycle Synchronization of ij	0.025*	0.030**	0.022	0.026*	0.026*	0.025*	0.026*	0.026*	0.026**	0.042
	(0.013)	(0.014)	(0.014)	(0.013)	(0.013)	(0.015)	(0.014)	(0.014)	(0.013)	(0.033)
Bilateral Bank Integration of ij			-0.011	0.012	0.012	0.011	0.022	0.022	0.012	-0.016
			(0.033)	(0.031)	(0.031)	(0.036)	(0.036)	(0.035)	(0.032)	(0.034)
Global Factor (global liquidity)				0.016**	0.016**	0.020**	0.019***	0.019**	0.018**	0.022*
				(0.006)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.013)
Global Factor Interacted with:										
x EMEs-EMEs Dummy					-0.001					
					(0.009)					
x EMEs-AEs Dummy					0.000					
					(0.006)					
x High Capital Account Openness with the World						-0.002				
						(0.005)				
x High Exchange Rate Regime (ij) (15 categories; high = more flexible)							-0.023***			
							(0.008)			
x High Exchange Rate Regime (ij) (6 categories; high = more flexible)								-0.009		
								(0.007)		
x High Financial Openness with the World (ij)									0.003	
									(0.006)	
GFC Period Dummy Interacted with:										
x Business Cycle Synchronization of ij										-0.032
										(0.038)
x Bilateral Bank Integration of ij										-0.022
										(0.035)
x Global Factor										-0.025*
										(0.012)
Post-GFC Period Dummy Interacted with:										
x Business Cycle Synchronization of ij										-0.039
										(0.035)
x Bilateral Bank Integration of ij										0.010
										(0.033)
x Global Factor										-0.029
										(0.018)
GFC Dummy										-0.137**
										(0.060)
Post-GFC Dummy										-0.044
										(0.052)
Observations	65,450	65,343	49,384	49,384	49,384	43,871	46,708	46,708	47,353	49,384
R-squared	0.227	0.354	0.251	0.230	0.230	0.233	0.224	0.223	0.241	0.232
Multiway Clustering	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Two-way
Group	All	All	All	All	All	All	All	All	All	All
Time FE and Country-Pair FE	Yes		Yes							
Time FE, Country-Pair FE, and country*time FE		Yes								
Quadratic Trend and Country-Pair FE				Yes	Yes	Yes	Yes	Yes	Yes	
Country-Pair FE										Yes

Source: Authors' estimates.

Note: GFC Dummy = a dummy variable that equals 1 during 2008–09, and zero otherwise. Post-GFC Dummy = a dummy variable that equals 1 during 2010–16, and zero otherwise. All regressors are lagged by one quarter. Institutional characteristics dummies are included in specifications 5 through 9, but are not shown above (specifically, dummy variables for EMEs-EMEs, EMEs-AEs, high capital account openness, high exchange rate regime, high financial openness are included in specifications 5 through 9, but not shown). High = a dummy variable that equals 1 when both countries are in the top fifth of the institutional characteristic. Standard errors (in parentheses) are three-way clustered (at country i, country j, and date), with the exception of regression (10), in which errors are two-way clustered (at country i, country j). AEs = advanced economies; EMEs = emerging market economies; FE = fixed effects; GFC = global financial crisis.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Table 2. House Price Gap Synchronicity at Country Level and Global Factors—Robustness Checks: Global Factors

Dependent Variable: House Price Gap Synchronization of Country Pair i and j (quasi-correlation)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Global liquidity		US FCI (↑=loosening)		Global FCI (↑=loosening)		VIX (Inverse)		US Shadow rate (Wu Xia)		US Shadow rate (Krippner)	
Business Cycle Synchronization of ij	0.026*	0.026*	0.039***	0.043***	0.022*	0.023*	0.022***	0.024***	0.014***	0.014***	0.016***	0.016***
	(0.013)	(0.014)	(0.011)	(0.012)	(0.012)	(0.013)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Bilateral Bank Integration of ij	0.012	0.022	0.016	0.031	0.004	0.018	0.015	0.031	-0.003	0.002	0.003	0.007
	(0.031)	(0.036)	(0.033)	(0.033)	(0.032)	(0.032)	(0.029)	(0.030)	(0.029)	(0.030)	(0.029)	(0.030)
Global Factor	**0.016****	**0.019*****	**0.060*****	**0.076*****	**0.037****	**0.049*****	**0.003****	**0.005*****	**0.049*****	**0.057*****	**0.026*****	**0.032*****
	(0.006)	(0.007)	(0.018)	(0.020)	(0.015)	(0.018)	(0.001)	(0.001)	(0.006)	(0.006)	(0.005)	(0.005)
Global Factor Interacted with:												
x High Exchange Rate Regime (ij) (15 categories; high = more flexible)		**-0.023*****		**-0.069****		**-0.056***		**-0.011****		**-0.025***		**-0.026****
		(0.008)		(0.034)		(0.033)		(0.004)		(0.014)		(0.011)
Observations	49,384	46,708	49,384	46,708	48,892	46,216	49,384	46,708	49,384	46,708	49,384	46,708
R-squared	0.230	0.224	0.228	0.223	0.229	0.223	0.225	0.219	0.234	0.229	0.229	0.224
Clustering	Multi-way	Multi-way	Two-way	Two-way	Two-way	Two-way	country-pair	country-pair	country-pair	country-pair	country-pair	country-pair
Quadratic Trend and Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' estimates.
Note: All regressors are lagged by one quarter. Institutional characteristics dummies are included in specifications, but are not shown above (specifically, dummy variables for high exchange rate regime). High = a dummy variable that equals 1 when both countries are in the top fifth of the institutional characteristic. Standard errors (in parentheses) are clustered as described above; FE = fixed effects.
*** p < 0.01; ** p < 0.05; * p < 0.1.

Table 3. House Price Gap Synchronicity at Country Level and Global Factors—Robustness Checks: Additional Controls

Dependent Variable: House Price Gap Synchronization of Country Pair i and j (quasi-correlation)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Baseline		Interest rate synchronization				Controlling for Trade		Controlling for Equity Synch	
Business Cycle Synchronization of ij	0.026*	0.026*					0.026*	0.026*	0.025*	0.024*
	(0.013)	(0.014)					(0.013)	(0.014)	(0.012)	(0.014)
Interest Rate Synchronization of ij			0.016	0.013	0.016**	0.013*				
			(0.040)	(0.041)	(0.008)	(0.008)				
Bilateral Bank Integration of ij	0.012	0.022	0.011	0.021	0.011	0.021*	0.009	0.019	0.015	0.024
	(0.031)	(0.036)	(0.033)	(0.036)	(0.011)	(0.011)	(0.031)	(0.036)	(0.032)	(0.037)
Global Factor	**0.016****	**0.019*****	**0.015****	**0.018*****	**0.015*****	**0.018*****	**0.016****	**0.019*****	**0.017****	**0.019*****
	(0.006)	(0.007)	(0.006)	(0.006)	(0.001)	(0.001)	(0.006)	(0.007)	(0.006)	(0.007)
Global Factor Interacted with:										
x High Exchange Rate Regime (ij) (15 categories; high = more flexible)		**-0.023*****		**-0.024*****		**-0.024*****		**-0.023*****		**-0.023*****
		(0.008)		**(0.008)**		**(0.004)**		**(0.008)**		**(0.008)**
Bilateral Trade Integration of ij							0.008	-0.001		
							(0.038)	(0.040)		
Equity Return Synchronization of ij									0.010	0.010
									(0.009)	(0.009)
Observations	49,384	46,708	47,830	45,188	47,830	45,188	48,890	46,215	48,973	46,308
R-squared	0.230	0.224	0.228	0.222	0.228	0.222	0.232	0.226	0.231	0.225
Clustering	Multi-way	Multi-way	Multi-way	Multi-way	VCE robust	VCE robust	Multi-way	Multi-way	Multi-way	Multi-way
Quadratic Trend and Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' estimates.
Note: All regressors are lagged by one quarter. Institutional characteristics dummies are included in specifications, but are not shown above (specifically, dummy variables for high exchange rate regime). High = a dummy variable that equals 1 when both countries are in the top fifth of the institutional characteristic. Standard errors (in parentheses) are clustered as described above; FE = fixed effects.
*** p < 0.01; ** p < 0.05; * p < 0.1.

