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Commercial Real Estate and Financial Stability: Evidence from the US Banking Sector

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This note analyzes the implications of changes in commercial real estate (CRE) prices for the stability of the US banking sector. Using detailed bank-level and CRE price data for US metropolitan statistical areas, the analysis shows that, following a decline in CRE prices, banks with greater exposures to CRE loans perform worse than their counterparts, experiencing higher non-performing CRE loans, lower revenues, and lower capital. These effects are particularly pronounced if the drop in CRE prices turns out to be persistent because of possible structural shifts in CRE demand—for example, because of an increased trend toward e-commerce and teleworking—even after the coronavirus disease (COVID-19) pandemic is over. The impact of a decline in CRE prices is especially true for small and community banks, which tend to have the highest CRE loan exposures. While the US banking sector has remained resilient during the pandemic crisis due to strong capital buffers and massive policy support, these findings suggest that continued vigilance is warranted with regard to potential downside risks to CRE prices amidst ongoing structural shifts in the sector.

INTRODUCTION[†]

The commercial real estate (CRE) sector in the United States has been hit hard during the COVID-19 pandemic. Following lockdown measures introduced to contain the spread of the virus and the associated decline in social mobility, the demand for contact-intensive CRE spaces such as traditional brick-and-mortar retail, restaurants, hotels, and offices plunged significantly in 2020. Consequently, CRE transaction volumes and prices, particularly, in the hotel, retail, and office segments, declined sharply (Figure 1). Compared to other regions, the decline in CRE transactions and prices has been more pronounced in the United States.

While the adverse shock to the CRE sector could be considered as temporary, at least partly reversing as the pandemic is brought under control and the economy recovers, the preexisting structural trends towards increased digitalization, e-commerce, and working-from-home—which have further accelerated during the pandemic crisis—create considerable uncertainly around the outlook for the sector and suggest that further price declines may be possible, at least in some CRE segments. Given the heavy reliance of the sector on bank financing in the United States,[1] a significant downward pressure on CRE valuations as a result of a persistent

[†] I would like to thank Andrea Deghi, Fabio Natalucci, Mahvash S. Qureshi, and Jérôme Vandenbussche for very helpful suggestions and comments, and Zhi Ken Gan for excellent assistance with the data.

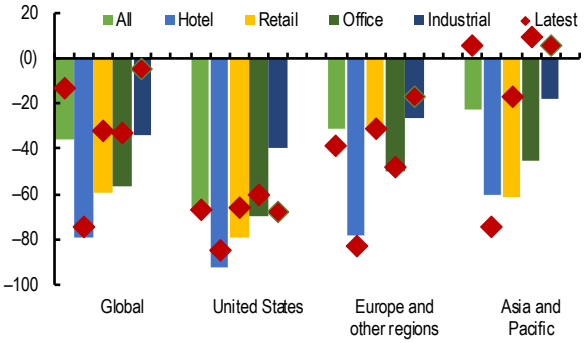
[1] Banks are the largest providers of CRE debt financing in the US and globally, but nonbank financial institutions such as pension funds, insurers and investment funds also play an important role. The share of total outstanding CRE debt held by banks is 54 percent in the US

drop in demand could be a potential source of stress for banks, especially for those with large CRE exposures, and pose financial stability risks (IMF, 2021).[2]

Figure 1. Commercial Real Estate Prices and Transaction Volumes during the COVID-19 Crisis

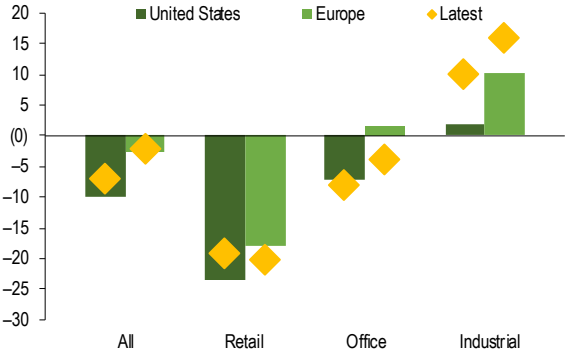
Total volume of CRE transactions in the US decreased significantly

1. Change in Commercial Real Estate Transaction Volumes (Percent, 2020:Q2 and latest, year-over-year)



Prices in the retail and office segments plunged

2. Commercial Real Estate Price Growth Rate (Percent, 2020:Q2 and latest, year-over-year)



Sources: Green Street Advisors; Real Capital Analytics; and author calculations.
Note: Panel 1 shows the year-over-year percent change in CRE transactions in the United States and other regions. Panel 2 shows the percent change in average CRE prices, based on appraisal values for different CRE segments in the United States and Europe. Latest corresponds to 2020:Q3 or later, depending on data availability. CRE=commercial real estate.

Against this backdrop, this note uses detailed US bank-level data and location-specific CRE prices over the period 2001–2020 to investigate the following questions:

- How does a decline in CRE prices affect banks' profitability and solvency?
- How large bank capital losses could be if CRE prices were to remain depressed permanently?

