Does More Capital Make Banks Safer? Market-Based Evidence From the 2011 European Banking Authority Capital Exercise

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Does More Capital Make Banks Safer?

Market-Based Evidence from the 2011 European Banking Authority

Capital Exercise

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Abstract

I exploit the 2011 EBA Capital Exercise as a quasi-natural experiment to estimate the impact of higher capital requirements on six market measures of bank risk, using difference-in-differences and matching strategies. I find that the Capital Exercise triggered significant increases in the risk of Capital Exercise banks relative to non–Capital Exercise banks according to four of the six risk measures, contrary to the predictions of standard financial theory. Moreover, among Capital Exercise banks, I find that the Capital Exercise generated larger increases in risk for more undercapitalized banks. These results are robust to potential confounders from pre-existing trends and the European sovereign debt crisis. My results indicate that policymakers must beware the signaling effects of raising capital requirements, particularly in times of crisis.

1 Introduction

Our financial system is safer. . . We put in place tough new rules on big banks.

— Barack Obama, President of the United States, 2013.

We have put into place numerous steps. . . that will strengthen these institutions, force them to hold a great deal of additional capital, and reduce their odds of failure. There will be much lower odds that a so-called systemic firm will fail.

— Janet Yellen, Chair of the Federal Reserve, 2014.

The capital requirements of our largest banks are now ten times higher than before the crisis. . . This substantial capital and huge liquidity gives banks the flexibility they need to continue to lend to UK businesses and households, even during challenging times.

— Mark Carney, Governor of the Bank of England and Chair of the Financial Stability Board, 2016.

The most recent stress tests indicate that, even after a severe global recession, capital levels at the largest banks would remain above regulatory minimums, and above the levels those banks held in good times before the crisis.

— Jerome Powell, Chair of the Federal Reserve, 2018.

In the aftermath of the 2008 financial crisis, politicians, policymakers, and pundits alike stressed the importance of comprehensive financial sector reform. The 2010 Dodd-Frank Act and Basel III were both implemented with the goal of making the banking system safer. At the center of these reforms was a drive to strengthen banks' balance sheets, by requiring banks to maintain higher levels of capital and to hold higher quality assets. Policymakers largely concur that these reforms have been successful.

To determine whether higher capital requirements have in fact reduced bank risk, suitable risk measures are needed. Policymakers tend to point to higher regulatory measures of capital as proof that banks are now safer. However, regulatory measures rely on balance sheet metrics that are only lagging indicators of banks' health. Regulatory measures are also susceptible to accounting manipulation and regulatory capital arbitrage (Jones 2000). In a variant of Goodhart's Law, balance sheet metrics are themselves directly regulated and thus do not provide a good indication of the efficacy of capital requirements.

Market measures provide an alternative standard of risk. They are timelier than balance sheet metrics, and have a far better track record in anticipating bank failures. Haldane and Madouros (2012) show that in a horse-race between the simplest market measure of risk—market value of equity as a proportion of total assets—and the most complex balance sheet measure—the Basel III Tier 1 ratio—the simplest market measure has about 10 times greater power in predicting bank failures. After all, market-based rather than balance sheet measures of capital determine whether a bank survives in a crisis. Market measures therefore have important advantages over balance sheet metrics in evaluating bank risk.

In this paper, I contribute to the ongoing debate on the efficacy of bank capital regulation. It is generally challenging to identify the impact of higher capital requirements. Changes in microprudential capital requirements generate concerns about reverse causality, since they actively target the insolvency risk of individual banks. On the other hand, changes in macroprudential capital requirements tend to occur gradually across entire banking sectors, making it hard to isolate their effect. In a rare exception, the European Banking Authority

(EBA) conducted an unanticipated Capital Exercise in 2011 that required a specific group of European banks to raise their core tier 1 capital ratios from 5% to 9% over a period of eight months. These Capital Exercise banks were selected by country in descending order of total assets, until at least 50% of the national banking sector was covered. Since the smaller banks beyond this threshold were not subject to the policy, I use the Capital Exercise as a quasi-natural experiment to analyze the effects of higher capital requirements on bank risk.