Table 4. House Price Gap Synchronicity at Country Level and Global Factors—Robustness Checks: Clustering of Standard Errors

Dependent Variable: House Price Gap Synchronization of Country Pair i and j (quasi-correlation)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Business Cycle Synchronization of ij	0.026*	0.026*	0.026**	0.026**	0.026**	0.026*	0.026**	0.026**	0.026***	0.026***	0.026***	0.026**	0.026***	0.026***	0.026***	0.026***
	(0.013)	(0.014)	(0.011)	(0.012)	(0.012)	(0.013)	(0.011)	(0.012)	(0.005)	(0.005)	(0.009)	(0.010)	(0.003)	(0.003)	(0.003)	(0.003)
Bilateral Bank Integration of ij	0.012	0.022	0.012	0.022	0.012	0.022	0.012	0.022	0.012	0.022	0.012	0.022	0.012	0.022**	0.012	0.022**
	(0.031)	(0.036)	(0.030)	(0.034)	(0.027)	(0.030)	(0.036)	(0.038)	(0.029)	(0.030)	(0.017)	(0.018)	(0.011)	(0.011)	(0.011)	(0.011)
Global Factor (global liquidity)	**0.016****	**0.019*****	**0.016*****	**0.019*****	**0.016****	**0.019*****	**0.016*****	**0.019*****	**0.016*****	**0.019*****	**0.016*****	**0.019*****	**0.016*****	**0.019*****	**0.016*****	**0.019*****
	(0.006)	(0.007)	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.002)	(0.002)	(0.004)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
Global Factor Interacted with:																
x High Exchange Rate Regime (ij) (15 categories; high = more flexible)		**-0.023*****		**-0.023****		**-0.023*****		**-0.023*****		**-0.023*****		**-0.023*****		**-0.023*****		**-0.023*****
		(0.008)		(0.009)		(0.007)		(0.008)		(0.007)		(0.003)		(0.004)		(0.004)
Observations	49,384	46,708	49,384	46,708	49,384	46,708	49,384	46,708	49,384	46,708	49,384	46,708	49,384	46,708	49,384	46,708
R-squared	0.230	0.224	0.230	0.224	0.230	0.224	0.230	0.224	0.230	0.224	0.230	0.224	0.230	0.224	0.230	0.224
Clustering	**ctr1 ctr2 time**	**ctr1 ctr2 time**	**ctr1 ctr2**	**ctr1 ctr2**	**ctr1 time**	**ctr1 time**	**ctr2 time**	**ctr2 time**	**country-pair**	**country-pair**	**time**	**time**	**VCE robust**	**VCE robust**	**no clustering**	**no clustering**
Quadratic Trend and Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

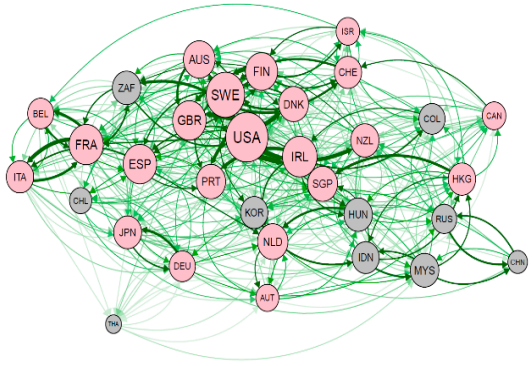
Source: Authors' estimates.
Note: All regressors are lagged by one quarter. Institutional characteristics dummies are included in specifications, but are not shown above (specifically, dummy variables for high exchange rate regime). High = a dummy variable that equals 1 when both countries are in the top fifth of the institutional characteristic. Standard errors (in parentheses) are clustered as described above; FE = fixed effects.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

IV. City-Level Analysis

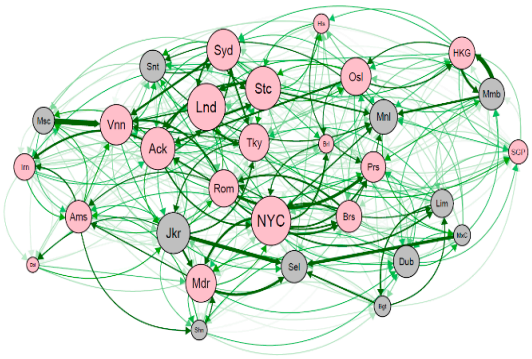
While house prices synchronicity may vary among country-pairs owing to their degree of exposure to bilateral linkages and global financial conditions as identified in the preceding section, house prices in major cities[18] may move in tandem due to increasing global presence even if their country-level house prices may not portray such dynamics. To dig deeper into city-level house price synchronicity, we first explore house price interconnectedness dynamics through a network analysis, and then move on to analyzing the drivers of city-level house price synchronicity empirically.

Figure 4. House Price Interconnectedness Among Countries vs. Cities

1. Country-Level House Price Interconnectedness



2. City-Level House Price Interconnectedness



Source: Authors' estimates.

Note: The figure is based on a vector autoregression of country-level/city-level house price growth rates (quarter over quarter) controlling for global factors, spanning 1990:Q1 to 2016:Q4 for country-level and 2004:Q1 to 2017:Q2 for city-level. For methodology details, see Annex III. See the footnote 18 for city selection criteria, conditional on data availability. Node size is based on the city's total outward spillovers. Pink nodes represent advanced economies and gray nodes represent emerging market economies. Arrows' thickness is based on link distribution. Only links above the 50th percentile for country-level and 66th percentile for city-level are considered. The figure layout is based on the algorithm by Fruchterman and Reingold (1991), and plotted using the "qgraph" R package. Ack = Auckland; Ams = Amsterdam; Bgt = Bogotá; Brl = Berlin; Brs = Brussels; Dbl = Dublin; Dub = Dubai; HKG = Hong Kong SAR; Hls = Helsinki; Jkr = Jakarta; Lim = Lima; Lnd = London; Mdr = Madrid; Mmb = Mumbai; Mnl = Manila; Msc = Moscow; Mxc = Mexico City; NYC = New York City; Osl = Oslo; Prs = Paris; Rom = Rome; Sel = Seoul; SGP = Singapore; Shn = Shanghai; Snt = Santiago; Stc = Stockholm; Syd = Sydney; Tky = Tokyo; Trn = Toronto; Vnn = Vienna. Following Morgan Stanley Capital International markets classification criteria, Korea (and thus Seoul) is classified as an emerging market economy; moreover, Korea (and thus Seoul) was not classified as an advanced economy in the IMF's World Economic Outlook country classification at the beginning of our sample period, which starts in 1990.

[18] The selection of cities is based on population and overlaps with the top 50 cities for global investors identified by Cushman & Wakefield (2017). The sample comprises over 70 cities (see Annex I) combining the Top 30 cities in global investors' ranking by Cushman & Wakefield's (2017) Global Capital Markets 2017 report, where economic scale, financial center, technology hub, and innovation criteria are considered. If none of the cities in a country (where data are available) are chosen based on the four pillars stated above, the largest city by population in the country is included. Moreover, an additional sample with 44 major cities off the above sample is also constructed.

A. Network Analysis: House Price Interconnectedness at City Level

Our network analysis uses the spillovers approach developed by Diebold and Yilmaz (2014) (see Annex III for detailed methodology) controlling for global financial conditions (proxied by the U.S. FCI). In fact, comparing the network analysis at country-level and city-level confirms that cities that are attractive to global investors may be at the core of the network and closer to other cities such as financial centers even if the respective countries are at the periphery (Figure 4). For instance, Tokyo and Rome are centrally located in the vicinity of global financial centers such as New York and London in the city-level network map below (Figure 4, Panel 2), while Japan and Italy are located at the periphery of the country-level network map (Figure 4, Panel 1).

B. Empirical Strategy

The determinants of city-level house price synchronicity are analyzed using a bilateral panel data analysis, where we specifically estimate the impact of country-level measures such as business cycle synchronicity and bilateral financial linkages, and global financial conditions on house price synchronicity within major cities. The analysis is estimated at quarterly frequency from 2004 to 2016 for over 70 major cities[19]. The econometric specification for the city-level analysis takes the following form:

$$HPsynch_{ijt} = \alpha_{ij} + \beta_1 BCS_{ijt-1} + \beta_2 FININT_{ijt-1} + \beta_3 GLOBAL_{t-1} + \beta_4 INST_{ijt-1} \text{ x } GLOBAL_{t-1} + \beta_5 INST_{ijt-1} + tr + \varepsilon_{ijt} \quad (5)$$

where $HPsynch_{ijt}$ is the synchronicity of house price gaps between city-pair *i* and *j* at quarter *t*. α_{ij}stands for city-pair fixed effects and tr stands for quadratic and linear time trends. $GLOBAL_{t-1}$stands for global financial conditions proxied by changes in the BIS' global liquidity in percent of global GDP. All other regressors are country-level variables that are defined in the section on the country-level analysis.

C. Results

Similar to our country-level analysis, we use the changes in BIS global liquidity to proxy for the global financial conditions and instantaneous quasi-correlation to measure city-level house price gap synchronicity. We find that global financial conditions are positively associated with city-level house price gap synchronicity; this impact is statistically significant even if standard errors are clustered using a more stringent form of multi-way clustering, while the significance level improves from a 10 percent confidence level to a

[19] The coefficients in the regression analysis are weighted by the number of major cities in each country.

