Financial Stability Risks during the COVID-19 Crisis and Beyond—Online Annexes

Online Annex 3.1 Data Sources

Online Annex Table 3.1.1. Data Description and Sources

Variable	Description	Source
Macroeconomic and Financial Variables		
Bank Stock Returns	Refinitiv Datastream's bank sector return index	Refinitiv Datastream
Broad Money	Broad money, seasonally adjusted	IMF, World Economic Outlook
Break Even Inflation	10-years break even inflation rate	Bloomberg
Capital Flow Management Measures	Measures that are designed to limit capital flows	Fernandez and others (2017); and IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER)
Capital Inflows	Sum of portfolio investment and foreign direct investment	IMF, Balance of Payments database
Consumer Price Index	Consumer price index, percent	IMF, World Economic Outlook
CRE and CMSB Delinquency Rates	The percentage of CRE and CMBS loans within a financial institution's loan portfolio whose payments are delinquent	Trepp
CRE Capitalization rate	Net Operating Income per CRE value	MSCI Real Estate
CRE Investments	Investments in commercial real estate	Real Capital Analytics
CRE Prices	Asset value index	MSCI Real Estate
CRE Vacancy Rates	Total market rental value in vacant units / total market rental value	MSCI Real Estate
Credit-to-GDP Ratio	Private-sector credit in percent of GDP	Bank for International Settlements
Credit-to-GDP Gap	Deviation of Credit-to-GDP Ratio from the trend.	Bank for International Settlements
Financial Condition Index	For methodology and variables included in the FCI, refer to Annex 3.2 of the October 2017 Global Financial Stability Report. Positive values of the FCI indicate tighter-than-average financial conditions.	IMF staff estimates
Gross Domestic Product	Gross domestic product (GDP)	IMF, World Economic Outlook
Global Liquidity Indicator	The sum of bank loans to non-banks and debt securities issuance by non-banks	Bank for International Settlements
Long-Term Nominal Interest Rate	10-years government bond yield (Please confirm. Just used the shared dataset).	IMF, World Economic Outlook
Long-Term Real Interest Rate	10-years real interest rate index	Bloomberg
Macroprudential Measures: CRE-specific measures	Measures that are designed to limit the build-up of vulnerabilities in CRE sector	IMF, The integrated Macroprudential Policy (iMaPP) database, BIS Macroprudential Database, ESRB Macroprudential Measures Database, ESRB (2015, 2018, 2019)
Macroprudential Measures: Capital Requirements	Capital requirements for banks, which include risk weights, systemic risk buffers, and minimum capital requirements. Countercyclical capital buffers and capital conservation buffers are captured in their sheets respectively and thus not included here.	IMF, The integrated Macroprudential Policy (iMaPP) database
Macroprudential Measures: Limits on the Debt-Service-to-Income Ratio	Limits to the debt-service-to-income ratio and the loan-to-income ratio, which restrict the size of debt services or debt relative to income. They include those targeted at housing loans, consumer loans, and commercial real estate loans.	IMF, The integrated Macroprudential Policy (iMaPP) database
Macroprudential Measures: Limits on the Loan-to-Value Ratio	Limits to the loan-to-value ratios, including those mostly targeted at housing loans, but also includes those targeted at automobile loans, and commercial real estate loans.	IMF, The integrated Macroprudential Policy (iMaPP) database
Net Operating Income	Total net operating income for the period as an absolute amount	MSCI Real Estate
Net Operating Income Yield	Total net operating income for the period in percent of CRE value	MSCI Real Estate
Short-Term Nominal Interest Rate	Short-term deposit rate	IMF, World Economic Outlook
Policy Rate	Monetary policy rate and shadow rate by Leo Krippner(2013, 2015)	IMF, World Economic Outlook, Bank for International Settlements, Leo Krippner(2013, 2015)
VIX	CBOE Volatility Index	Refinitiv Datastream

Online Annex Table 3.1.1. Data Description and Sources (concluded)