To address these questions, the analysis proceeds in three steps. First, the effect of CRE loan exposure on bank performance is empirically identified. Next, these estimates are used to conduct a capital loss scenario, which assesses the credit and revenue losses that banks may incur under different CRE price forecasts, and potential bank capital losses based on a forward-looking provisioning rule.[3]

The findings show that, following a decline in CRE prices, banks with ex-ante higher CRE loan exposures perform considerably worse. They experience a significantly higher CRE non-performing loans ratio, higher CRE loan charge-off rates, lower revenues, and lower capital. Bank capital losses are estimated to be modest on average under a variety of CRE price scenarios, but significantly larger for small and geographically concentrated community banks, especially if the CRE price drop were to be persistent. As such, policymakers should remain vigilant amidst ongoing structural shifts in the CRE sector, and may benefit from maintaining the frequency of stress tests for small/community banks to assess financial stability risks in a timely way.[4]

(and about 70 percent in Europe and Asia), while that held by nonbank financial institutions is 24 percent in the US (and less than 20 percent in Europe and in Asia; IMF, 2021).

[2] Lower CRE prices–which generally coincide with lower economic activity and reduced cash flow for firms–could affect financial stability by adversely impacting the credit quality of borrowers. Concurrently, loan-to-value (LTV) constraints may also be triggered, especially when the price drop is steep and/or for loans with already high LTV ratios. In extreme cases, a loan balance could even be worth more than the property value, making it excessively risky for lenders to retain the exposure, in particular if the price drop appears persistent. Eventually, following an increase in non-performing CRE loans and lower revenues, bank capital could decline (D'Erasmo, 2019).

[3] Identifying how changes in CRE prices could affect bank capital ideally requires supervisory loan-level data and a real-time appraisal value of real estate assets backing each loan. Such granular data is not publicly available, and the analysis in this note relies on bank-level data on CRE loan exposures (Call Reports) and Metropolitan Statistical Area (MSA)-level data on average CRE prices (obtained from the MSCI).

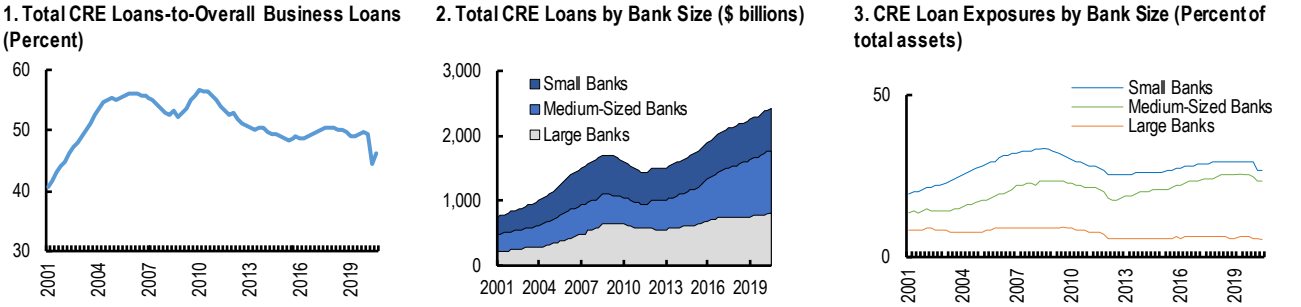
[4] See IMF (2020) for a detailed assessment of US financial system stability and policy recommendations to strengthen financial system resilience.

BANK FINANCING OF THE COMMERCIAL REAL ESTATE SECTOR

Commercial banks are important players in the CRE debt market in the US, and CRE lending is a significant component of their overall business lending.[5] On average, CRE loans accounted for nearly half of the total business loans made by banks over the last decade (Figure 2, panel 1). Beyond the sheer volume, which surpassed $2.3 trillion prior to the pandemic, a disproportionately large share of these loans has been extended by small- and medium-sized banks (defined as banks with total assets less than $100 billion). Although such banks collectively account for about 30 percent of total banking sector assets, they hold a much larger share (two-thirds) of overall CRE loans (Figure 2, panel 2). CRE loans also make up a significant share of US banking sector assets, constituting about 6 percent for large banks and 30 percent for small banks (Figure 2, panel 3).

Figure 2. Commercial Real Estate Loans in the United States

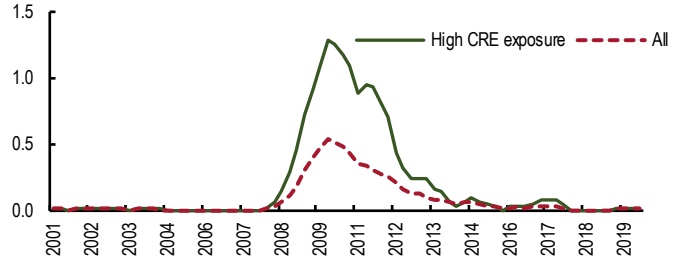
CRE loans make up a significant fraction of overall business lending, and are mostly concentrated in smaller banks.



Sources: Call Reports; and author calculations.
Notes: Panel 1 shows the ratio of total CRE loans to the sum of total business and CRE loans by US banks. Panel 2 shows total CRE loans made by banks of different sizes, with banks considered as small if their total assets do not exceed $5 billion during the sample period (2001:Q1–2020:Q3), as medium if their total assets exceed $5 billion at least once but do not exceed $100 billion, and as large if their total assets exceed $100 billion at least once. Panel 3 shows the total CRE loans-to-total assets ratio. CRE = commercial real estate.

A high bank exposure to CRE loans can raise financial stability concerns. In fact, high CRE loan exposures have historically been a key determinant of bank failures in the US, as observed for instance in the aftermath of the global financial crisis during which overall CRE prices declined by 30 percent (Figure 3).[6] The high concentration of CRE loans in smaller banks is also a cause for concern, as these banks tend to have a lower capacity to raise external funds especially during episodes of market stress (Kashyap and Stein 2000). Given that these banks have more geographically concentrated exposures,[7] stress in these banks could have important regional implications.