1 percent confidence level if two-way clustering is employed instead (column 4 in Tables 5 and 6).

In line with our country-level findings, city-level analysis also confirms that higher exchange rate flexibility tends to be attenuating the positive association between the global factor and the city-level house price synchronicity; this impact is statistically significant at a 5 percent confidence level even when more stringent form of standard error clustering is used (column 7 in Tables 5 and 6).

Furthermore, the impact of global financial conditions on city-level house price synchronicity is higher among city-pairs residing within advanced economies than that of city-pairs residing either within emerging economies or advance-emerging economy pairs (column 5 in Tables 5 and 6). While the impact for advanced economies is statistically significant even when more stringent forms of standard errors are used, the interaction term for advance-emerging pairs is significant only when a less stringent form of clustering is used (such as two-way clustering at country-pair and time level; column 5 in Table 5). The interaction term for emerging economies is not statistically significant when two-way clustering is used.

In contrast to our country-level analysis, the city-level empirical findings suggest that greater financial openness at country-level tends to amplify the positive association between global financial conditions and city-level house price synchronicity. In other words when a *de jure* measure of financial openness is used (i.e., Chinn-Ito index of capital account openness). However, we find that this impact is not statistically significant if standard errors are clustered in a more stringent manner (column 6 in Table 6). We fail to find statistically significant results when a *de facto* measure of financial openness is used (i.e., Lane and Milesi-Ferretti (2007) measure of financial openness).

The city-level analysis also confirms that the global financial conditions were positively associated with city-level house price synchronicity prior to the global financial crisis (column 10 in Tables 5 and 6).

Table 5. House Price Gap Synchronicity at City Level and Global Factors—Two-Way Clustering

Dependent Variable: House Price Gap Synchronization of City Pair i and j (quasi-correlation)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Business Cycle Synchronization of ij	0.011	0.021*	0.011	0.019*	0.019*	0.016	0.018	0.017	0.016	0.079***
	(0.010)	(0.012)	(0.010)	(0.010)	(0.010)	(0.010)	(0.011)	(0.011)	(0.010)	(0.027)
Bilateral Bank Integration of ij			0.008	0.016	0.019	0.020	0.021	0.020	0.021	0.066
			(0.045)	(0.045)	(0.045)	(0.050)	(0.046)	(0.046)	(0.047)	(0.057)
Global Factor (global liquidity)				0.018***	0.030***	0.012**	0.021***	0.023***	0.018***	0.024**
				(0.005)	(0.008)	(0.005)	(0.006)	(0.006)	(0.005)	(0.009)
Global Factor Interacted with:										
x EMEs-EMEs Dummy					-0.019					
					(0.011)					
x EMEs-AEs Dummy					-0.018**					
					(0.008)					
x High Capital Account Openness with the World						0.018**				
						(0.008)				
x High Exchange Rate Regime (ij) (15 categories; high = more flexible)							-0.017**			
							(0.008)			
x High Exchange Rate Regime (ij) (6 categories; high = more flexible)								-0.012*		
								(0.007)		
x High Financial Openness with the World (ij)									0.001	
									(0.016)	
GFC Period Dummy Interacted with:										
x Business Cycle Synchronization of ij										-0.081***
										(0.029)
x Bilateral Bank Integration of ij										-0.058
										(0.049)
x Global Factor										-0.025**
										(0.010)
Post-GFC Period Dummy Interacted with:										
x Business Cycle Synchronization of ij										-0.078***
										(0.029)
x Bilateral Bank Integration of ij										-0.071*
										(0.040)
x Global Factor										-0.026**
										(0.011)
GFC Dummy										0.010
										(0.038)
Post-GFC Dummy										0.014
										(0.049)
Observations	66,575	66,572	66,575	66,575	66,575	59,353	63,691	63,691	62,588	66,575
R-squared	0.260	0.343	0.260	0.254	0.256	0.265	0.251	0.252	0.268	0.260
Clustering	Two-way	Two-way	Two-way	Two-way	Two-way	Two-way	Two-way	Two-way	Two-way	Two-way
Time FE and Country-Pair FE	Yes		Yes							
Time FE, Country-Pair FE, and country*time FE		Yes								
Quadratic Trend and Country-Pair FE				Yes	Yes	Yes	Yes	Yes	Yes	
Country-Pair FE										Yes

Source: Authors' estimates.
Note: GFC Dummy = a dummy variable that equals 1 during 2008–09, and zero otherwise. Post-GFC Dummy = a dummy variable that equals 1 curing 2010–16, and zero otherwise. All regressors are lagged by one quarter. Institutional characteristics dummies are included in specifications 5 through 9, but are not shown above (specifically, dummy variables for EMEs-EMEs, EMEs-AEs, high capital account openness, high exchange rate regime, high financial openness are included in specifications 5 through 9, but not shown). High = a dummy variable that equals 1 when both countries are in the top fifth of the institutional characteristic. Standard errors (in parentheses) are two-way clustered (at country ij, and date). AEs = advanced economies; EMEs = emerging market economies; FE = fixed effects; GFC = global financial crisis.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Table 6. House Price Gap Synchronicity at City Level and Global Factors—Multi-Way Clustering

Dependent Variable: House Price Gap Synchronization of City Pair i and j (quasi-correlation)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Business Cycle Synchronization of ij	0.011	0.021	0.011	0.019	0.019	0.016	0.018	0.017	0.016	0.079
	(0.013)	(0.013)	(0.013)	(0.012)	(0.012)	(0.014)	(0.014)	(0.013)	(0.013)	(0.060)
Bilateral Bank Integration of ij			0.008	0.016	0.019	0.020	0.021	0.020	0.021	0.066
			(0.029)	(0.031)	(0.030)	(0.046)	(0.037)	(0.037)	(0.038)	(0.051)
Global Factor (global liquidity)				0.018*	0.030*	0.012	0.021*	0.023*	0.018*	0.024*
				(0.009)	(0.016)	(0.008)	(0.011)	(0.011)	(0.009)	(0.014)
Global Factor Interacted with:										
x EMEs-EMEs Dummy					-0.019					
					(0.016)					
x EMEs-AEs Dummy					-0.018					
					(0.014)					
x High Capital Account Openness with the World						0.018				
						(0.014)				
x High Exchange Rate Regime (ij) (15 categories; high = more flexible)							-0.017**			
							(0.008)			
x High Exchange Rate Regime (ij) (6 categories; high = more flexible)								-0.012		
								(0.008)		
x High Financial Openness with the World (ij)									0.001	
									(0.024)	
GFC Period Dummy Interacted with:										
x Business Cycle Synchronization of ij										-0.081
										(0.062)
x Bilateral Bank Integration of ij										-0.058
										(0.073)
x Global Factor										-0.025*
										(0.014)
Post-GFC Period Dummy Interacted with:										
x Business Cycle Synchronization of ij										-0.078
										(0.062)
x Bilateral Bank Integration of ij										-0.071
										(0.058)
x Global Factor										-0.026
										(0.017)
GFC Dummy										0.010
										(0.050)
Post-GFC Dummy										0.014
										(0.045)
Observations	66,575	66,572	66,575	66,575	66,575	59,353	63,691	63,691	62,588	66,575
R-squared	0.260	0.343	0.260	0.254	0.256	0.265	0.251	0.252	0.268	0.260
Clustering	Multi-way	Multi-way	Multi-way	Multi-way	Multi-way	Multi-way	Multi-way	Multi-way	Multi-way	Multi-way
Time FE and Country-Pair FE	Yes		Yes							
Time FE, Country-Pair FE, and country*time FE		Yes								
Quadratic Trend and Country-Pair FE				Yes	Yes	Yes	Yes	Yes	Yes	
Country-Pair FE										Yes

Source: Authors' estimates.
Note: GFC Dummy = a dummy variable that equals 1 during 2008–09, and zero otherwise. Post-GFC Dummy = a dummy variable that equals 1 curing 2010–16, and zero otherwise. All regressors are lagged by one quarter. Institutional characteristics dummies are included in specifications 5 through 9, but are not shown above (specifically, dummy variables for EMEs-EMEs, EMEs-AEs, high capital account openness, high exchange rate regime, high financial openness are included in specifications 5 through 9, but not shown). High = a dummy variable that equals 1 when both countries are in the top fifth of the institutional characteristic. Standard errors (in parentheses) are three-way clustered (at country i, country j, and date). AEs = advanced economies; EMEs = emerging market economies; FE = fixed effects; GFC = global financial crisis.
*** p < 0.01; ** p < 0.05; * p < 0.1.