Banking Variables		
Capital Ratio	Ratio of total bank equity capital to total assets	Call Reports; and IMF staff calculations
Commercial Real Estate Loans	The sum of construction, land development, and other land loans and loans secured by multifamily (5 or more) residential properties and loans secured by nonfarm nonresidential properties	Call Reports; and IMF staff calculations
Community Bank	Consistent with the FDIC (2012), a bank is defined as a community bank if the following conditions are satisfied: (i) the bank has total assets less than $1 billion (in 2010 terms), or (ii) if the bank has total assets higher than $1 billion (in 2010 terms), then its loan-to-assets ratio is higher than 33%, core deposits-to-total assets is higher than 50%, and number of states with offices is less than or equal to three. Even if a bank satisfies the criteria above, if it has no loans or no core deposits or foreign deposits-to-total deposits ratio greater than 10%, then that bank is labeled as a non-community bank.	FDIC (2012); and IMF staff calculations
Consumer Loans	Loans to individuals for household, family, and other personal expenditures (such as consumer loans) (includes purchased paper)	Call Reports; and IMF staff calculations
Liquidity Ratio	(Cash and balances due from depository institutions + securities + federal funds sold and securities purchased under agreements to resell) / total assets	Call Reports; and IMF staff calculations
Location	5-digit zip code (mapped to US Metropolitan State Area (MSA))	Call Reports; and IMF staff calculations
Net Commercial Real Estate Loan Charge-off Rate	Charge-offs minus recoveries summed over each CRE loan segment (see above), divided by commercial real estate loans	Call Reports; and IMF staff calculations
Residential Real Estate Loans	Loans secured by 1-4 family residential properties (revolving, open-end plus closed-end secured by first or junior liens)	Call Reports
Total Assets	Book value of total assets of a bank	Call Reports
Total Loans	The sum of residential real estate loans, commercial real estate loans, consumer loans and commercial and industrial loans	Call Reports; and IMF staff calculations
Corporate Investment Analysis Variables		
Accumulated Depreciation: Buildings	The portion of accumulated depreciation that relates to the reduction in the useful economic life of the plant, office complex or warehouse from the wear and tear on those buildings.	Refinitiv Datastream
Accumulated Depreciation: Land	The portion of accumulated depreciation that relates to the reduction in the useful economic life of land.	Refinitiv Datastream
Accumulated Depreciation: Rental and Lease Properties	The portion of accumulated depreciation that relates to the reduction in the useful economic life of rental/leased property.	Refinitiv Datastream
Age	Number of years since establishment. If establishment year is not available, number of years since incorporation.	Refinitiv Datastream; and IMF staff calculations
Buildings	The architectural structure used in a business such as a factory, office complex or warehouse	Refinitiv Datastream
Capital Expenditures	Funds used to acquire fixed assets other than those associated with acquisitions. It includes but is not restricted to additions to property, plant, and equipment, investments in machinery and equipment (net of disposal)	Refinitiv Datastream
Cash	Money available for use in the normal operations of the company (cash on hand/banks/in escrow, restricted cash, undeposited checks, checks in transit, money orders, letters of credit, non-interest bearing demand deposits)	Refinitiv Datastream
Dividend Payout Policy	=1 if the firm makes cash dividend payment within the calendar year, and 0 otherwise	Refinitiv Datastream
Land	Real estate without buildings held for productive use	Refinitiv Datastream
Location	Zip code (US) or postal code (matched to a city and country). Cross-checked with city names provided. If zip code or postal code is not available for a given firm, city name strings are used.	Refinitiv Datastream; and IMF staff calculations
Long-Term Debt	All interest bearing financial obligations, excluding amounts due within one year. It is shown net of premium or discount	Refinitiv Datastream
Price-to-Book Ratio	Ratio of market price-year end to book value per share	Refinitiv Datastream
Property, Plant, and Equipment	Gross property, plant and equipment less accumulated reserves for depreciation, depletion and amortization	Refinitiv Datastream
Rental and Lease Properties	Assets that the company owns and rents or leases to others	Refinitiv Datastream
Return on Assets	(Net Income Bottom Line + ((Interest Expense on Debt-Interest Capitalized) * (1-Tax Rate))) / Average of Last Year's and Current Year's Total Assets * 100	Refinitiv Datastream
Risk Rating	Moody's Expected Default Frequency (5-year)	Moody's
Sector	First-digit of the main sector of a firm	Refinitiv Datastream; and IMF staff calculations
Short-Term Debt	Total debt minus long-term debt, where total debt is all interest bearing and capitalized lease obligations	Refinitiv Datastream

Online Annex 3.2. Commercial Real Estate Prices and Fundamentals

Stylized Facts

The core sample of economies of the analysis in the Chapter include: Australia, Austria, Belgium, Canada, China, Czech Republic, Denmark, France, Germany, Hong Kong SAR, Hungary, Indonesia, Ireland, Italy, Japan, Korea, Malaysia, Netherlands, New Zealand, Norway, Poland, Portugal, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, United Kingdom, and United States.

A Structural Model for the Price-to-Net-Operating-Income Ratio

This section provides information on the methodology and sample used in the analysis of fair values and price misalignments in CRE markets.

Campbell-Shiller Decomposition. The analysis investigates the extent to which CRE prices reflect economic fundamentals and estimates the misalignment as a residual of actual CRE prices from those implied by fundamentals. Following Campbell and Shiller (1989), the CRE price can be expressed in terms of the current and expected growth of net operating income (NOI), and the current and expected total returns on CRE holdings:

$$\log\left(\frac{Price_t}{NOI_t}\right) = \kappa + \rho \log\left(\frac{Price_{t+1}}{NOI_{t+1}}\right) + \Delta \log(NOI_{t+1}) - Return_{t+1} \quad (1)$$

where $Price_t$, NOI_t and $Returns_t$ represent CRE prices deflated by CPI, net operating income deflated by CPI and total returns deflated by CPI during quarter t. The total returns are expressed as the sum of the real 3-month short-term interest rate and the spread of total returns over real 3-month rate. Namely, $Return_t = \frac{Price_t + NOI_t}{Price_{t-1}} \times 100 = Spread_t + 3MRate_t - Inflation_t$.

Structural vector autoregression. The variables in equation (1) are assumed to be determined in a general equilibrium framework, expressed as a structural vector autoregression (SVAR), as follows:

$$\boldsymbol{A}\boldsymbol{y_t} = \boldsymbol{B_0} + \boldsymbol{B}(L)\boldsymbol{y_{t-1}} + \boldsymbol{u_t} \quad (2)$$

where $y_t =$
$$\left(NOI\ Growth_t, Risk\ Premium_t, 3MRate_t, OutputGap_t, Inflation_t, CreditGap_t, \frac{BroadMoney_t}{Output_t}_t, \frac{CapitalFlow_t}{Output_t}\right)',$$
$\boldsymbol{A}$ is a matrix that captures the contemporaneous relation between variables, and $\boldsymbol{B}(L)$ captures the lagged effect from past shocks. The variables considered as economic fundamentals include output gap ($OutputGap_t$), CPI-based year-on-year inflation ($Inflation_t$), non-financial corporate credit-to-output gap ($CreditGap_t$), 3-month short-term interest rates ($3MRate_t$), broad money-to-output ($BroadMoney_t/Output_t$), and capital flow-to-output ($CapitalFlow_t/Output_t$). All variables except output gap and non-financial credit-to-output gap are demeaned. The output gap is estimated by HP-filtering GDP (the smoothing parameter is 1600). Credit-to-GDP gap is directly obtained from the Bank for International Settlements. As the NOI_t, $RiskPremium_t$, and $3MRate_t$ are affected by fundamentals according to equation

(1), the price would also be affected by these fundamentals. Note that the level of NOI can be written by $\log(NOI_{t+\tau}) = \log(NOI_t) + \sum_{k=0}^{\tau} \operatorname{dlog}(NOI_{t+k})$. Finally, $\boldsymbol{u_t}$ represents a vector of corresponding structural shocks.