Figure 3. Commercial Bank Failure Rate in the United States (Percent)



Sources: Federal Deposit Insurance Corporation; and author calculations.
Note: The figure plots the frequency of failures for commercial banks with "high CRE exposure" versus failures for all banks in the United States. High CRE exposure is defined according to the Federal Reserve Guideline "Concentration in Commercial Real Estate Lending, Sound Risk Management Practices" and meet the following criteria: CRE loans of the institution increased by at least 50 percent over the past 3 years, and outstanding CRE loans are at least three times the institution's total risk-based capital. CRE = commercial real estate.

[5] The Federal Deposit Insurance Corporation (FDIC) Banker Resource Center defines CRE lending as *"… acquisition, development, and construction financing and the financing of income-producing real estate."*, where *"(I)ncome-producing real estate includes real estate held for lease to third parties and nonresidential real estate that is occupied by its owner or a related party."* For a detailed overview of the US banking sector's exposure to CRE market developments, see Adams-Kane (2018).

[6] In the context of the global financial crisis, Cole and White (2012) find that real estate construction and development loans, commercial mortgages, and multi-family mortgages were significantly associated with a higher likelihood of bank failure, whereas residential single-family mortgages did not play a significant role.

[7] Based on FDIC Survey of Deposits database, more than 90 percent of small banks (in particular, banks with total assets that never exceed $5 billion throughout our sample period) have offices in a single state and in at most two metropolitan statistical areas (MSAs). In contrast,

CRE PRICE CHANGES AND BANK STABILITY

The empirical analysis shows that a decline in CRE prices has a significant impact on bank CRE loans, revenues and capital.[8] Following a decline in CRE prices, banks with ex-ante higher CRE loan exposures experience significantly higher CRE non-performing loan ratios and CRE loan charge-off rates (Figure 4, panel 1a). As CRE loans underperform and the resulting provisioning expenses are higher for banks with a greater CRE exposure, they experience a stronger decline in pre-provision net revenues and regulatory capital (Figure 4, panel 2a).

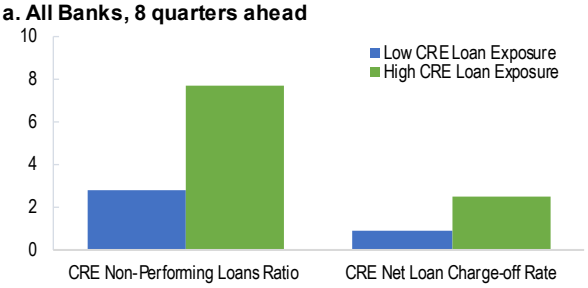
Figure 4. Commercial Real Estate Price Decline and Bank CRE Loans, Revenues and Capital

For banks with high CRE exposures, a drop in CRE prices leads to a higher share of nonperforming CRE loans and higher loan charge-offs…

…as well as lower bank revenues and capital.

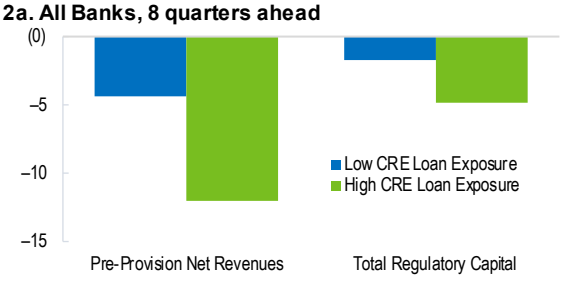
1. Change in CRE Loan Portfolio Performance of Banks with High vs. Low CRE Exposures (Percentage points)