V. Extensions: The Impact of Macroprudential Policies

In this section, we focus on the relationship between macroprudential policies (MPPs) and house price synchronicity with regional and global cycles.[20] MPPs targeted at dampening the accumulation of domestic vulnerabilities in the financial and housing sectors may have indirect effects of weakening the correlation of house price cycles, thereby leaving room for policymakers to regain control over local house price dynamics.

Macroprudential tools, which have been used more actively since the global financial crisis (Alam et al. 2018; Cerutti, Claessens, and Laeven 2015), aim at curbing leverage and reducing financial vulnerabilities in order to decrease the likelihood of domestic asset bubbles and financial crises. MPPs are usually domestically targeted, with a large share of measures focused on domestic credit and housing market conditions. However, in countries experiencing deeper financial integration and where business cycles are more intertwined at the regional and global levels, house prices are, in part, driven by other factors, such as capital flows from global investors and by global financial conditions.[21] Thus, the relationship between macroprudential tools and house price synchronicity might be ambiguous because it may be offset by other factors.

Recent empirical literature (Vandenbussche, Vogel, and Detragiache 2015; Cerutti, Dagher, and Dell'Ariccia 2015) suggests that the role of macroprudential policies in mitigating house prices is less clear and may vary according to policy type. For instance, measures targeting housing finance (Akinci and Olmstead-Rumsey 2017) and those that complement monetary policy (Bruno, Shim, and Shin 2017) seem to be most effective in mitigating house price growth. In contrast, there is no robust evidence for policies such as risk-weighting and provisioning requirements (Kuttner and Shim 2016).

A. Empirical Strategy

The analysis gauges the effectiveness of macroprudential tools in reducing house price synchronicity across 41 countries from the second quarter of 1990 through the last quarter of 2016. More specifically, the following panel regression specification is estimated, with *i* denoting country and *t* representing quarter:

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[20] Synchronicity with regional cycles may pose further financial stability concerns, as macro-financial shocks could transmit more easily from one country to another through interconnected bank balance sheets and collateral values. In some regions, house price synchronicity with the regional cycle is stronger than with the global cycle, reflecting deeper intra-regional financial and trade integration (see also Katagiri 2018). As depicted in Annex Figure 1.2., we find that the median correlation with the global cycle is roughly 0.4, while the one with the regional cycle is about 0.5 across all countries and time.

[21] House price synchronicity with the global cycle is heterogeneous across regions, potentially reflecting deeper intraregional financial and trade integration.

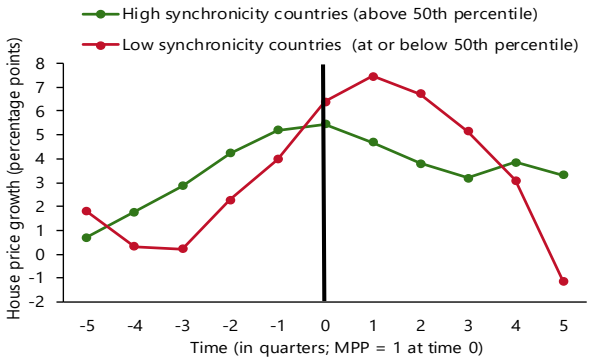
$$HPS_{i,t} = \rho BCS_{i,t-1} + \beta\, MPP_{i,t-1} + \gamma X_{i,t-1} + \alpha_i + \epsilon_{i,t} \quad (8)$$

where α_i denotes country fixed effects. The dependent variable *HPS* refers to house price cycle synchronicity (instantaneous quasi-correlation) with either the regional or the global cycle. *BCS* is business cycle synchronicity with the region or the rest of the world. *X* is a vector of controls (including global financial conditions, financial integration with the region or the world, and institutional characteristics). *MPP* is a macroprudential tool (such as limits to loan-to-value ratios or debt-to-income ratios, or fiscal-based measures that include sellers' and buyers' stamp duty taxes) or a macroprudential group index (such as loan-targeted, supply-side [capital, general, loans], or demand-side tools).[22]

B. Results

House price growth evolved differently after the adoption of demand-side MPPs such as loan-to-value (LTV) limits, depending on the level of synchronicity (Figure 5). Before the adoption of these policies, house prices grew similarly in countries with high or low house price synchronicity. Following the adoption of MPPs, house price growth declined in both groups of countries, but the decline was stronger and more sustained in low-synchronicity countries. These simple patterns suggest that policymakers may have more control over the dynamics of the housing markets in low-synchronicity countries. At the same time, it suggests that a high degree of synchronicity does not render MPPs ineffective. This could be the case if the financial factors behind house price synchronicity operate, at least partially, through local financial intermediaries.

Figure 5. Average House Price Growth and Demand-side Macroprudential Policies



Source: Authors' estimates.
Note: The figure depicts the average year-over-year house price growth for high-synchronicity and low-synchronicity countries within a period of plus or minus five quarters around the implementation of demand-side macroprudential policies (MPPs). Demand-side MPPs include limits to debt-service-to-income and loan-to-value (LTV) ratios. Total number of demand-side events is 47, and t = 0 is identified as the first quarter in which demand-side MPPs were implementated within the plus-or-minus-five-quarter window. Synchronicity is based on the quasi-correlation of house price gaps with the global cycle. A country is classified in the high-synchronicity group when its average syncronicity (over the sample period) with the global cycle is above the 50th percentile in the sample, and vice versa.

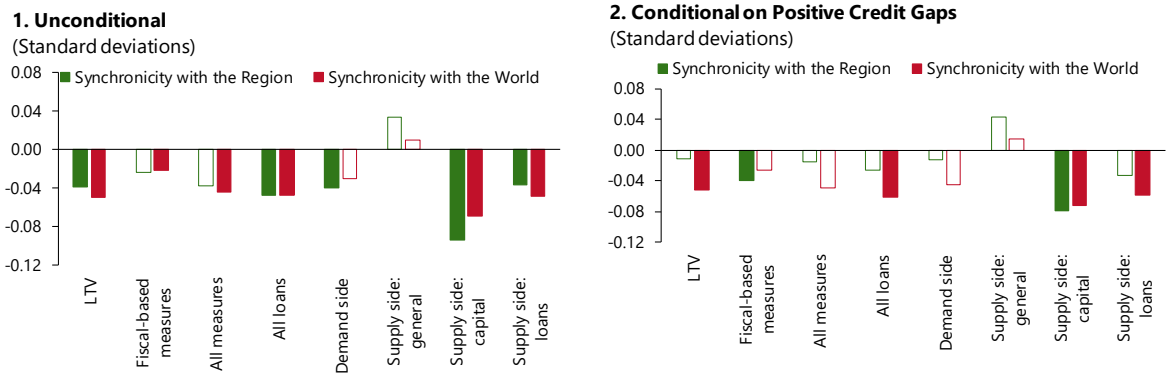
MPPs are also associated with a reduction in house price synchronicity (Figure 6, Panel 1 and Annex Table 4.1); in fact, tighter macroprudential tools targeting bank capital and credit

[22] For more details regarding the macroprudential tools database, see Alam et al. (2018).

conditions are found to be associated with lower house price synchronicity. Since these tools mostly affect local financial intermediaries and domestic demand, this finding also suggests that factors driving house price co-movement operate, to some degree, through these channels. The relationship between capital-based measures, which include countercyclical capital buffers, and house price synchronicity seems the most highly negative. Likewise, loan-targeted measures, including LTV limits, and supply-side loan-targeted tools, such as limits on foreign currency, are found to lessen correlations with the global and regional house price cycles. The adoption of fiscal-based measures, such as ad valorem and buyer's stamp duty taxes that could potentially deter global investors from engaging in speculative real estate purchases is also associated with a decline in synchronicity, but to a lesser extent than other MPPs.[23] When looking only at periods with credit booms, the results are both qualitatively and quantitatively similar, although the relationships are slightly less significant (Figure 6, panel 2 and Annex Table 4.2).

Figure 6. Impact of Macroprudential Measures on House Price Synchronicity

Loan-specific measures such as LTV limits seem effective in reducing synchronicity with both the region and the global cycle.



Source: Authors' estimates.
Note: Figure depicts estimated average effects of macroprudential tools on house price synchronicity with the regional cycle (green) and global cycle (red). Shaded bars show statistically significant standardized coefficients, at the 10 percent confidence level. Estimated panel regressions use data for 41 countries (panel 1) spanning over 1990:Q2 – 2016:Q4 period. Regressions control for business cycle synchronicity, financial integration, and global financial conditions. All regressors are lagged one quarter. Supply side (loans) consists of limits on credit growth, loan loss provisions, loan restrictions, and limits on foreign currency loans. Supply side (capital) consists of capital requirements, conservation buffers, the leverage ratio, and the countercyclical capital buffer. Supply side (general) consists of reserve requirements, liquidity requirements, and limits on foreign exchange positions. Demand-side includes limits to debt-service-to-income and LTV ratios. All loans measures include demand side and supply side (loans). Fiscal-based measures include taxes such as ad valorem, seller's and buyer's stamp duty, or other taxes.