I assess bank risk using a suite of six market risk measures: equity volatility, implied volatility, equity beta, the implied probability of default, the price-to-book ratio, and the price-to-earnings ratio. According to standard financial theory, market measures of bank risk should fall substantially following an increase in capital requirements (Schwert 1989). With less leverage, bank equity should become less volatile, while the market's expectation of future volatility should also decline. In addition, better-capitalized banks should have lower systematic risk, as measured by the comovement of their share prices with the market, along with lower probabilities of default. Valuation metrics like price-to-book and price-to-earnings ratios should be higher, reflecting higher-quality book capital in the former and a lower risk premium in the latter.

I use difference-in-differences and matching strategies to estimate the impact of the Capital Exercise on each of the market risk measures. Both of these approaches identify the impact of the Capital Exercise by comparing a treatment group of Capital Exercise banks (CEBs) with a control group of non–Capital Exercise banks (non-CEBs). I use difference-in-differences to observe the dynamic effects of the Capital Exercise, while I use the bias-corrected matching estimator from Abadie and Imbens (2002) to construct a control group of non-CEBs that are most similar to the CEBs over a set of relevant characteristics. I also use difference-in-differences with a continuous treatment to uncover heterogeneity in the effects of the Capital Exercise on CEBs according to the magnitude of their capital shortfalls.[1]

I find evidence that higher capital requirements can strongly increase the market's per-

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[1]Since the minimum core tier 1 ratio was raised to 9% for all CEBs, those with larger capital shortfalls were mechanically subject to larger effective increases in capital requirements.

ception of bank risk. In particular, I show that the Capital Exercise triggered significant increases in the equity volatility, implied volatility, and default probability of CEBs relative to non-CEBs. I also show that the Capital Exercise led to substantial and persistent reductions in price-to-book ratios, contrary to the beliefs of economists and policymakers (e.g. Vickers 2019). Moreover, I find that the Capital Exercise generated larger increases in risk for more undercapitalized CEBs, which were effectively subject to larger increases in capital requirements. However, these increases in the risk measures largely dissipated beyond the deadline for meeting the new capital requirements, indicating that the market's higher expectations of risk generally failed to materialize. Altogether, these results suggest the Capital Exercise may have been counterproductive, sending a strong negative signal to market participants while failing to make CEBs safer.

I conduct a series of robustness checks to assess the sensitivity and validity of my baseline results. One prominent concern is that the parallel trends identifying assumption required for difference-in-differences may not be satisfied. I therefore control nonparametrically for pre-existing trends using a dynamic difference-in-differences specification with CEB × quarter interactions. I show that these pre-trend controls do not qualitatively alter my baseline results. Another major concern is that the Capital Exercise coincided with the European sovereign debt crisis, which may have impacted larger CEBs differently from smaller non-CEBs. I address this concern in two ways. First, I control for country-specific risk factors using the volatility of the national benchmark index. Second, I re-estimate my baseline results using a subsample that excludes banks in Greece, Ireland, Italy, Portugal, and Spain (the so-called GIIPS countries), which were the countries most affected by the sovereign debt crisis and the European Central Bank's longer-term refinancing operations. I confirm that my results are robust to each of these alternative specifications.

Before the crisis, capital requirements were primarily used to incentivize better risk management and to mitigate moral hazard concerns arising from explicit and implicit subsidies to banks, such as deposit insurance and government bailouts. Policymakers (e.g. Tarullo 2011)

have argued that pre-crisis capital regulation was not stringent enough because it failed to account for systemic risk. Economic theory shows that when bank distress is not idiosyncratic, banks may respond in ways that create negative externalities. Distressed banks are often constrained by agency costs arising from debt overhang (Myers 1977) and asymmetric information in equity issuance (Myers and Majluf 1984), leading them to respond to a common shock by shrinking their assets instead of raising new capital.[2] For instance, if some banks are forced to sell their assets in response to a liquidity shortage, the resulting fire sale can weaken the balance sheets of other banks. Davila and Korinek (2018) identify this dynamic as a "collateral externality" arising from price-dependent financial constraints. These systemic repercussions suggest a macroprudential role for capital regulation, with the aim of limiting the social costs associated with fire sale externalities and credit crunch effects.