1a. All Banks, 8 quarters ahead

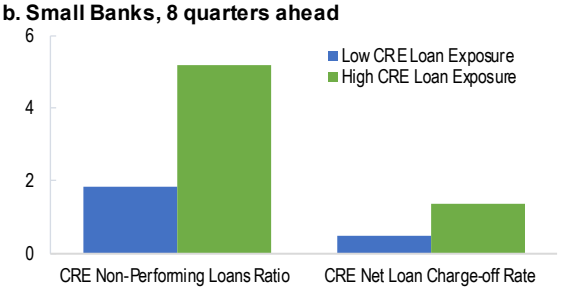


2. Change in Revenue and Risk-Based Capital of Banks with High vs. Low CRE Exposures (Percent)

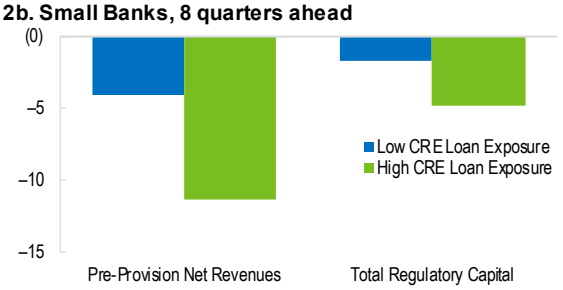
2a. All Banks, 8 quarters ahead



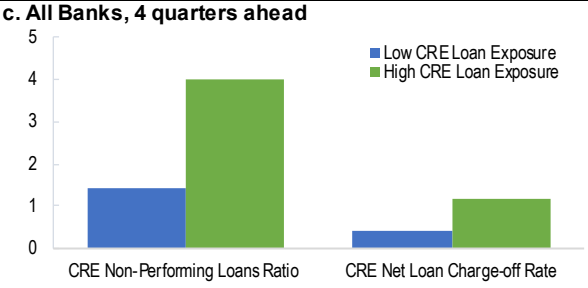
1b. Small Banks, 8 quarters ahead



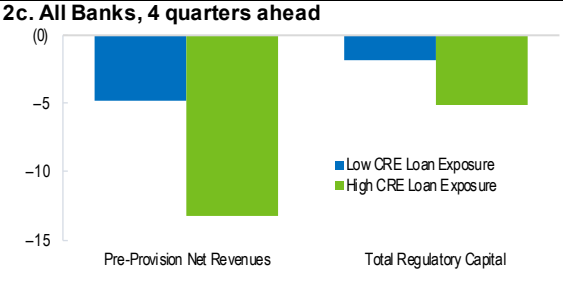
2b. Small Banks, 8 quarters ahead



1c. All Banks, 4 quarters ahead



2c. All Banks, 4 quarters ahead



Sources: Federal Financial Institutions Examination Council Call Reports; MSCI Real Estate; and author calculations.
Notes: The panels show the effect of a change in commercial real estate (CRE) prices on banks' cumulative CRE nonperforming loan rate, cumulative CRE net loan charge-off rate, net revenues before provisioning, and total regulatory capital. Banks with high (low) CRE exposure correspond to banks with an ex ante CRE-loans-to-total-assets ratio that is at the 75th (25th) percentile of the distribution of the ratio of CRE loans to total assets (which corresponds to 43(16) percentage points exposure). All estimated effects are statistically significant at 10 percent or less (panels 1a, 1b, and 1c report cumulative effects, for which average p-values are less than 10 percent).

top 41 banks (that correspond to banks with total assets that exceed $100 billion at least once throughout the sample period) have offices in 9 states or 45 MSAs on average (and 42 states and 253 MSAs at the maximum).

[8] See the Annex for details on the empirical methodology and data.

Quantitatively, following a one standard deviation decline in local CRE prices over an eight quarter horizon—which corresponds to a 16 percent cumulative decline in CRE prices—banks at the 75th percentile of the distribution of CRE loan exposure experience an 8 percentage points higher non-performing CRE loan ratio and a 3 percentage points higher CRE loan charge-offs rate (compared to banks with no CRE loan exposure).[9] Following these, their pre-provision net revenues and total regulatory capital are lower (by 12 percent and 5 percent, respectively). Banks with low CRE loan exposure experience milder effects, while still performing worse than banks with no CRE loan exposure.

These results are broadly similar in the sample that considers only small banks, for which the price and location of CRE assets can be captured more accurately (Figure 4, panels 1b and 2b), and when a shorter horizon (four quarters) is considered for the CRE price decline (Figure 4, panels 1c and 2c).

BANK CAPITAL ADEQUACY UNDER CRE SECTOR STRESS

Using the sensitivities of banks' CRE loan charge-offs rates and pre-provision net revenues to CRE price changes estimated previously, this section analyzes how bank capital adequacy could be affected if CRE prices were to drop persistently.[10] To do so, two approaches are followed. First, the marginal impact of bank CRE loan exposures on bank capital adequacy is reported, without considering the impact of other macroeconomic factors. Second, macroeconomic factors are also incorporated into the picture, by taking into account time-varying location-specific effects.

The exercise is conducted with two stressed CRE price scenarios, where the price paths are derived from the valuation model in IMF (2021). The first scenario, labeled as "mild", assumes a cumulative one-standard-deviation decline in CRE prices after eight quarters and corresponds to a 1¼ percent permanent increase in the CRE vacancy rate. The second scenario, labeled as "severe", assumes a CRE price path consistent with a permanent increase in the CRE vacancy rate by 5 percentage points (which corresponds to the rate observed during the global financial crisis), and implies a decline in CRE prices by about 30 percent in the long-run. For simplicity, projected price paths are considered to be common across all metropolitan statistical areas (MSAs) (Figure 5, panel 1).

The results presented in Figure 5 show that while the average projected drop in capital adequacy is mild (0.14 percentage point on average), there is noticeable heterogeneity across banks (driven primarily by the variation in banks' CRE loan exposures). Projected credit and revenue losses could reach more than 1 percent of pre-shock total risk-weighted assets for banks with very high CRE loan exposures (that is, those in the top 3 percent of CRE loan exposure). Nearly all banks in the left tail (5th percentile of the distribution of loss ratio) are small or community banks.[11] Moreover, a permanently high CRE vacancy rate implies significantly higher losses, with average capital losses almost twice as large as under the mild (first) scenario.

Next, macroeconomic effects are incorporated into the analysis by taking into account location-specific effects (as described in the Annex). The average decline in capital adequacy ratio turns out to be larger in this case, reaching 1.4 percentage points (Figure 6, panel 1).[12] This stronger effect is hardly surprising given that CRE price declines, especially when they are steep, coincide with lower economic activity and market stress (for example, lower GDP, higher unemployment, higher stock market volatility). Consistent with the findings

[9] The third quartile of the distribution of CRE loan exposure corresponds to the total CRE loans-to-total assets ratio of 43 percent. For further details on banks' CRE loan exposures, see Annex Table A1.

[10] The methodology adopted here broadly follows Hirtle et al. (2015), and is not intended to be strictly comparable to a formal top-down stress test, where the entire bank balance sheet is assumed to be under stress under certain macroeconomic scenarios and given assumptions about tax, dividend and other capital distributions over the forecast horizon. See the Annex for a detailed description of the methodology.