[23] In some instances, fiscal-based measures target speculative investments, including by foreign buyers (see IMF 2018b).

VI. Conclusions

Using various proxies for global financial conditions, this paper confirms that the abundance of liquidity owing to accommodative financial conditions is positively associated with house price synchronicity at country and city levels. While higher house price synchronicity may benefit countries in some cases, positive association with global financial conditions could also suggest a stronger transmission of external shocks into the domestic economy or to major cities within an economy. Moreover, house price synchronicity dynamics among major cities may vary from that of their respective countries' owing to the attractiveness of these cities to global investors. Our analysis also finds that the positive association of global financial conditions with house price synchronicity was stronger preceding the global financial crisis.

Countries with more flexible exchange rate regimes, on average, may possess the ability to attenuate the positive impact of global financial conditions on house price synchronicity. Moreover, our empirical analysis suggests that major cities located in countries with more flexible exchange rate regimes possess the ability of attenuating the impact of global financial conditions on city-level house price synchronicity as well.

Finally, we find that house price growth in countries that experience lower house price synchronicity with the rest of the world, on average, are more sensitive to macroprudential policies that are aimed at reducing domestic vulnerabilities, compared to high synchronicity countries. However, our empirical analysis suggests that macroprudential policies intended at addressing domestic vulnerabilities also possess the unintended effect of reducing house price synchronicities, thereby allowing policymakers to regain partially control over local house price dynamics.

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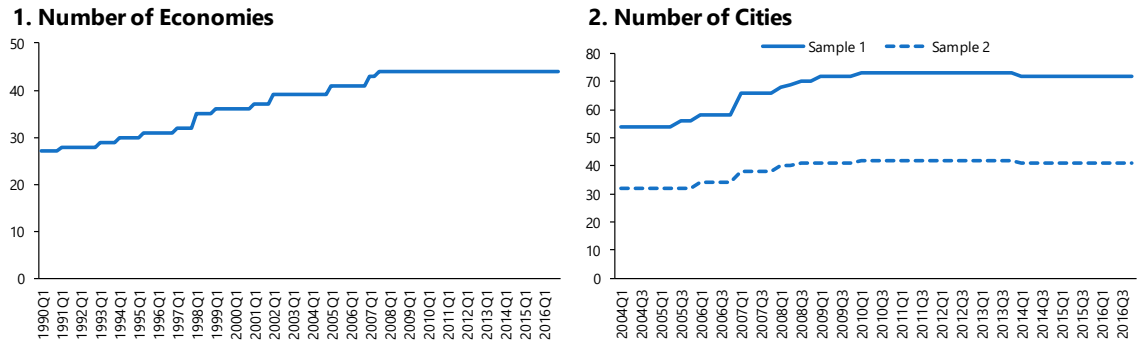
ANNEX I: DATA SOURCES, COVERAGE, AND SUMMARY STATISTICS

Annex Table 1.1. Data Sources

Variable	Description	Source
Country-Level Variables		
Real House Price Indices	Residential property prices (seasonally adjusted) at country level (also at city level)	Bank for International Settlements; CEIC Data Co. Ltd; Emerging Markets Econom Data Ltd; Global Financial Data Solutions; Global Property Guide; Haver Analytics IMF, Research Department house price dataset; Organisation for Economic Co-operation and Development; Thomson Reuters Datastream; IMF staff calculations
Real House Price Indices (long historical)	Annual nominal house prices starting 1870 for 17 advanced economies (adjusted for inflation)	Jordà-Schularick-Taylor Macrohistory database; IMF staff calculations
Real GDP	GDP at constant prices, seasonally adjusted	Haver Analytics; Organisation for Economic Co-operation and Development; IMF, Global Data Source database; IMF, World Economic Outlook database
Real GDP (long historical)	Annual real GDP starting 1870 for 17 advanced economies	Jordà-Schularick-Taylor Macrohistory database
Nominal GDP	GDP at current prices, seasonally adjusted (both in national currency and US dollars)	Haver Analytics; Organisation for Economic Co-operation and Development; IMF, Global Data Source database; IMF, World Economic Outlook database
Inflation	Percent change in the consumer price index	Haver Analytics; IMF, Global Data Source database; IMF staff calculations
Inflation (long historical)	Percent change in the consumer price index for 17 advanced economies starting 1870	Jordà-Schularick-Taylor Macrohistory database
Total Bank Claims and Liabilities	Total locational assets and liabilities vis-à-vis the world in percent of GDP	Bank for International Settlements; IMF staff calculations
Financial Openness	Foreign assets plus foreign liabilities in percent of GDP	Lane Milesi-Ferretti dataset (2007; updated)
Capital Account Openness	Chin-Ito index, measuring a country's degree of capital account openness	Chinn and Ito (2006) dataset (updated)
Exchange Rate Regime	De facto exchange rate regime of a country (variables based on 15 categories and 6 categories are used)	Ilzetzki, Reinhart, and Rogoff (2017) dataset
Macroprudential Policies	Macroprudential policy tools at quarterly frequency	Alam and others (forthcoming)
Bilateral-Level Variables		
Bilateral Bank Claims vis-à-vis Counterparty Economies	Bilateral locational cross-border claims on residency basis	Bank for International Settlements International Banking Statistics confidential datab
Bilateral Gross Trade vis-à-vis Counterparty Economies	Gross exports vis-à-vis counterparty economies	IMF, Direction of Trade database; IMF staff calculations
Global-Level Variables		
Global Liquidity	Total claims of all Bank for International Settlements reporters vis-à-vis the world, in percent of world GDP	Bank for International Settlements; Haver Analytics
US Financial Conditions Index	Positive values of the FCI indicate tighter-than-average financial conditions. For methodology and variables included in the FCI, refer to Annex 3.2 of the October 2017 *Global Financial Stability Report.*	IMF, October 2017 *Global Financial Stability Report* (Chapter 3)
Global Financial Conditions Index	Based on a PCA of all FCIs estimated; Positive values of the FCI indicate tighter-than-average financial conditions. For methodology and variables included in the FCI, refer to Annex 3.2 of the October 2017 *Global Financial Stability Report.*	IMF, October 2017 *Global Financial Stability Report* (Chapter 3)
VIX	Chicago Board Options Exchange Volatility Index	Haver Analytics
US Shadow Interest Rates	Wu-Xia and Krippner Shadow Federal Funds Rates	Bloomberg Finance L.P.; Haver Analytics

Source: Authors.
Note: FCI = financial conditions index; PCA = principal component analysis; VIX = Chicago Board Options Exchange Volatility Index.

Annex Figure 1.1. Sample Coverage



Source: Authors' calculations.
Note: Cities selected are the largest cities based on population, and overlap with the top 50 cities for global investors identified by Cushman & Wakefield (2017). The sample comprises over 70 cities based on the top 30 cities for global investors in Cushman & Wakefield's (2017) Global Capital Markets 2017 report's economic scale, financial center, technology hub, and innovation pillars are also used in robustness checks. If none of the cities in a country (where data are available) are chosen based on the four pillars stated above, the largest city by population in the country is included. Moreover, an additional sample with 44 major cities is also constructed.

Annex Table 1.2. List of Economies and Cities in the Analysis

Economies

Australia	Euro area	Italy	Singapore
Austria	Finland	Japan	Slovenia
Belgium	France	Korea	South Africa
Canada	Germany	Malaysia	Spain
Chile	Greece	Mexico	Sweden
China	Hong Kong SAR	Netherlands	Switzerland
Colombia	Hungary	New Zealand	Taiwan Province of China
Cyprus	India	Norway	Thailand
Czech Republic	Indonesia	Portugal	Turkey
Denmark	Ireland	Russia	United Kingdom
Estonia	Israel	Serbia	United States

Cities [1]

Amsterdam*	Dublin*	Manila*	Seattle
Athens*	Dusseldorf	Melbourne	Shanghai*
Atlanta	Frankfurt	Mexico City*	Shenzhen
Auckland*	Guangzhou	Miami	Singapore (core central region)*
Austin	Greater Stockholm*	Milan	Suzhou
Bangkok*	Hamburg	Montreal	Sydney*
Barcelona	Finland metro area*	Moscow*	Taipei*
Beijing	Hong Kong SAR (urban areas)*	Mumbai*	Tallinn*
Belgrade*	Houston	Munich	Tianjin
Berlin*	Inner Paris*	Nagoya	Tokyo*
Bogotá*	Istanbul*	New York*	Toronto*
Boston	Jakarta*	Osaka	Vancouver
Brussels*	Kuala Lumpur*	Oslo*	Vienna*
Budapest*	Lake Geneva Area	Philadelphia	Washington DC
Buenos Aires*	Lima*	Prague*	Zurich*
Chicago	Lisbon*	Rome*	
Copenhagen*	Ljubljana*	San Francisco	
Dallas	London*	South Santiago*	
Delhi	Los Angeles	Southern Seoul*	
Dubai*	Madrid*	São Paulo*	