By transforming the vector of variable $\boldsymbol{y}_t$ into companion form, it can be written as $\tilde{\boldsymbol{y}}_t = \mathbf{M}_0 + \mathbf{M}\tilde{\boldsymbol{y}}_{t-1} + \tilde{\boldsymbol{u}}_t$ where $\tilde{\boldsymbol{y}}_t = [\boldsymbol{y}_t, \boldsymbol{y}_{t-1}, \cdots, \boldsymbol{y}_{t-p}]'$, $\mathbf{M}_0 = [\boldsymbol{B}_0\ \mathbf{0} \cdots \mathbf{0}]'$, $\mathbf{M} = \left[[\boldsymbol{B}_1 \cdots \boldsymbol{B}_p; \boldsymbol{I}_{p\times p}]\ \mathbf{0}_{p\times 1}\right]$, $\boldsymbol{B}_i$ is the lagged coefficient with order i for $i = 1,2,\cdots,p$**,** and $\tilde{\boldsymbol{u}}_t = [\boldsymbol{u_t}\ \mathbf{0}_{p\times 1}]'$. $p = 2$ was chosen based on the robustness and explanatory power. The variables at time t can be decomposed as:

$$\tilde{\boldsymbol{y}}_t = \left(\boldsymbol{I}_{p\times p} - \mathbf{M}\right)^{-1}\mathbf{M_0} + \sum_{k=0}^{J} \mathbf{M^k}\tilde{\boldsymbol{u}}_{t-k} \quad (3)$$

Assuming $\tilde{\boldsymbol{y}}_t$ is detrended, the initial value and constant term are negligible.

CRE Price and Misalignment. The logarithm of CRE price can be written in terms of the sum of the logarithm of CRE Price-to-NOI plus the logarithm of NOI.

$$\log(Price_t) = \log\left(\frac{Price_t}{NOI_t}\right) + \log(NOI_t) = \log\left(\frac{Price_t}{NOI_t}\right) + \log(NOI_0) + \sum_{k=0}^{t} d\log(NOI_{t-k}) \quad (4)$$

Ignoring the $\log(NOI_0)$ on the right-hand side of the equation, the NOI can be determined by the SVAR, and the Price-to-NOI ratio can be primarily determined by the growth of NOI, risk premium, and interest rate (equation (1))**,** as well as the price misalignment. To measure the misalignment that cannot be sustained permanently, this exercise targets the logarithm of the Price-to-NOI ratio and NOI that are detrended with the Hodrick–Prescott filter. According to equations (1) and (3), the detrended logarithm of Price-to-NOI can be written as follows:

$$\begin{aligned}\log\left(\frac{Price_t}{NOI_t}\right) &= \sum_{j=0}^{\infty} E_t\rho^j\left(\Delta\log\left(NOI_{t+j+1}\right) - Return_{t+j+1}\right) + m_t \\ &= (\boldsymbol{d_{NOIGrowth}} - \boldsymbol{d_{RiskPremium}} - \boldsymbol{d_{3MRate}})\rho\mathbf{M}\left(\mathbf{I_{p\times p}} - \rho\mathbf{M}\right)^{-1}\tilde{\boldsymbol{y}}_t \\ &+ \boldsymbol{d_{Inflation}}\rho^2\mathbf{M^2}\left(\mathbf{I_{p\times p}} - \rho\mathbf{M}\right)^{-1}\tilde{\boldsymbol{y}}_t + m_t \quad (5)\end{aligned}$$

where m_t represents the misalignment and d_j represents a selection vector that takes the value one at the j-th element and zero otherwise. The misalignment can be interpreted as the component of the detrended log Price-to-NOI ratio that is not expected to be driven by economic fundamentals. Furthermore,

$$\begin{aligned}\log(Price_t) &= (\boldsymbol{d_{NOIGrowth}} - \boldsymbol{d_{RiskPremium}} - \boldsymbol{d_{3MRate}})\rho\mathbf{M}\left(\mathbf{I_{p\times p}} - \rho\mathbf{M}\right)^{-1}\tilde{\boldsymbol{y}}_t \\ &+ \boldsymbol{d_{Inflation}}\rho^2\mathbf{M^2}\left(\mathbf{I_{p\times p}} - \rho\mathbf{M}\right)^{-1}\tilde{\boldsymbol{y}}_t + \boldsymbol{d_{NOIGrowth}}\sum_{s=0}^{t}\tilde{\boldsymbol{y}}_{t-s} + m_t \quad (6)\end{aligned}$$

Hence the misalignment m_t in the Price-to-NOI ratio is in fact equivalent to the CRE price misalignment and reflects the component of the CRE price that cannot be explained by economic fundamentals. A positive (negative) value can be interpreted as over (under) confidence in the market future economic fundamentals that cannot be reconciled with the model. It may also include other factors that could cause mispricing such as mis-specification errors, numerical errors, parameter uncertainty, market interventions, etc.

Identification of Shocks in SVAR and CRE Prices. To model the impact of shocks to fundamentals on CRE prices, the model is extended to include the vacancy rate. This allows in turn to capture the CRE market-specific demand shock that generates movements in demand for CRE separately from shocks in aggregate demand. The model is thus extended as follows:

$$y_t = \begin{pmatrix} NOIGrowth_t, RiskPremium_t, 3MRate_t,\ OutputGap_t, Inflation_t, \\ \dfrac{Credit}{Output_t}, \dfrac{BroadMoney_t}{Output_t}, \dfrac{CapitalFlow_t}{Output_t}, VacancyRate_t \end{pmatrix}' \quad (7)$$

where $VacancyRate_t$ is the inverse logit-transformation of the vacancy rate. To investigate the underlying shocks affecting the market, the contemporaneous parameters need to be identified. Once the dynamics of economic fundamentals that drive CRE prices is expressed in terms of shocks, the dynamics of CRE prices could also be expressed as a sum of those shocks and the misalignments. This allows to simulate the impact of any additional shocks on CRE prices.

Sign Identification and Priors. To identify the contemporaneous parameters, the signs of the endogenous relations are defined following Baumeister and Hamilton (2015, 2018) in Online Annex Table 3.2.1.