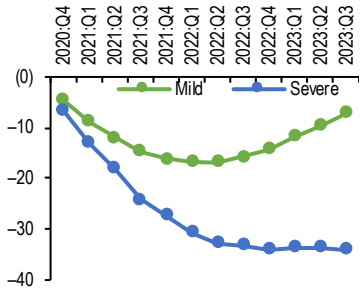
[11] In the left tail (the lowest 5th percentile) of the distribution of projected capital losses, 90 percent are small banks, 10 percent are medium-sized banks, and 99 percent are community banks.

[12] To incorporate macroeconomic effects into the picture, a path for time-varying locational factors is assumed over the forecast horizon (proxied by fixed effects). See the online annex for further details.

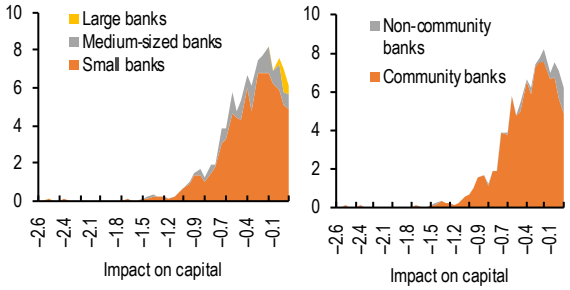
discussed previously, the results also show that banks at the left tail of the distribution of losses are small or community banks (panel 1), and that their losses reach 1.5 percentage points in this scenario (panel 2).

Figure 5. Decline in Bank Capital under Different Price Scenarios: Marginal Impact

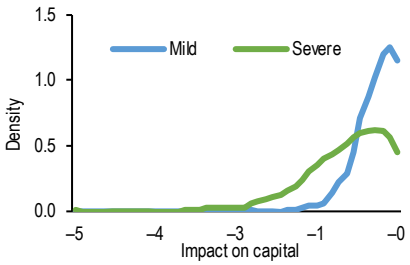
1. Cumulative Change in Average CRE Prices under Different Scenarios (Percent)



2. Distribution of Projected Capital Losses under the Mild Adverse Scenario (Percent of pre-shock risk-weighted assets)



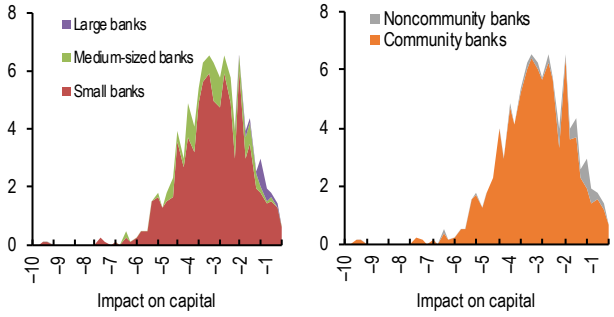
3. Distribution of Projected Capital Losses with Permanent Shocks to Vacancy Rates (Percent of pre-shock risk-weighted assets)



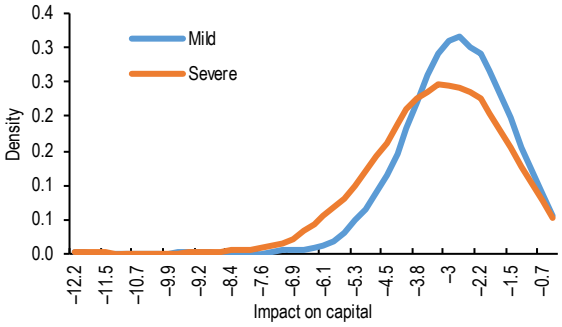
Sources: Call Reports; Federal Deposit Insurance Corporation Deposit Survey; and author calculations.
Note: Panel 1 shows CRE price forecast scenarios based on different assumptions about a permanent increase in the vacancy rate. Panel 2 shows the distribution of the eight-quarter-ahead projected capital losses due to a sustained CRE price decline as in the mild adverse scenario. The panel shows the distribution for different bank groups (depending on size or on whether the bank is a community bank). Panel 3 shows the capital loss distribution using an alternative CRE price forecast scenario that assumes a 5 percentage points permanent increase in CRE vacancy rates. CRE = commercial real estate.

Figure 6. Decline in Bank Capital Decline under Different Price Scenarios: With Macroeconomic Factors

1. Distribution of Projected Capital Losses under Mild Adverse Scenario (Percent of pre-shock risk-weighted assets)



2. Distribution of Projected Capital Losses with Permanent Shocks to Vacancy Rates (Percent of pre-shock risk-weighted assets)



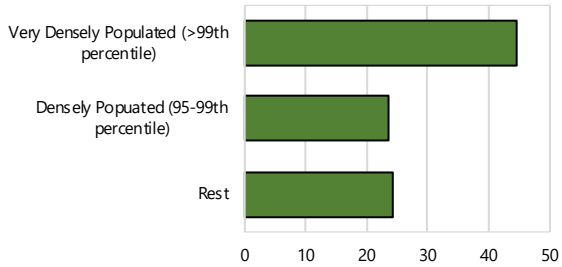
Sources: Call Reports; Federal Deposit Insurance Corporation Deposit Survey; and author calculations.
Note: Panels 1 and 2 show the distribution of 8-quarter-ahead projected capital losses similar to panels 2 and 3 in Figure 5, respectively, using an alternative specification that incorporates macroeconomic effects (by including location interacted with time fixed effects over the forecast horizon).