In recent years, economists have begun to question policymakers' optimistic assessments of the efficacy of post-crisis capital regulation. Sarin and Summers (2016) examine a range of market risk measures and find to their surprise that large banks appear at least as risky as they did before the crisis. However, Sarin and Summers only compare the average levels of these risk measures before and after the crisis, and all banks in their sample were subject to post-crisis regulatory reforms. Consequently, their main finding—that market risk measures have on average been higher after the crisis—cannot be solely attributed to increases in capital requirements, due to contemporaneous changes in banks' business models and investors' bailout expectations (Schäfer et al. 2016). Gao et al. (2018) seek to resolve this issue by estimating the reactions of stock prices and bond yields to key events in the passage of the Dodd-Frank Act. They find that large financial institutions had negative abnormal stock returns and positive abnormal bond returns relative to a control group of small and medium-sized financial institutions. The authors take this as evidence that the Dodd-Frank Act was effective in reducing risk-taking by large financial institutions. However, large financial institutions differ from small and medium-sized financial institutions in other important

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[2]In fact, this is precisely how CEBs responded to the Capital Exercise (Gropp et al. 2019).

ways that are likely confounding their results.

The 2011 EBA Capital Exercise used a country-specific selection rule that generated a considerable overlap in size between CEBs and non-CEBs, making it particularly well-suited to evaluating the impact of higher capital requirements. Previous research on the Capital Exercise has generally bypassed the question of bank risk in favor of analyzing the pass-through effects on lending to the real economy. Mésonnier and Monks (2015) find that annualized growth in loans was 1.2 percentage points lower for CEBs than non-CEBs, and non-CEB lending failed to substitute for previous CEB lending. Meanwhile, Degryse et al. (2019) find that CEBs required loans to be collateralized more often after the Capital Exercise, especially for collateral favored by regulatory risk weights.

My paper contributes to an emerging literature that assesses the impact of the Capital Exercise through the lens of the market. Schmidt (2019) finds a strong reduction in the cost of capital for CEBs relative to non-CEBs. On the other hand, Bostandzic et al. (2017) show that the Capital Exercise exacerbated three measures of systemic risk: Marginal Expected Shortfall[3], ΔCoVaR[4], and SRISK[5]. In comparison, I focus on whether the Capital Exercise was effective in reducing the risk of CEBs relative to non-CEBs at the individual bank level, by analyzing the impact of the Capital Exercise on a suite of six market risk measures.

The rest of the paper proceeds as follows. Section 2 summarizes the timeline and implementation of the Capital Exercise. Section 3 describes the dataset, while Section 4 explains the methodology. In Section 5, I present my baseline difference-in-differences and matching estimates of the impact of the Capital Exercise on the six market risk measures. In Section 6, I perform robustness checks to assess the sensitivity and validity of my baseline results. Section 7 concludes.

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[3]Marginal Expected Shortfall is defined as the expected fall in a bank's share price conditional on a large shock to the financial system (Acharya et al. 2017).

[4]ΔCoVaR is defined as the change in the value at risk of the financial system conditional on an institution being under distress relative to its median state (Adrian and Brunnermeier 2016).

[5]SRISK is defined as the capital shortfall of a firm conditional on a severe market decline (Brownlees and Engle 2017).