Online Annex Table 3.2.1. Sign Assumptions

	Shock								
Variable	Supply	Demand	Conv. Monetary Policy	Spread	NOI Growth	Credit-to-Output	Broad money-to-output	Capital flow-to-output	Vacancy Rate
$Output\ Gap$	+	+	−			+	+	+	−
$Inflation$	−	+	−						
$3MRate$			+						
$Spread$				+	+				
$NOI\ Growth$	−	+	−		+		+		−
$Credit/Output$						+			−
$Broad\ Money/Output$							+		
$Capital\ flow/Output$								+	
$Vacancy\ Rate$		−	+		+		−		+

Similarly, prior parameter distribution and prior values are set following Baumeister and Hamilton (2015, 2018). The prior of the contemporaneous matrix $\mathbf{A}$ is set by truncated t-distribution to satisfy the above sign restrictions. Other prior parameters such as the magnitude of shocks (standard deviation of $\tilde{u}$) is given by the inverse Gamma distribution. The lagged structural coefficients $\boldsymbol{B}(L)$ are assumed to be normal and set by Minnesota priors.

Sample. The analysis in this section is performed country-by country over the period 2001:Q2 to 2019:Q4 for the following countries (unless stated otherwise): Australia, Canada, Denmark, Germany, Italy, Portugal, South Africa, Spain, Sweden, United Kingdom and United States.

Historical Decomposition. According to Equation (3), any variable in the SVAR could be written as the sum of past shocks. Ignoring the constant term, this implies the following:

$$\tilde{\boldsymbol{y}}_{\boldsymbol{t}} = \sum_{\boldsymbol{k=0}}^{\infty} \mathbf{M}^{\mathbf{k}} \tilde{\boldsymbol{u}}_{\boldsymbol{t-k}} \quad (8)$$

Similarly, the logarithm of the price could further be decomposed into fundamental shocks.

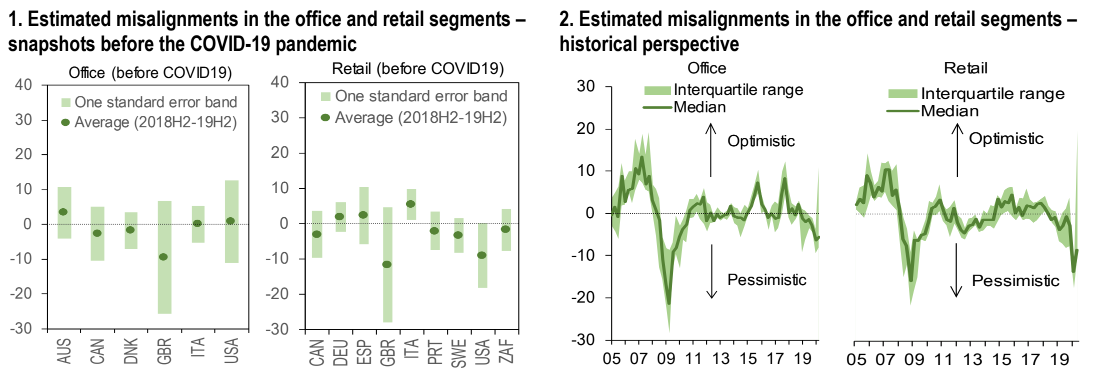
$$\log(Price_t) = \log(Price_0) + (\boldsymbol{d_{NOIGrowth}} - \boldsymbol{d_{RiskPremium}} - \boldsymbol{d_{3MRate}})\rho\mathbf{M}(\mathbf{I}_{\mathbf{p}\times\mathbf{p}} - \rho\mathbf{M})^{-1}\sum_{k=0}^{\infty}\mathbf{M}^{\mathbf{k}}\tilde{\boldsymbol{u}}_{t-k} + \boldsymbol{d_{Inflation}}\rho^2\mathbf{M}^2(\mathbf{I}_{\mathbf{p}\times\mathbf{p}} - \rho\mathbf{M})^{-1}\sum_{k=0}^{\infty}\mathbf{M}^{\mathbf{k}}\tilde{\boldsymbol{u}}_{t-k} + \boldsymbol{d_{NOIGrowth}}\sum_{s=0}^{t}\sum_{k=0}^{\infty}\mathbf{M}^{\mathbf{k}}\tilde{\boldsymbol{u}}_{t-s-k} + m_t \quad (9)$$

Using the fair value model and the estimated SVAR, the CRE price can be decomposed into the underlying economic shocks as well as the misalignments. Looking at the U.S., for example, the CRE fair price in 2020 is below the actual price (Figure 3.6 in the main text of Chapter 3). This can be mainly attributed to the large adverse demand shock resulting from the COVID-19 pandemic. By contrast, the drop in aggregate supply and loose monetary policy (proxied by broad money-to-output) have helped to lift fair values.

Segment Analysis

In addition to the total CRE market, misalignments in the office and retail segments are estimated using the valuation model described above. The segment analysis is performed for a narrower universe of countries due to data availability. Results are shown in Online Annex Figure 3.2.1.

Online Annex Figure 3.2.1. Misalignments in the office and retail segments



Sources: Bloomberg, L.P., Haver, MSCI Real Estate; and IMF Staff calculations
Notes: The misalignments are based on the estimated residuals of the fair-price model that is applied to the real CRE price deviations from trend.

Simulating CRE Prices

Once the contemporaneous parameters are identified, the simulation of the model is performed by adding one standard deviation permanent shock to the vacancy rate that represents CRE-specific demand shock in the structural shock vector u_t. The impulse response (Imp) is defined as the deviation of the simulated path of the prices forecasted under the shock to j ($u_{vacancy,t} = 1\sigma$) from the one forecasted without shocks ($u_{vacancy,t} = 0$). The impulse response at horizon T with the j-th shock is given by the following.

$$Imp(Price_{t+T}) = E\left[Price_{t+T}|\tilde{u}_{vacancy,t} = 1\sigma \; for \; all \; t \leq T\right] - E\left[Price_{t+T}|\tilde{u}_{vacancy,t+T} = 0 \; for \; all \; t \leq T\right] \quad (10)$$

Expectations are computed using the companion form $\tilde{y}_t = \mathrm{M}_0 + \mathrm{M}\tilde{y}_{t-1} + \tilde{u}_t$ and equation (5). Price-to-NOI and NOI can be simulated by forward iteration with respect to time. Since the model is linear, any given size of the shock can be performed by rescaling the impulse response. In panel 4 of Figure 3.6 (Chapter 3), the size of the shock is calibrated so that the vacancy rate would gradually increase on average by 5 percentage points in the next 10 years.