STRUCTURAL SHIFTS IN THE CRE SECTOR AND BANK PROVISIONING

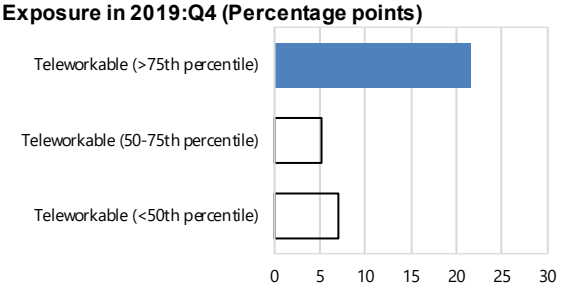
The effect of structural shifts in the CRE sector, such as those related to the rise of e-commerce and teleworking, on CRE market valuations could be stronger in areas that are more densely populated or with a higher share of less contact-intensive jobs that can be performed remotely. In turn, local banks operating in such regions could also be more adversely affected, potentially due to greater non-performing CRE loans. While a lack of publicly available disaggregated data does not permit a direct testing of this hypothesis, simple correlations of provision expenses to CRE loan exposures provide supportive evidence. Community banks in very densely populated areas or in areas with a higher share of teleworkable jobs seem to have increased their provisions more strongly during 2020 than other banks (Figure 7).

Figure 7. Sensitivity of Provisions in 2020 to Local Population Density and Teleworkability

1. Sensitivity of Total Provisions-to-PPNR Ratio to CRE Loan Exposure in 2019:Q4 (Percentage points)



2. Sensitivity of Total Provisions-to-PPNR Ratio to CRE Loan Exposure in 2019:Q4 (Percentage points)



Sources: Federal Financial Institutions Examination Council Call Reports; US Census Bureau, Dingel and Neiman (2020); and author calculations.

Note: Panel 1 shows the estimated coefficient from the regression of the ratio of total provisions during 2020:Q1-2020:Q3 to pre-provision net revenues in 2019 on the total CRE loans-to-total assets ratio in 2019:Q4. "Very Densely Populated" corresponds to community banks headquartered in zip codes with population densities above the 99th percentile. Similarly, "Densely Populated" corresponds to those above the 95th percentile and less than the 99th percentile. "Teleworkable (>75th percentile)" correspond to community banks headquartered in MSAs with a share of jobs that can be done at home greater than the 75th percentile and similarly for others. Solid bars indicate that the estimated relation is statistically significant at the 5 percent level of significance. CRE = commercial real estate; PPNR = pre-provision net revenue.

CONCLUDING REMARKS

The COVID-19 crisis has hit the commercial real estate sector hard in the US. The structural shifts in CRE demand pose considerable uncertainly around the outlook for the sector and suggest that further price declines may be possible, at least in some CRE segments. This note shows that such price declines may potentially be a source of stress for banks, especially for smaller and community banks with higher CRE loan exposures.

So far, the banking sector in the US has been largely resilient to the developments in the CRE sector during the COVID-19 crisis because of strong bank capital buffers and the unprecedented policy support and regulatory responses during the crisis.[13] Large banks have also been more prudent in their CRE lending compared to the pre-global financial crisis period, with their exposures declining notably. Going forward, maintaining the frequency of stress tests for small/community banks, particularly for those with high levels of exposures to riskier CRE segments, would be beneficial to assess the risks to financial stability in a timely fashion.

[13] See Fed (2021) for a summary of Federal Reserve's policy responses to the COVID-19 crisis.

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ANNEX. DATA AND EMPIRICAL STRATEGY

Three main data sources have been used to obtain information for the empirical analyses: (i) Federal Financial Institutions Examination Council 031 and 051 Report Forms (Call Reports) for detailed bank-level data at a quarterly frequency on commercial real estate (CRE) loans,[14] several outcome indicators and bank controls (to be defined in this Annex), and the location of bank headquarters at the zip code level; (ii) MSCI Real Estate for average quarterly CRE prices in the metropolitan statistical area (MSA) where the bank headquarters are located;[15] and (iii) the Federal Deposit Insurance Corporation (FDIC) Deposit Survey to measure the geographical concentration of banks. These databases are matched using unique bank identifiers. The sample period is 2001:Q1–2020:Q3, and includes a total of 10,796 reporting banks (5,116 banks in 2020:Q3).

The analysis of the impact of a change in CRE prices on banks' performance is based on the following model:

$$Y_{b,t}^{l} = \alpha^{k} \cdot CRE\ Exposure_{b,t-k}^{l} * \Delta P_{t,t-k}^{l}\ \mathrm{I}\left(\Delta \mathrm{P}_{\mathrm{t,t-k}}^{\mathrm{l}} < 0\right) + \beta^{k} \cdot CRE\ Exposure_{b,t-k}^{l} * \Delta P_{t,t-k}^{l} + Controls_{b,t-k}^{l} + \mu_{b} + \eta_{l,t} + \varepsilon_{b,t}^{l} \quad (1)$$

where $Y_{b,t}^{l}$ is (i) the nonperforming CRE loan ratio at *t*, (ii) the net CRE loan charge-off rate at *t*, (iii)the log change in pre-provision net revenues from *t-k* to *t*, and (iv) the log change in total regulatory capital from *t-k to t*.[16] *l* denotes the MSA where bank *b*'s headquarter resides. $CRE\ Exposure_{b,t-k}^{l}$ 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.[17] $\Delta P_{t,t-k}^{l}$ denotes (log) change in average CRE price index in MSA *l* from *t-k* to *t*. $\mathrm{I}\left(\Delta \mathrm{P}_{\mathrm{t,t-k}}^{\mathrm{l}} < 0\right)$ is an indicator variable equal to 1 if $\Delta P_{t,t-k}^{l}$ <0, and 0 otherwise, and is introduced to account for the potential asymmetry in the relation. As such, the key parameters of interest are α^{k} and β^{k}, where α^{k}+ β^{k} reflects by how much the outcome variable is estimated to differ across banks with different ex ante CRE loan exposures, following a decline in CRE prices over a horizon of *k* quarters.