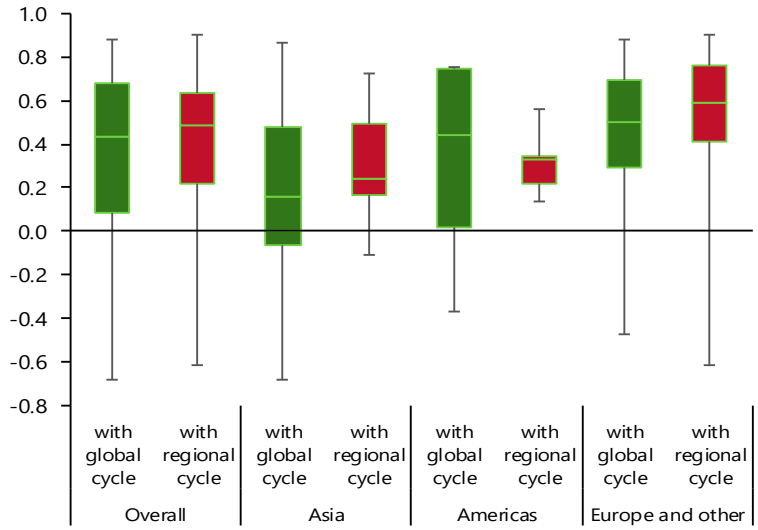
Source: Authors' calculations.
[1] See the Annex Figure 1.1 note above for city selection criteria. Cities with asterics are included in the smaller sample.

Annex Table 1.3. Standard Deviations of the Variables Used in Empirical Analyses

	Country-level	City-level
House price synchronization [Synch1]	0.10	0.10
Business cycle synchronization [Synch1]	0.01	0.02
House price synchronization [Quasi-correlation]	0.84	0.99
Business cycle synchronization [Quasi-correlation]	1.33	1.28
Bilateral bank integration of ij	1.04	0.97
Global factor (global liquidity)	**3.90**	**4.48**
Global liquidity : AE-AE pairs	2.51	3.09
Global liquidity : EM-EM pairs	0.95	0.95
Global liquidity : AE-EM pairs	2.84	3.10
Global liquidity : Sample with high capital account openness	2.84	3.25
Global liquidity : Rest of the sample	2.77	3.22
Global liquidity : Sample with high FX regime	1.01	1.93
Global liquidity : Rest of the sample	3.76	4.04
Global liquidity : Sample with high financial openness	1.11	0.71
Global liquidity : Rest of the sample	3.81	4.52
Global liquidity : Pre-crisis sample	2.13	1.99
Global liquidity : GFC sample	2.24	5.84
Global liquidity : Post-GFC sample	1.62	2.31
Analysis on the Impact of Macroprudential Policies:		
House price synchronization with the region [Quasi-correlation]	0.99	...
House price synchronization with the world [Quasi-correlation]	0.97	...
LTV	0.39	...
Fiscal-based measures	0.17	...
All measures	1.36	...
All loans	0.73	...
Demand side	0.51	...
Supply side	1.02	...
Supply side: general	0.79	...
Supply side: capital	0.40	...
Supply side: loans	0.39	...

Source: Authors' calculations.

Annex Figure 1.2. House Price Synchronicity with Global and Regional Cycles



Source: Authors' estimates.
Note: Panel 1 depicts distributions of the house price synchronization with global cycle (green) and regional cycle (red) for the overall sample (41 countries) and for each region: Asia (13), Americas (5), and Europe and Other (23). Top and bottom horizontal lines show min and max; top/middle/bottom box lines show 75th/50th/25th percentile of the distribution. The global cycle is computed as the median house price cycle across all countries. The regional cycle is the median house price cycle in each region. House price cycles are extracted using the band pass filter developed by Christiano and Fitzgerald (2003).

ANNEX II: ALTERNATIVE MEASURES OF HOUSE PRICE SYNCHRONICITY

A. Alternative Measure 1: Inverse Absolute Gap Difference (Synch1)

Following Kalemli-Ozcan et al. (2013a; 2013b), $HPsynch_{ijt}$ is calculated as the inverse of the absolute difference of house price gaps in country *i* and *j* at quarter t as below:

$$HPsynch_{ijt} = Synch1_{ijt} = -\left|HPgap_{it} - HPgap_{jt}\right|, \quad \text{(A2.1)}$$

where $HPgap_{it}$ and $HPgap_{jt}$ stand for house price gap of countries *i* and *j* respectively at quarter *t*.[24]

Empirical Strategy

Similar to equation 4 in Section III of this paper, we estimate the impact of business cycle synchronicity, bilateral financial linkages, and global financial conditions on house price synchronicity using Synch1 measure of house price synchronicity.

$$Synch1_{ijt} = \alpha_{ij} + \beta_1 BCS_{ijt-1} + \beta_2 FININT_{ijt-1} + \beta_3 GLOBAL_{t-1} + \beta_4 INST_{ijt-1} \text{ x } GLOBAL_{t-1} + \beta_5 INST_{ijt-1} + tr + \varepsilon_{ijt} \quad \text{(A2.2)}$$

where $Synch1_{ijt}$ is the synchronicity of house price gaps between country-pair *i* and *j* at quarter *t* measured as presented in equation A2.1 BSC_{ij} denotes business cycle synchronicity between country *i* and *j* measured as presented in footnote 24. All other independent variables are as same as in equation 4 introduced in Section III.

Results

Impact of Bilateral Linkages on House Price Gap Synchronicity

We estimate the impact of bilateral linkages—business cycle synchronicity (BCS) and bilateral banking integration—on house price synchronicity using $Synch1_{ijt}$ as an alternative measure of house price and business cycle synchronicity. Given $Synch1_{ijt}$ is perceived more as of a medium-term measure of synchronicity compared to the instantaneous quasi-correlation, while bilateral banking linkages are measured using stock of assets and liabilities from balance sheet side, we believe $Synch1_{ijt}$ is a better measure to capture the

[24] Business cycle synchronicity (BCS) measure is similar to the house price synchronicity measure presented above.

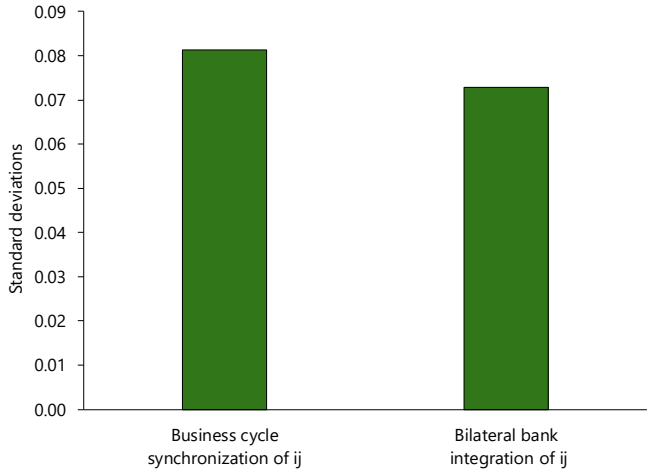
$$BCS_{ijt} = -\left|Ygap_{it} - Ygap_{jt}\right|,$$

where $Ygap_{it}$ and $Ygap_{jt}$ stand for output gap of country i and j respectively at quarter t and measured using Christiano and Fitzgerald band-pass filter (2003), with the maximum length adjusted for business cycles instead of financial cycles.

bilateral linkages that we are analyzing. The global factor that measures global financial conditions (more of a short-term indicator) is included in these specifications only as a control variable and to provide consistency across regression tables.

The results are presented in Table A2.1 below. We find that both BCS and bilateral banking integration have statistically significant positive association with house price synchronicity (columns 1 to 3). For comparability of the coefficients, we present the results of the baseline specification (column 4), further standardized in Figure 3. The figure suggests that the impact of both BCS and bilateral bank integration on house price gap synchronicity is comparable in magnitude.

Annex Figure 2.1. Impact of Bilateral Linkages on House Price Synchronicity



Source: Authors' estimates.
Note: Synchronicity is measured by the Synch1 of gaps measure. Figure shows statistically significant standardized coefficients that are calculated using the coefficients in specification 4 in Table 1 and their respective standard deviations and presented in terms of standard deviations of the dependent variable; this specification also controls for the global financial conditions (proxied through the global liquidity) in addition to country-pair fixed effects, quadratic and linear time trends (standard errors are clustered at multi-way at time, country i and country j). Standard deviation of the country-level dependent variable (synch1) is approximately 0.10; standard deviation of the country-level BCS (measured using synch1) is 0.01; standard deviation of the bilateral bank integration is 1.04. i = country 1 and j = country 2 in the country pair.