Online Annex 3.3. Macro-Financial Effects of Commercial Real Estate Prices

Growth-at-Risk Model

The potential amplification of CRE price misalignment on the downside risks to real GDP growth is assessed using the local projections approach in a quantile regression setting (see for example, Adrian and others 2019). The panel quantile estimation follows Canay (2011). The model specification is the following:

$$\Delta_h Y_{i,t,\tau} = \alpha_{i,\tau}^h + \beta_\tau^h \text{CRE Misalignment}_{\text{i,t}-1} + \theta_\tau^h Controls_{i,t-1} + \epsilon_{i,t,\tau}^h \quad (11)$$

where $\Delta_h Y_{i,t,\tau}$ denotes the (average) percentage change in real GDP growth in country i from the base quarter t to $t+h$ $(h = 1, 2, \ldots, 16)$, at a specific quantile τ (5[th] percentile). The indicator related to CRE Misalignment is the (sign inverted) deviation of log capitalization rate from a historical trend. Controls include lag GDP growth, financial condition index (purged of CRE price variation), credit-to-GDP gap and house price growth. The analysis uses unbalanced panel data for 30 economies (23 advanced and 7 emerging market economies) from 2000:Q1 to 2019:Q4. For robustness, (11) is estimated with an alternative panel quantile estimator following the Machado and Santos Silva (2019) approach. The model is also estimated on a smaller sample of countries using the misalignment measure described in Online Annex 3.2. Results are broadly consistent.

Bank-Level Analysis

Empirical Strategy. Combining Metropolitan-Statistical-Area (MSA)-level CRE price data with detailed information obtained from U.S. Bank Call Reports for the period of 2001:Q1-2020:Q3, the impact of changes in CRE prices on banks' performance is examined by estimating the following model:

$$Y_{b,t}^l = \alpha^k \cdot CRE\ Exposure_{b,t-k}^l * \Delta P_{t,t-k}^l \, \mathrm{I}\left(\Delta \mathrm{P}_{\mathrm{t,t-k}}^{\mathrm{l}} < 0\right) + \beta^k \cdot CRE\ Exposure_{b,t-k}^l * \Delta P_{t,t-k}^l + Controls_{b,t-k}^l + \mu_b + \eta_{l,t} + \varepsilon_{b,t}^l \quad (12)$$

where for bank *b*, $Y_{b,t}^l$ is i) the non-performing CRE loans (90+ days overdue)-to-total CRE loans ratio at *t*; (ii) the charged off CRE loans (net of recoveries)-to total CRE loans ratio at *t*; (iii) the log change in pre-provision net revenues from *t-k* to *t*; or (iv) the log change in total regulatory capital from *t-k to t*. *l* denotes the Metropolitan Statistical Area (MSA) where bank *b*'s headquarter resides.[1] $CRE\ Exposure_{b,t-k}^l$ denotes bank *b*'s exposure to CRE loans at *t-k*, measured as total CRE loans extended by its US-domiciled offices divided by its total assets.[2]

$\Delta P_{t,t-k}^l$ denotes (log) change in average CRE price index in MSA *l* from *t-k* to *t*. MSA-level CRE price indices are obtained from the MSCI Real Estate Portal. $\mathrm{I}\left(\Delta \mathrm{P}_{\mathrm{t,t-k}}^{\mathrm{l}} < 0\right)$ is an

[1] The location of each bank, as given by its 5-digit zip code in the Call Report, is matched to its MSA using US Census Bureau database.

[2] Banks' exposure to CRE prices is proxied by their outstanding CRE loans (relative to their total assets). In addition to CRE loans, banks' holdings of CRE-derived securities (CMBS) and real estate may also expose them to fluctuations in CRE prices.

indicator variable equal to 1 if $\Delta P^{l}_{t,t-k}$ is negative, and 0 otherwise, and is introduced to account for potential asymmetry as in Hirtle and others (2015) (e.g., declines rather than increases in prices are likely to trigger LTV constraints). $k \geq 1$ capture potential lags in the transmission. *Controls* is a set of key bank-level variables, all measured at *t-k*, such as the capital ratio, liquidity ratio, and (log) total asset size (see Online Annex Table 3.1.1. for the definition of variables). Interaction terms of these control variables with $\Delta P^{l}_{t,t-k}$, and the level of $CRE\ Exposure^{l}_{b,t-k}$ are also included. In addition, equation (12) includes bank fixed effects (μ_b), and location (MSA) *x* quarter fixed effects ($\eta_{l,t}$) to control for possible demand-side factors that may affect outcome variables. The key parameters of interest are α^k and β^k. For instance, following a decline in CRE prices from *t-8* to *t*, if banks with higher CRE loan exposure 8 quarters ago experience higher non-performing loans ratio in the current quarter, that would imply $\alpha^{k=8} + \beta^{k=8} < 0$.

The estimation is done via weighted least squares (WLS), where the weight of each bank at a given quarter is given by the log of its total assets. Standard errors are double clustered at the bank and quarter level, to account for potential correlation in error terms for a given bank (e.g., driven by management practices) or within a given quarter (e.g., driven by common shocks). For identification, the sample is restricted to MSAs with multiple banks, but the results are strongly robust to including single-bank MSAs in the analyses (there are 4 MSAs with a single bank headquarter).