k≥1 capture potential lags in the transmission and k=8 quarters is used as the baseline. *Controls* are bank capital ratio, liquidity ratio, and (log) total asset size, all measured at *t-k*, the interaction of these variables with $\Delta P_{t,t-k}^{l}$, and the level of $CRE\ Exposure_{b,t-k}^{l}$. In addition, the model includes bank fixed effects (μ_{b}) to absorb any time-invariant bank characteristics, and location (MSA) *x* quarter fixed effects ($\eta_{l,t}$) to control for possible demand-side or MSA-level common factors that may affect outcome variables. The estimation is done using weighted least squares (WLS), where the weights are proportional to the log of bank total assets. Standard errors are double clustered at the bank and quarter levels.

The identification is through the within-MSA variation in bank ex-ante CRE loan exposures (at a given quarter). Similar to Khwaja and Mian (2006), 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 four MSAs with a single bank headquarters). Bank fixed effects and further controls help to better quantify the effect of CRE loan exposures.[18]

[14] Commercial real estate loans throughout the analyses are defined as (i) construction, land development, and other land loans; (ii) loans secured by multi-family (five or more) residential properties; and (iii) loans secured by nonfarm, nonresidential properties (owner-occupied and other nonfarm nonresidential properties).

[15] While MSCI provides CRE price indices across different CRE segments–for example, office, retail, industrial, and 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 are used.

[16] See Table A2 for a detailed definition of the variables used in the analyses.

[17] Banks' exposure to CRE markets 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. To the extent banks' CRE loan exposures are correlated with their CMBS or real estate holdings, the results should go through.

[18] For instance, as presented in panel 3 of Figure 1, large banks on average have lower CRE loan exposures compared to smaller banks. Controlling for bank size mitigates a potential concern that the identified effect of CRE loan exposure is mismeasured due to its interplay with bank size.

There are a few data limitations. First, CRE price indices are available only for 69 major MSAs.[19] In the baseline estimations, banks located in these MSAs are used, which, on average, cover more than 50 percent of total banking sector assets. The results are robust, using an expanded sample that includes all banks.[20] Second, bank CRE loans by segments such as loans secured by office, retail, industrial, or lodging properties, are not available in Call Reports. Therefore, average CRE prices—as reported by the MSCI for each MSA—are used. A further limitation is that locations of underlying properties is not known. In the analyses, banks (or loan performance) are assumed to be exposed to CRE price changes in the MSAs where the bank headquarters is located. This limitation, however, may not be as restrictive as it may appear since most banks in the US are small and tend to have geographically concentrated loan portfolios.

Table A1 reports the definition and summary statistics of the key variables used in the analyses.

Table A1. Definition and Summary Statistics

Dependent Variables:	Definition	Mean	Std	Obs.	**Independent Variables:**	Definition	Mean	Std	Obs.
CRE NPL Ratio (in ppt)	Nonperforming CRE loans (90+ days overdue)-to-total CRE loans ratio	1.56	3.45	94521	CRE Loans to Total Assets	The sum of construction, land development, and other land loans; loans secured by multi-family (5 or more) residential properties; and loans secured by nonfarm nonresidential properties-to-total assets ratio	0.30	0.19	94521
CRE Charge-Off Rate (net of recovery rate)	Charged off CRE loans (net of recoveries)-to total CRE loans ratio	0.00	0.01	90447	Bank Total Assets (in logs)	Book value of total assets of a bank	12.73	1.56	94521
Change in Pre-Provision Net Revenues	8-quarter log change in annual pre-provision net revenues	0.15	0.75	94521	Bank Liquid Assets-to-Total Assets Ratio	Cash and balances due from depository institutions + securities + federal funds sold and securities purchased under agreements to resell (to total assets)	0.26	0.17	94521
Change in Regulatory Capital	8-quarter log change in regulatory capital	0.17	0.24	93462	Bank Equity Capital-to-Total Assets	Ratio of total bank equity capital to total assets	0.13	0.13	94521
					Change in CRE Prices	8-quarter log change in MSA-level average CRE prices	0.09	0.16	121187