2 Background on the 2011 EBA Capital Exercise

The European Banking Authority (EBA) announced its first Capital Exercise on October 26, 2011, following the release of its stress test results on July 15, with the objective of strengthening large banks' capital positions and restoring confidence in the European banking system. The Capital Exercise, which was unanticipated, required a specific group of 71 European banks to raise their minimum core tier 1 capital ratio from 5% to 9% by June 2012. This group was chosen by selecting the largest banks from each European Union (EU) member state in descending order of total assets at the end of 2010, such that at least 50% of each national banking sector was covered (EBA 2011). Between October 26, 2011 and June 30, 2012, 10 of the original 71 banks were forced to drop out due to restructuring, leaving 61 banks that successfully completed the Capital Exercise. The EBA published initial country-level estimates of capital shortfalls on October 26, 2011, followed by a formal recommendation on December 8, 2011 with bank-level figures. The EBA identified 27 banks as having an aggregate capital shortfall of €76 billion, and therefore required these banks to submit their capital plans to the EBA by January 20, 2012. The EBA published its preliminary report on July 11, 2011, followed by its final report on October 3, 2012. According to the final report, the 27 banks deemed to have a capital shortfall increased their capital by €94.4 billion: €71.6 billion of this fresh capital came from "direct capital measures," while the remaining €22.8 billion resulted from reductions in risk-weighted assets.

There are three main reasons why the EBA Capital Exercise is well-suited to evaluating the effects of higher capital requirements. First, since the announcement was unanticipated, banks could not have adjusted their capital ratios beforehand. Second, both the mandated increase (from 5% to 9%) and the actual increase in capital ratios were large: CEBs raised their core tier 1 ratios by 1.9 percentage points more than non-CEBs (Gropp et al. 2019). Third, the EBA's country-specific selection rule generated a considerable overlap in size between CEBs and non-CEBs, helping to isolate the effect of the increase in capital requirements from other effects associated with bank size.

3   Data

I collect two main types of data at the individual bank level: balance sheet characteristics and market measures of risk.

For the balance sheet characteristics, I combine annual data from *Bureau van Dijk Orbis: Global Financials for Banks* and quarterly data from *Compustat Global: Fundamentals Quarterly*. From *Compustat*, I obtain data on bank total assets, tier 1 capital ratios, total capital ratios, short-term funding, long-term funding, bank and customer deposits, and net interest income. From *Orbis*, I obtain additional data on bank equity, liquid assets, non-performing loans (NPLs), net income, and profit margins.

In my initial sample, I keep all banks from all 19 countries with at least one bank subject to the Capital Exercise, as well as Switzerland which participates in the European Single Market as a member of the European Free Trade Association. However, since Switzerland is not a member of the EU, no Swiss banks were subject to the Capital Exercise. I add an indicator for the 61 CEBs that completed the Capital Exercise. For each bank in the dataset, I have quarterly observations (from *Compustat*) and annual observations (from *Orbis*) on their fundamentals from 2008 to 2018. To accommodate the different frequencies of the two datasets, I use cubic spline interpolation to convert the annual data from *Orbis* into quarterly data. Although interpolation only provides estimates of the actual quarterly data, the balance sheet characteristics from *Orbis* are sufficiently slow-moving to make interpolation appropriate. I then merge the two datasets by matching on International Securities Identification Number (ISIN) and quarter.

To obtain market risk measures, I first restrict my sample to listed banks. I then select a suitable control group of non-CEBs. One issue with the Capital Exercise is that it selected banks by country in descending order of size. Consequently, CEBs were generally larger than non-CEBs, creating difficulties in isolating the effects of higher capital requirements from other effects associated with bank size. I mitigate this problem by constructing an overlap sample that only includes listed banks from the merged dataset with total assets larger than

the smallest CEB and smaller than the largest non-CEB. This approach follows Abadie et al. (2002) by matching CEBs (the treatment group) with similar non-CEBs (the control group). In order to match on total assets, I convert all observations for total assets from the local currency to euros at the nominal exchange rate at the end of the corresponding quarter. I then construct the overlap sample by excluding banks with total assets less than the smallest listed CEB (Denmark's Sydbank with assets of €20.1 billion) or greater than the largest listed non-CEB (Switzerland's UBS with €925 billion) at the end of 2010, prior to the announcement of the Capital Exercise. This procedure yields a sample of 80 listed banks, comprising 35 listed CEBs and 45 listed non-CEBs. The sample contains a considerable overlap in size between CEBs and non-CEBs, owing to the different sizes and concentrations of European national banking sectors.