The broad sample includes all banks that submit FFIEC 031 and 051 Report Forms (Call Reports). While there is a total of 10,796 banks over the entire sample period, the total number of banks changes from year to year, and there are 5,116 reporting banks in the last available quarter (2020:Q3). Due to data limitations on CRE prices, we focus on banks located in one of the 69 major MSAs for which CRE price indices are available–which on average cover more than 50 percent of total banking sector assets. The results are robust to using an expanded sample that include all banks.[3] While MSCI provides CRE price indices across different segments, for example, office, retail, industrial, lodging, for each MSA at a given quarter, such disaggregated segment-level data on bank loans is not available. Therefore, average CRE prices reported by the MSCI is used. A limitation is that banks are assumed to be exposed to CRE price changes in their headquarter MSAs. This is not as restrictive as it may a priori seem, since the majority (over 95 percent) of banks in the US are small or community banks which are geographically concentrated, and the results are robust to using these sub-samples of banks. Moreover, noise due to potential mismeasurement of CRE locations and prices are likely to induce an attenuation bias.

Capital Loss Scenario. Next, using estimated sensitivity of banks' CRE loan charge-offs rates and pre-provision net revenues to CRE price changes, a capital loss scenario is studied.

*Empirical Strategy***.** The procedure broadly follows the related literature on top-down stress tests (Hirtle and others 2015). For simplicity, CRE loan segments (construction, multi-family, and non-

[3] The results are qualitatively robust to expanding the sample by using average of MSA-level CRE prices within a state- or Census Bureau region, and accordingly, also including banks that are not located in one of these MSAs. The drawback of this approach is the incompatibility within the estimation equation regarding what is meant by location (*l*). In particular, "location"-specific CRE prices and location fixed effects cannot span the same geographical area by definition. Despite this drawback, the results are qualitatively similar.

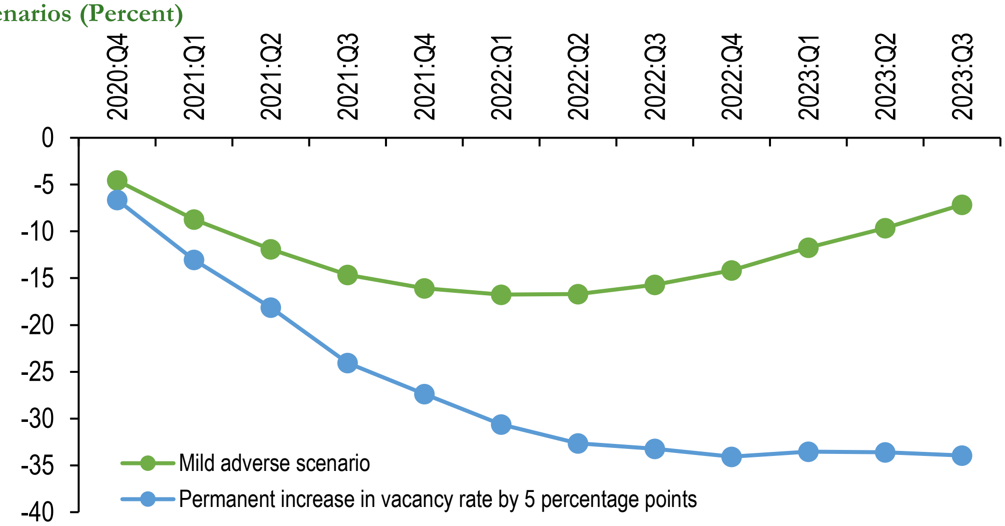
farm non-residential) are aggregated, and two major channels are studied: credit losses and decline in total pre-provision net revenues. Formally, we first estimate equation (12) with the dependent variable "(ii)", i.e., net CRE loan charge-off rate. Forwarding the estimated equation by *k* periods, we then calculate for each horizon *k*

$$Y^{l}_{b,t+k} = \left(\widehat{\alpha^{k}} + \widehat{\beta^{k}}\right) * CRE\ Exposure^{l}_{b,t} \ * \Delta P^{l}_{t+k,t} \quad (13)$$

where $\widehat{\alpha^{k}}$ and $\widehat{\beta^{k}}$ are the estimated values of α^{k} and β^{k} based on historical data. CRE prices are assumed to follow a path implied by the valuation model in Section 2, that amounts to, in the mild adverse scenario, a 1.15 percent permanent increase in the vacancy rate and a cumulative drop in CRE prices by 16 percent after 8 quarters (Online Annex Figure 3.3.2). An alternative scenario assumes a permanent increase in vacancy rates by 5 percentage points, as projected by the valuation model described in the previous section and implies about 30 percent decline in CRE prices in the long-run.

For transparency and due to lack of MSA-specific CRE price forecasts, a common price path across the MSAs is assumed. Having an estimate for CRE loan net charge-off rate at each future horizon *k*, $Y^{l}_{b,t+k}$, the next step is to multiply the projected charge-off rate with the projected amount of CRE loans to reach a dollar estimate of total CRE loan losses --at each forecast horizon and for each bank. Total outstanding CRE loans are assumed to decline by 2 percent quarterly for each bank.

Online Annex Figure 3.3.2. Cumulative Change in Average CRE Prices Under Different Scenarios (Percent)



Sources: MSCI Real Estate; and IMF staff calculations.
Notes: The Figure shows CRE price forecast scenarios based on different assumptions about permanent increase in the vacancy rate.

We assume that Allowance for Loan & Lease Losses (ALLL) due to CRE loan exposure is equal to four quarters of projected net CRE loan charge-offs, and calculate provision expenses accordingly (Hirtle and others 2015, Assumption 2 for Reserves and Provision Expense in the

CLASS Model).[4] Next, equation (12) is estimated with the dependent variable "(iii)", i.e. percentage change in pre-provision net revenues (PPNR). Using the PPNR in 2020:Q3 and estimated percentage change in the PPNR for a given CRE price scenario, PPNR losses (in dollar amounts) is estimated (for each horizon *k* and bank *b* using estimated coefficients). Finally, CRE-driven provision expenses and losses in the PPNR are summed and divided by pre-shock total risk weighted assets (2020:Q3).[5,6]