[19] MSAs included in the analyses are the following: Allentown-Bethlehem-Easton, PA-NJ; Anderson, IN; Atlanta-Sandy Springs-Marietta, GA; Austin-Round Rock-San Marcos, TX; Baltimore-Towson, MD; Birmingham-Hoover, AL; Boston-Cambridge-Quincy, MA-NH; Boulder, CO; Bridgeport-Stamford-Norwalk, CT; Cape Coral-Fort Myers, FL; Charlotte-Concord-Gastonia, NC-SC; Chicago-Joliet-Naperville, IL-IN-WI; Cincinnati-Middletown, OH-KY-IN; Columbia, MO; Columbia, SC; Columbia, TN; Columbus, OH; Dallas-Fort Worth-Arlington, TX; Denver-Aurora-Lakewood, CO, NC-SC; Detroit-Warren-Dearborn, MI; Durham-Chapel Hill, NC; Greenville-Anderson-Mauldin, SC; Harrisburg-Carlisle, PA; Hartford-West Hartford-East Hartford, Houston-The Woodlands-Sugar Land, TX; Indianapolis-Carmel, IN; Jacksonville, FL; Kansas City, MO-KS; Knoxville, TN; Lakeland-Winter Haven, FL; Las Vegas-Henderson-Paradise, NV; Los Angeles-Long Beach-Santa Ana, CA; Louisville/Jefferson County, KY-IN; Memphis, TN-MS-AR; Miami-Fort Lauderdale-Pompano Beach, FL; Milwaukee-Waukesha-West Allis, WI; Minneapolis-St. Paul-Bloomington, MN-WI; Naples-Marco Island, FL; Nashville-Davidson--Murfreesboro—Franklin, TN; New Haven-Milford, CT; New Orleans-Metairie-Kenner, LA; New York-Newark-Jersey City, NY-NJ-PA; North Port-Bradenton-Sarasota, FL; Oklahoma City, OK; Orlando-Kissimmee-Sanford, FL; Oxnard-Thousand Oaks-Ventura, CA; Philadelphia-Camden-Wilmington, PA-NJ-DE-MD; Phoenix-Mesa-Glendale, AZ; Pittsburgh, PA; Port St. Lucie, FL; Portland-Vancouver-Hillsboro, OR-WA; Providence-Warwick, RI-MA; Raleigh, NC; Reno, NV; Riverside-San Bernardino-Ontario, CA; Sacramento--Arden-Arcade--Roseville, CA; Salt Lake City, UT; San Diego-Carlsbad-San Marcos, CA; San Francisco-Oakland-Fremont, CA; San Jose-Sunnyvale-Santa Clara, CA; Santa Rosa, CA; Seattle-Tacoma-Bellevue, WA; St. Louis, MO-IL; Stockton-Lodi, CA; Tampa-St. Petersburg-Clearwater, FL; Tucson, AZ; Virginia Beach-Norfolk-Newport News, VA-NC; Washington-Arlington-Alexandria, DC-VA-MD-WV; and Worcester, MA.

[20] The results are qualitatively robust to expanding the sample by using the average of the 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. In particular, "location"-specific CRE prices and location fixed effects would not span the same geographical area.

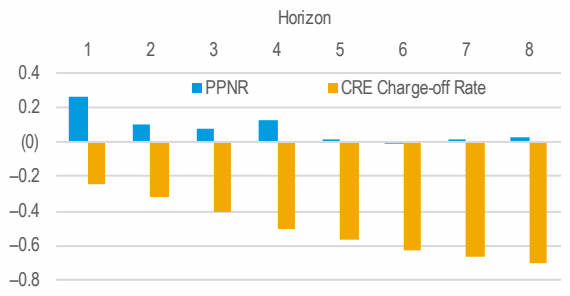
Scenario Analysis. Using the estimated values of α^k and β^k in equation (1), we calculate $Y^l_{b,t+k} = (\widehat{\alpha^k} + \widehat{\beta^k}) * CRE\ Exposure^l_{b,t} * \Delta P^l_{t+k,t}$, where $Y^l_{b,t+k}$ is (i) *k*-quarters-ahead net CRE charge-off rate; or (ii) change in the pre-provision net revenue (PPNR) over *k* quarters, and $\Delta P^l_{t+k,t}$ is the CRE price path given by panel 1 of Figure 3.

A forward-looking provisioning rule in line with supervisory practices is assumed, where provision expenses are calculated based on Allowance for Loan and Lease Losses (ALLL) due to CRE loan exposure equal to four quarters of projected net CRE loan charge-offs. Total CRE loan balances are assumed to decline by 2 percent quarterly, which is in line with the CRE charge-off rates observed during the global financial crisis.[21]

In the next step, by how much banks' capital could go under stress is calculated. In particular, projected provision expenses and losses in pre-provision net revenues are divided by total risk-weighted assets, where total risk-weighted assets are assumed to be equal to the last historical observation (2020:Q3).

Incorporating macroeconomic effects into the picture. Macroeconomic effects are incorporated into the picture by including location-specific factors (proxied by MSA x time fixed effects) in the forecast horizon. These fixed effects are assumed to follow a path observed during the global financial crisis.

Figure A1. Correlation of Time-Varying Location-Specific Factors with Changes in MSA-Level CRE Prices



Sources: Call Reports; and author calculations.
Note: The figure shows the correlation of estimated MSA x time fixed effects with MSA-level change in CRE prices (for different horizons). The correlation coefficients are statistically significant at 10 percent or lower (except horizon 6 for the PPNR specification). CRE = commercial real estate; PPNR = pre-provision net revenue.

Figure A1 assesses the information content of MSA x time fixed effects (estimated for the two specifications, that is, the CRE charge-off rate and PPNR, and for different horizons). It shows that these fixed effects are significantly correlated with MSA-level change in CRE prices. The correlations are weaker for the PPNR specification (as banks' overall PPNR could potentially be more correlated with macroeconomic conditions than the CRE charge-off rate), and stronger for the CRE charge-off rate specification.

[21] Assuming a decline in CRE loan balances in the forecast path implies that banks are assumed to be less willing to originate new CRE loans or reluctant to re-finance existing ones, so that in equilibrium, the existing stock of CRE loan balances declines. Assuming constant CRE loan balances over the forecast horizon implies mildly stronger results.