We also find that the impact of bilateral banking integration on house price gap synchronicity is lower among emerging market economy country pairs, compared to that of advanced economy country-pairs (column 5). Moreover, when both countries in the country-pair are de facto more financially open, the positive impact of bilateral banking integration on house price gap synchronicity is muted; this result is statistically significant at a 5 percent confidence interval (column 9). While the impact of banking integration on house price gap synchronicity is positive in our baseline specification in Table A2.1, we fail to find statistically significant impact for the post-GFC period (column 10).

Annex Table 2.1. House Price Gap Synchronicity at Country-Level and Bilateral Linkages

Dependent Variable: House Price Gap Synchronization of Country Pair i and j (Synch1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Business Cycle Synchronization of ij	0.766***	0.675**	0.733***	0.657**	0.658**	0.746***	0.725***	0.725***	0.675**	0.706**
	(0.254)	(0.293)	(0.243)	(0.254)	(0.253)	(0.262)	(0.261)	(0.262)	(0.253)	(0.337)
Bilateral Bank Integration of ij			0.006*	0.007**	0.012	0.009*	0.007**	0.007*	0.007**	0.004
			(0.003)	(0.003)	(0.007)	(0.004)	(0.003)	(0.004)	(0.003)	(0.005)
Global Factor (global liquidity)				-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.001
				(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Bilateral Bank Integration Interacted with:										
x EMEs-EMEs Dummy					-0.016*					
					(0.009)					
x EMEs-AEs Dummy					-0.009					
					(0.010)					
x High Capital Account Openness with the World						-0.005				
						(0.003)				
x High Exchange Rate Regime (ij) (15 categories; high = more flexible)							-0.005			
							(0.004)			
x High Exchange Rate Regime (ij) (6 categories; high = more flexible)								-0.001		
								(0.004)		
x High Financial Openness with the World (ij)									-0.019***	
									(0.004)	
GFC Period Dummy Interacted with:										
x Business Cycle Synchronization of ij										-0.080
										(0.516)
x Bilateral Bank Integration of ij										0.008**
										(0.004)
x Global Factor										0.001
										(0.001)
Post-GFC Period Dummy Interacted with:										
x Business Cycle Synchronization of ij										0.380
										(0.456)
x Bilateral Bank Integration of ij										0.007
										(0.005)
x Global Factor										0.004
										(0.003)
GFC Dummy										0.048***
										(0.011)
Post-GFC Dummy										0.042***
										(0.009)
Observations	65,450	65,343	49,384	49,384	49,384	43,871	46,708	46,708	47,353	49,384
R-Squared	0.353	0.498	0.386	0.356	0.356	0.361	0.356	0.356	0.360	0.360
Multiway Clustering	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Two-way
Group	All	All	All	All	All	All	All	All	All	All
Time FE and Country-Pair FE	Yes		Yes							
Time FE, Country-Pair FE, and country*time FE		Yes								
Quadratic Trend and Country-Pair FE				Yes	Yes	Yes	Yes	Yes	Yes	
Country-Pair FE										Yes

Source: Authors' estimates.

Note: GFC Dummy = a dummy variable that equals 1 during 2008–09, and zero otherwise. Post-GFC Dummy = a dummy variable that equals 1 curing 2010–16, and zero otherwise. All regressors are lagged by one quarter. Institutional characteristics dummies are included in specifications 5 through 9, but are not shown above (specifically, dummy variables for EMEs-EMEs, EMEs-AEs, high capital account openness, high exchange rate regime, high financial openness are included in specifications 5 through 9, but not shown). High = a dummy variable that equals 1 when both countries are in the top fifth of the institutional characteristic. Standard errors (in parentheses) are three-way clustered (at country i, country j, and date), with the exception of regression (10), in which errors are two-way clustered (at country i, country j). AEs = advanced economies; EMEs = emerging market economies; FE = fixed effects; GFC = global financial crisis.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

B. Alternative Measure 2: Pearson Correlations

In a separate exercise, regressions were run using a panel of three non-overlapping seven-year periods (in other words, three non-overlapping 28 quarter periods), in which the house price and business cycle synchronicity is captured by the bilateral Pearson correlation coefficients for the period. All other explanatory variables are the average values for the period. Further robustness checks in this exercise were employed by collapsing the other explanatory variables using the last value of the previous period instead. The interaction term of the global factor and foreign exchange regime continues to be statistically significant, in addition to the global factor itself (Table A2.2).

Annex Table 2.2. House Price Gap Synchronicity at Country Level and Global Factors—Pearson Correlations with 3 Non-overlapping Periods

Dependent Variable: House Price Gap Synchronization of Country Pair i and j	(1)	(2)	(3)	(4)
(Non-overlapping period-wise Pearson correlation)	Control variables collapsed by Mean		Control variables collapsed by last obs of previos period	
Business Cycle Synchronization of ij	0.104*	0.058	0.089	0.058
	(0.061)	(0.062)	(0.060)	(0.062)
Bilateral Bank Integration of ij	0.019	0.008	0.029	0.037
	(0.029)	(0.032)	(0.023)	(0.024)
Global Factor (global liquidity)	**0.013***	**0.019****	**0.043*****	**0.051*****
	(0.007)	(0.007)	(0.013)	(0.014)
Global Factor Interacted with:				
x High Exchange Rate Regime (ij) (15 categories; high = more flexible)		**-0.117*****		**-0.168*****
		(0.023)		(0.064)
Observations	1,660	1,553	1,660	1,553
R-squared	0.369	0.380	0.375	0.380
Clustering	country-pair	country-pair	country-pair	country-pair

Source: Authors' estimates.

Note: Pearson correlation coefficients of house price synchronicity are measured as $House\ Price\ Synch_{ijt} = PCORR_{ijt} = \frac{cov(HPgap_i, HPgap_j)}{\sigma_i^{gap}\sigma_j^{gap}}$, where Hpgapi and Hpgapj stand for house price gap of country i and j respectively, cov is the covariance, and σ is the standard deviation (business cycle synchronicity presented here is also measured similarly using pearson correlation coeficients of the output gaps). All regressors are lagged by one quarter. Institutional characteristics dummies are included in specifications, but are not shown above (specifically, dummy variables for high exchange rate regime). High = a dummy variable that equals 1 when both countries are in the top fifth of the institutional characteristic. Standard errors (in parentheses) are clustered as described above; FE = fixed effects.

*** p < 0.01; ** p < 0.05; * p < 0.1.

C. Alternative Measure 3: Synchronicity with Longer time series

The relationship between house price gap synchronicity and BCS is found to be positive and statistically significant when Jordà-Schularick-Taylor (2017) dataset is considered. This analysis contains annual observations from 1870 to 2013 for 17 advanced economies is used (Table A2.3). Additional analysis was limited by data availability.

Annex Table 2.3. House Price Gap Synchronicity at Country Level and Business Cycle Synchronicity—Estimations using Jordà-Schularick-Taylor Dataset—1870–2013

Dependent Variable: House Price Gap Synchronization of Country Pair i and j	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Synch 1				Quasi-correlation			
Business Cycle Synchronization of ij	**0.902****	**0.902****	**0.902*****	**0.902*****	**0.042**	**0.042***	**0.042*****	**0.042*****
	(0.385)	(0.311)	(0.153)	(0.089)	(0.032)	(0.024)	(0.015)	(0.008)
Observations	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818
R-squared	0.143	0.143	0.143	0.143	0.071	0.071	0.071	0.071
Clustering	Multi-way	Two-way	VCE robust	No	Multi-way	Two-way	VCE robust	No
Quadratic Trend and Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' estimates.
Note: See equations 1, 2, A2.1 and A2.2 for Synch1 and Quasi-correlation methodologies. Regressors are lagged by one year; FE = fixed effects.
*** p < 0.01; ** p < 0.05; * p < 0.1.

ANNEX III: METHODOLOGY—HOUSE PRICE INTERCONNECTEDNESS ANALYSIS

Following the methodology proposed by Diebold and Yilmaz (2014), we measure house price interconnectedness based on a large-scale vector autoregressive (VAR) model. The econometric framework is estimated separately using quarter-on-quarter house price growth rates at the country- and city-level, while controlling for global financial conditions. Within the VAR model, the interconnectedness is defined as the fraction of H-quarter-ahead forecast error variance of country/city j's house price growth that can be accounted for by country/city i's house prices growth dynamics.