Assessing the Impact of CRE Prices on Corporate Investment

The empirical model for the baseline analyses is:

$$Investment_{i,t} = \beta \cdot RE\ Value_{i,baseline} * \frac{P_t^c}{P_{baseline}^c} + \gamma \frac{P_t^c}{P_{baseline}^c} + \sum_k k_k \cdot X_{k,baseline}^i \cdot \frac{P_t^c}{P_{baseline}^c} + [Controls]_{i,t} + \alpha_i^c + \delta_{s,t}^c + \epsilon_{i,t} \qquad (14)$$

where $Investment_{i,t}$ is the ratio of capital expenditures of firm *i* in year *t* normalized by the lagged value of properties, plant and equipment (PPE), $RE\ Value_{i,baseline}$ is the market value of real estate holdings of firm *i* in the baseline year normalized by lagged PPE.[7] $P_t^c / P_{baseline}^c$ is the change in CRE prices in city *c* (where *c* is the location of firm *i*'s headquarters) over the baseline year to year *t*.[8] $X_{k,baseline}^i$ is a set of firm-level characteristics that impact its real estate ownership decision in the baseline year (size, age, return on assets). *Controls* are the ratio of current cash flows to lagged PPE, the lagged ratio of market to book value of assets, the interaction of these controls with changes in the CRE prices. α_i^c and $\delta_{s,t}^c$ denote firm and city-sector(1-digit)-year fixed effects, respectively.

Robustness. The key results hold (i) across different sample periods (2004-2007; 2008-2009; 2010-2019); (ii) for small firms *within* cities (firms with total assets less than the 25 percentile of total assets of firms located within that city), for which potential impact of investment on real estate prices (potential reverse causality) would be much more limited (iii) and using alternative dependent variables such as change in PPE net of change in (book value of) real estate assets, or three-year forward looking investment (average capital expenditures in the current year and over

[4] An alternative empirical model could be to use ALLL as a dependent variable at the first place. However, ALLL is not as disaggregated as is the case for loan charge-offs (e.g., there is no reporting for CRE-related change in ALLL).

[5] Note that the procedure here is not intended to be comparable to a formal top-down stress test, where the whole balance sheet of banks are assumed under stress, and forecasts of macroeconomic variables (e.g., GDP growth, unemployment, term spreads or stock market returns/volatility) are also incorporated. Rather, it estimates the marginal impact of a decline in CRE prices on bank capital through credit and revenue losses, for a given macroeconomic scenario and regulatory capital rules over the forecast horizon. Moreover, idiosyncratic differences across banks are assumed away as commonly assumed in top-down approaches.

[6] In extensions of the capital loss scenario analysis, macroeconomic effects can also be incorporated by including location x quarter fixed effects in the forecast horizon, $\eta_{l,t+k}$ in equation (13) and assuming a path for $\eta_{l,t+k}$ (for k=1, 2, … 8).

[7] To estimate the market value of real estate holdings, we follow Chaney and others (2012). In particular, we first estimate average age of Buildings of a firm, by choosing a baseline year and assuming a depreciable life of 40 years: AgeInBaselineYear= (Accumulated Depreciation on Buildings)/Buildings x 40 . The market value of Buildings is then computed by inflating the book value of Buildings with city-level CRE prices. The same calculations are done for Land (assuming no depreciable life), and Rental and Lease Properties (assuming 40 years depreciable life).

[8] The underlying assumption is that firms hold most of their real estate assets within the city of their headquarters. This assumption is typically made in the literature due to lack of data on the exact location of firms' real estate holdings.

the next 2 years) to account for the longer time that firms might take to invest following an increase in collateral values; or using firm-level investment adjusted by the overall investment of firms within the same 1-digit sector (to account for the possibility that investment might be concentrated in specific sectors where firms tend to own real estate –which is already partially accounted for via sector fixed effects in the baseline model). Finally, the results are robust to the choice of the baseline year (including 2004, 2008, 2010).

Limitations. There are a few limitations worth mentioning. First, there is no data available on the exact location of firms' real estate holdings. As is also assumed in the related literature, it is assumed that firms tend to hold most of their real estates in the city of their headquarters. Note that the unavailability of exact location of firms' real estate holdings essentially leads to attenuation bias in the estimates, implying the estimates would likely be stronger if data were available. Second, the empirical strategy itself is tailored to mitigate potential causality from investment (left hand side variable) to market value of real estate holdings (right hand side variable). This is essentially achieved via fixing firms' real estate holdings at a baseline year (and inflating its value over the subsequent years via location-specific CRE prices). Still, firm investment could affect commercial real estate prices, especially for large firms (note that the results are robust to focusing on small firms within cities). As shown below, this does not pose a significant concern. In particular, we follow Chaney and others (2012) and instrument CRE prices in the U.S. via land supply constraints following Saiz (2010). In particular, we first estimate

$$P_t^c = \alpha^c + \delta_t + \gamma\ [Land\ Supply\ Elasticity]^c\ x\ IR_t + \varepsilon_t^c \quad (15)$$

where IR_t is the 30-year Treasury bill rate. We would expect a larger effect of a drop in interest rates in cities where land supply is more constrained. Indeed, the results point to an estimate of 0.0155 (p-value: 0.0017) for γ , with an adjusted R^2 of 0.95 and N=880. Using the estimated P_t^c (first-stage regression), we next estimate market value of real estates by using the estimated P_t^c and re-run the baseline equation as the second-stage regression (for the US only sample). The results are strongly robust. The estimated coefficient for our focus variable, β, is reduced from 0.033 to 0.031 while preserving its significance at the 0.01 level.

Online Annex 3.4. The Impact of Policies on CRE Prices

This section describes the methodology used to analyze the impact of policies on CRE prices. The set of policy measures includes macroprudential and capital flow management measures. The analysis uses unbalanced panel data for 30 economies (23 advanced and 7 emerging market economies) from 2000:Q1 to 2019:Q4.

To understand the link between policies and CRE prices, a quantile regression model is used to assess the impact of policy measures on the 5th percentile of the distribution of future changes in CRE prices. The baseline panel quantile model to be estimated is as follows:

$$\Delta_h Y_{i,t,\tau} = \alpha_{i,\tau}^h + \beta_\tau^h \Delta MPP_{i,t} + \gamma_\tau^h MP_{i,t} + \theta_\tau^h Controls_{i,t-1} + \epsilon_{i,t,\tau}^h \quad (16)$$

where $\Delta_h Y_{i,t,\tau}$ denotes the (average) percentage change in real CRE prices in country i from quarter t to quarter $t+h$ $(h = 1, 2, \ldots, H)$, at a specific quantile τ. $\Delta MPP_{i,t}$ is the change in macroprudential policy stance, $MP_{i,t}$ is the monetary policy shock, $Controls$ are control variables including (lagged) real GDP growth, changes in credit-to-GDP ratio, capital inflows to GDP ratio, the VIX index, and α_i^h are country fixed effects.