Given this sample, I obtain the following daily market data from *Bloomberg*: stock prices for both the banks themselves and their national benchmarks (local equivalents of the US S&P 500), option-implied volatility, implied probabilities of default[6], price-to-book (P/B) ratios, and price-to-earnings (P/E) ratios. I am unable to collect data on credit default swap (CDS) spreads from either *Bloomberg* or *Thomson Reuters Datastream*, since CDS data around the time of the Capital Exercise are almost universally missing from both sources. I use the daily stock prices to compute equity volatility and equity beta by quarter. For each of the other four market risk measures, I compute means by quarter. I then merge all six market risk measures by matching on bank ticker and quarter. I add tickers to the merged *Orbis-Compustat* dataset by bank, which finally enables me to merge the fundamentals data with the market data by ticker and quarter.

This merged dataset is an unbalanced panel consisting of 3,200 observations from 20 countries, but concentrated in countries with larger banking sectors such as France, Germany, Italy, Switzerland, and the United Kingdom. During the period for which I have data (2008–2018), all 20 countries participated in the EU Single Market as members of the EU or the

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[6]I obtain these using the *Bloomberg* DRSK function.

European Free Trade Association. The panel is unbalanced due to missing observations in the *Compustat* data and the *Bloomberg* market data. However, there are no missing observations for the *Compustat* controls used in the difference-in-differences specifications in Section 4. For the matching specification in Section 4, I drop observations with missing data for any of the six matching covariates. The missing observations from *Bloomberg* are concentrated in the data for option-implied volatility and price-to-earnings ratios. For each difference-in-differences and matching specification, I drop any observations for which the outcome variable is missing. I address concerns about the possible distortionary effects of this procedure on sample composition in Section 6.

Following the classification by the National Bureau of Economic Research (NBER), I consider the financial crisis to end in June 2009, which provides a 27-month pre–Capital Exercise period between the end of the crisis and the announcement of the Capital Exercise, as well as a six-year post–Capital Exercise period between the conclusion of the Capital Exercise (June 2012) and the end of the dataset (2018 Q4). In order to focus on the effects of the Capital Exercise itself, I restrict my analysis to a 27-month post–Capital Exercise period with the same duration as the pre–Capital Exercise period. Table 1 displays summary statistics on bank balance sheet characteristics, comparing CEBs with non-CEBs before and after the Capital Exercise.

Table 1 shows that the CEBs and non-CEBs in the overlap sample are broadly comparable across a wide range of balance sheet characteristics, except for total assets as expected. The total assets of CEBs fell on average by 9.5% following the Capital Exercise (columns 1 and 4), while the total assets of non-CEBs grew 8.1% (columns 2 and 5).[7] On the other hand, CEBs raised their tier 1 capital ratios by 2.4 percentage points, whereas non-CEBs raised theirs by 2.0 percentage points. CEBs also raised their total capital ratios by 3.0 percentage points, compared with 2.0 percentage points for non-CEBs.

Table 2 presents similar summary statistics for the six market risk measures, again com-

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[7]This is consistent with Gropp et al. (2019), who find that banks increased their capital ratios by shrinking their assets rather than raising equity.