Quarterly house price growth rates are computed using seasonally adjusted real house prices either at country-level or at city-level. Global financial conditions in this analysis are proxied by the U.S. Financial Conditions Index (FCI) constructed in line with IMF 2017.[25] The estimation period for the country-level analysis spans from 1990:Q1 to 2016:Q4, while for city-level interconnectedness analysis, owing to data limitations, is estimated for a period spanning from 2004:Q1 to 2017:Q2.

The number of countries and cities in our samples ─ that enters as the set of variables in the VAR setting ─ is large (n=30). Following Demirer et al. (2018), Song and Bickel (2011), the VAR is estimated using machine learning techniques such as lasso and elastic net which allow for the estimation of large-scale VARs.

The baseline house price interconnectedness specification we estimated can be described as follows:

$$Y_t = \alpha + \sum_{i=1}^{p} \gamma_i Y_{t-i} + \sum_{j=0}^{p} \beta_j X_{t-j} + u_t$$
$$u_t \sim iid(o, \Sigma_u)$$

, where Y stands for quarterly house price growth variavles for 32 countries or 30 major cities that enter as endogenous variables in the VAR setting. U.S. FCI is used to contol for global financial conditions, where robustness checks were performed with variables mentioned in the footnote 25.

[25] Robustness checks were performed using the global FCI and the VIX index, and results are found to be very similar.

ANNEX IV: IMPACT OF MACROPRUDENTIAL MEASURES ON HOUSE PRICE SYNCHRONICITY—REGRESSION RESULTS

Annex Table 4.1. Unconditional Estimation Sample

Dependent variable: house price gap synchronicity (quasi-correlation) with:	(1) Region	(2) World	(3) Region	(4) World	(5) Region	(6) World	(7) Region	(8) World	(9) Region	(10) World	(11) Region	(12) World	(13) Region	(14) World	(15) Region	(16) World	(17) Region	(18) World
Global factor (FCI)	-0.051	-0.084**	-0.050	-0.083**	-0.053	-0.086**	-0.052	-0.085**	-0.052	-0.084**	-0.052	-0.085**	-0.049	-0.083**	-0.058	-0.089**	-0.051	-0.084**
	(0.037)	(0.040)	(0.037)	(0.040)	(0.037)	(0.040)	(0.037)	(0.040)	(0.037)	(0.040)	(0.037)	(0.040)	(0.037)	(0.040)	(0.037)	(0.040)	(0.037)	(0.040)
Business cycle synchronicity with the region	0.028		0.030		0.029		0.028		0.029		0.029		0.030		0.027		0.029	
	(0.020)		(0.019)		(0.019)		(0.019)		(0.020)		(0.019)		(0.020)		(0.019)		(0.019)	
Bank integration with the region	0.013		0.012		0.013		0.013		0.013		0.012		0.012		0.013		0.013	
	(0.013)		(0.013)		(0.013)		(0.013)		(0.013)		(0.013)		(0.013)		(0.013)		(0.013)	
Business cycle synchronicity with the world		0.041**		0.043**		0.042**		0.042**		0.042**		0.043**		0.043**		0.041**		0.043**
		(0.020)		(0.019)		(0.019)		(0.019)		(0.020)		(0.019)		(0.019)		(0.019)		(0.019)
Bank integration with the world		0.027		0.026		0.027		0.027		0.027		0.027		0.027		0.028		0.027
		(0.020)		(0.020)		(0.020)		(0.020)		(0.020)		(0.020)		(0.020)		(0.020)		(0.020)
Macroprudential measures																		
LTV	-0.097**	-0.128***																
	(0.045)	(0.040)																
Fiscal-based measures			-0.132	-0.122*														
			(0.144)	(0.067)														
All measures					-0.027	-0.032**												
					(0.019)	(0.016)												
All loan-targeted							-0.064***	-0.064**										
							(0.022)	(0.025)										
Demand side									-0.077**	-0.059								
									(0.033)	(0.038)								
Supply side: all											-0.020	-0.026						
											(0.029)	(0.024)						
Supply side: general													0.042	0.012				
													(0.030)	(0.031)				
Supply side: capital															-0.230***	-0.174**		
															(0.074)	(0.071)		
Supply side: loans																	-0.092**	-0.123**
																	(0.044)	(0.055)
Observations	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520
R-squared	0.008	0.017	0.007	0.015	0.008	0.017	0.009	0.017	0.008	0.016	0.007	0.015	0.008	0.015	0.015	0.020	0.008	0.017

Source: Authors' estimates.

Note: All regressors are lagged by one quarter. Supply side (loans) consists of limits on credit growth, loan loss provisions, loan restrictions, and limits on foreign currency loans. Supply side (capital) consists of capital requirements, conservation buffers, the leverage ratio, and the countercyclical capital buffer. Supply side (general) consists of reserve requirements, liquidity requirements, and limits on foreign exchange positions. Demand-side includes limits to debt-service-to-income and LTV ratios. All loan-targeted measures include demand side and supply side (loans). Fiscal-based measures include taxes such as ad valorem, seller's and buyer's stamp duty, or other taxes. All regressions include country fixed effects. Robust standard errors are presented in parentheses.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Annex Table 4.2. Conditional on Positive Credit Gaps

Dependent variable: house price gap synchronicity (quasi-correlation) with:	(1) Region	(2) World	(3) Region	(4) World	(5) Region	(6) World	(7) Region	(8) World	(9) Region	(10) World	(11) Region	(12) World	(13) Region	(14) World	(15) Region	(16) World	(17) Region	(18) World
Global factor (FCI)	-0.127***	-0.159***	-0.128***	-0.159***	-0.127***	-0.162***	-0.127***	-0.161***	-0.127***	-0.160***	-0.127***	-0.160***	-0.125***	-0.158***	-0.133***	-0.165***	-0.127***	-0.160***
	(0.040)	(0.042)	(0.040)	(0.042)	(0.040)	(0.042)	(0.040)	(0.042)	(0.040)	(0.042)	(0.040)	(0.042)	(0.041)	(0.042)	(0.040)	(0.041)	(0.040)	(0.041)
Business cycle synchronicity with the region	0.043**		0.043**		0.043**		0.042**		0.043**		0.043**		0.044**		0.041**		0.042**	
	(0.019)		(0.019)		(0.019)		(0.019)		(0.019)		(0.019)		(0.019)		(0.019)		(0.019)	
Bank integration with the region	0.036***		0.036***		0.036***		0.036***		0.036***		0.036***		0.036***		0.037***		0.037***	
	(0.012)		(0.012)		(0.012)		(0.012)		(0.012)		(0.012)		(0.012)		(0.012)		(0.012)	
Business cycle synchronicity with the world		0.060***		0.062***		0.060***		0.060***		0.060***		0.061***		0.061***		0.059***		0.061***
		(0.017)		(0.017)		(0.017)		(0.017)		(0.017)		(0.017)		(0.017)		(0.017)		(0.017)
Bank integration with the world		0.056***		0.056***		0.058***		0.057***		0.057***		0.059***		0.058***		0.060***		0.058***
		(0.013)		(0.013)		(0.013)		(0.013)		(0.014)		(0.014)		(0.014)		(0.014)		(0.014)
<u>Macroprudential measures</u>																		
LTV	-0.028	-0.131*																
	(0.051)	(0.074)																
Fiscal-based measures			-0.257***	-0.178														
			(0.074)	(0.174)														
All measures					-0.011	-0.037												
					(0.021)	(0.027)												
All loan-targeted							-0.033	-0.082**										
							(0.025)	(0.037)										
Demand side									-0.023	-0.087								
									(0.039)	(0.054)								
Supply side: all											-0.004	-0.023						
											(0.038)	(0.039)						
Supply side: general													0.054	0.019				
													(0.048)	(0.047)				
Supply side: capital															-0.194**	-0.188*		
															(0.096)	(0.102)		
Supply side: loans																	-0.075	-0.142*
																	(0.046)	(0.074)
Observations	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139	2,139
R-squared	0.036	0.052	0.037	0.049	0.036	0.051	0.037	0.053	0.036	0.051	0.036	0.049	0.038	0.049	0.042	0.054	0.037	0.052

Source: Authors' estimates.

Note: All regressors are lagged by one quarter. Supply side (loans) consists of limits on credit growth, loan loss provisions, loan restrictions, and limits on foreign currency loans. Supply side (capital) consists of capital requirements, conservation buffers, the leverage ratio, and the countercyclical capital buffer. Supply side (general) consists of reserve requirements, liquidity requirements, and limits on foreign exchange positions. Demand-side includes limits to debt-service-to-income and LTV ratios. All loan-targeted measures include demand side and supply side (loans). Fiscal-based measures include taxes such as ad valorem, seller's and buyer's stamp duty, or other taxes. All regressions include country fixed effects. Robust standard errors are presented in parentheses.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.