In the analysis two different categorizations are made of the macroprudential policies.[9] The first one considers *targeted* measures ("CRE-specific") that apply specifically to the CRE sector and limit *borrowers*' access to bank credit (such as CRE-specific loan-to-value (LTV) ratio or debt-servicing ratio (DSR)), or enhance *banks*' resilience and increase the cost of CRE lending through higher risk weights or sectoral capital buffers for CRE exposures. CRE-specific measures are defined as categorical variable taking values -1, 0, or 1 if there was a loosening action, no change, or a tightening action respectively in a quarter. The indicators are purged of credit-to-GDP to address potential endogeneity concerns. Online Annex Table 3.4.1. shows examples of CRE-specific measures implemented across the countries in the core sample.

The second categorization of macroprudential interventions consider instead *borrower-based measures* that include measures targeting the residential segment and could have an indirect effect on other segments of the CRE market. These are based on a two-year rolling sum of the individual measures (with +1=tightening, 0=no change, -1=loosening). Similarly, to the previous category, also these measures are purged of credit-to-GDP to address potential endogeneity concerns.

The monetary policy shock is captured by the predicted residual of a regression of the policy rate on contemporary and lagged macro variables (such as real GDP, inflation and stock returns) as well as a quadratic time trend as in Iacoviello and Navarro (2019). For some countries (US, Euro

[9] Information on macroprudential policies will be obtained from the IMF's integrated macroprudential policy(iMaPP) database (Alam and others, 2019) as well as BIS and ESRB's policy databases.

Area, UK, Japan, Switzerland, Canada, Australia, New Zealand), the shadow rate by Leo Krippner[10] is used as the policy rate to capture the unconventional monetary policy.[11]

Finally, the model evaluates the association between capital flow management measures and downside risks to CRE prices as follows:

$$\Delta_h Y_{i,t,\tau} = \alpha_{i,\tau}^h + \beta_\tau^h \Delta CFM_{i,t} + \gamma_\tau^h MP_{i,t} + \theta_\tau^h Controls_{i,t-1} + \epsilon_{i,t,\tau}^h \quad (17)$$

where $\Delta CFM_{i,t}$ is the change in capital flow management measures. The capital flow management measure is the overall capital inflow restrictions index or the real-estate-specific capital inflow restriction index from the Fernández and others (2017) database updated with the most recent policy announcements. The indices are based on a two-year rolling sum of individual measures (with +1=tightening, 0=no change, -1=loosening) and purged from variations in capital flows-to-GDP.

[10] The shadow rates are available on https://www.ljkmfa.com/test-test/international-ssrs/.

[11] For robustness check, we also consider different model specification with additional variables. First, when calculate the monetary policy shocks, we also consider the actual policy rate and the shadow rate by Wu and Xia (2016).

Online Annex Table 3.4.1. CRE-Specific Macroprudential Policies

Country	Date	Description
Denmark	Jun. 2003	60% LTV limit on recreational dwellings, office properties and retailing properties, industrial properties and craftsman's properties, collective energy-supply plants.
Hong Kong SAR	Feb. 2013	10 pp lower LTV limit on mortgage loans for all commercial and industrial properties
Hong Kong SAR	May 2017	Lower the applicable DSR limit by 10 percentage points for mortgage to borrowers whose income is mainly derived from outside of Hong Kong SAR
Indonesia	Jun. 2012	LTV limit of 70% on 2nd loan for an office/shop house; 60% for 3rd or more loans for an office/shop house
Indonesia	Jun. 2015	Lifting LTV ratio for property (including office houses) loans
Indonesia	Aug. 2016	Lifting LTV limit on office houses based on banks' internal policy (first loan), 85% (second loan), 80% (third loan or more)
Indonesia	Jun. 2018	Lifting regulatory limits on the first mortgage on home stores/home offices
Ireland	Jan. 2007	Minimum risk weight on commercial property lending increased from 50% to 100%
Ireland	Jan. 2014	Minimum risk weight applied to commercial property lending was increased to 100% from 50%
Norway	Sep. 2014	Risk weight of 100% on CRE lending for banks using the standardized approach
Poland	Jan. 2005	100% risk weight on non-residential property
Poland	Jun. 2014	75% or 80% LTV limit on CRE loans if the part above 75% is insured or collateralized with funds on bank account, government or NBP securities
Poland	Dec. 2017	For banks using the Standardized Approach to determine capital requirement: 100% risk weight on exposures secured by commercial immovable property located in Poland
Singapore	Jan. 2013	Seller's stamp duties for industrial properties
Singapore	Jun. 2013	Total Debt Servicing Ratio (TDSR) to the loan applied for both residential and nonresidential property (e.g., industrial and commercial property), and covers property both in- and outside of Singapore
Sweden	Jan. 2014	Risk-weight floor framework for commercial mortgages at 100% for exposures calculated according to the standardized approach for credit risk
United Kingdom	Jan. 2014	Stricter criterion requirement for firms to determine whether the annual average loss rates for lending secured by mortgage on commercial real estate in the UK did not exceed 0.5% over a representative period
United Kingdom	Oct. 2014	Stricter criteria for the eligibility of the 50% risk weight (RW) exposures fully and completely secured by mortgages on commercial real estate located in non-EEA country entered into force
United States	Dec.2006	Guidance to banks with high CRE risk concentrations to tighten managerial controls
United States	Jan. 2015	150% risk weight on High-Volatility Commercial Real Estate (HVCRE) exposure held by a banking organization
United States	Dec.2016	Implementation of risk retention rule. The risk retention rules require that at least one sponsor of a securitization (or its majority owned affiliate) retain a 5 percent interest in the credit risk of the securitized assets.

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