Table 1: Mean Bank Characteristics Before and After the Capital Exercise

	Before (2009 Q3 – 2011 Q3)			After (2012 Q3 – 2014 Q3)		
	CEB	Non-CEB	p	CEB	Non-CEB	p
Total Assets (€billion)	637	101	<0.001	576	110	<0.001
Asset Share[1] (%)	28.0	6.1	<0.001	28.6	6.9	<0.001
Deposits/Assets (%)	12.4	15.3	0.343	11.0	14.9	0.218
Liquid Assets/Assets (%)	20.1	19.7	0.922	20.0	17.3	0.489
Equity/Assets (%)	12.9	7.8	0.196	13.4	14.6	0.803
Tier 1 Capital Ratio (%)	11.6	13.9	0.080	14.0	15.9	0.083
Total Capital Ratio (%)	13.6	15.6	0.102	16.6	17.6	0.403
Short-Term Debt/Assets (%)	8.5	8.3	0.949	10.3	7.8	0.235
Long-Term Debt/Assets (%)	18.1	16.7	0.645	17.2	14.9	0.480
NPLs/Gross Loans (%)	6.6	5.5	0.490	7.5	8.4	0.701
Profit Margin (%)	16.2	15.2	0.910	22.6	26.1	0.643

Note: This table displays summary statistics for a range of balance sheet characteristics available in my dataset. CEBs and non-CEBs are broadly comparable across all characteristics except total assets, as evidenced by the p-values in columns 3 and 6.
[1] Asset share is calculated as the ratio of a bank's total assets to the total assets of the corresponding national banking sector.

Table 2: Mean Market Risk Measures Before and After the Capital Exercise

	Before (2009 Q3 – 2011 Q3)			After (2012 Q3 – 2014 Q3)		
	CEB	Non-CEB	p	CEB	Non-CEB	p
Equity Daily Return (%)	-0.080	-0.051	0.572	-0.120	-0.088	0.505
Equity Volatility (pp)	37.8	25.3	0.025	36.0	31.0	0.196
Implied Volatility (pp)	34.0	32.1	0.455	30.0	52.9	0.097
Equity Beta	0.313	0.400	0.441	0.622	0.525	0.281
Default Probability (%)	0.607	0.323	0.048	0.531	0.326	0.224
Price-to-Book Ratio	0.829	0.951	0.315	1.08	0.915	0.327
Price-to-Earnings Ratio	18.7	14.1	0.181	32.3	21.0	0.378

Note: This table displays summary statistics for each of the six market risk measures, along with daily stock price returns.

paring CEBs with non-CEBs before and after the Capital Exercise. I proceed to discuss the data for each of these risk measures in detail.

Equity volatility is calculated as the standard deviation in the daily returns of a bank's share price by quarter, scaled by a factor of $\sqrt{252}$ to provide an annualized figure that can be compared with implied volatility as reported by *Bloomberg*.[8] Implied volatility reflects the market's expectation of future equity volatility, and Cao et al. (2010) find that implied volatility is a better predictor of CDS spreads than realized volatility because it contains an embedded volatility risk premium. Both equity and implied volatility moved in opposite directions for CEBs and non-CEBs between the pre-treatment and post-treatment periods. Equity volatility decreased slightly for CEBs from an average of 37.8 percentage points before the Capital Exercise to an average of 36.0 percentage points afterwards, while equity volatility for non-CEBs increased from 25.3 percentage points beforehand to 31.0 percentage points afterwards. Implied volatility followed a similar but more pronounced path, falling from 34.0 to 30.0 percentage points for CEBs but rising sharply from 32.1 to 52.9 percentage points for non-CEBs.

I also show time series plots of both equity and implied volatility for CEBs and non-CEBs (Figure 1). These plots appear to challenge the conclusion of Sarin and Summers (2016) that market risk measures indicate banks are no safer following increases in capital requirements. My analysis underscores the importance of having a control group for comparison.

Equity beta is calculated as the within-quarter correlation between the stock price and the national benchmark index, and is generally higher for CEBs since they comprise a larger proportion of the index. Equity beta is an important risk measure because it captures systematic risk and determines banks' cost of equity. For example, the canonical capital asset pricing model (CAPM) developed by Sharpe (1964) and Lintner (1965) predicts that the cost of equity will be linearly related to equity beta according to the equation:

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[8]There are approximately 252 trading days in a typical year, so the annualized variance is around 252 times the daily variance for independent and identically distributed share prices. Annualized volatility, which is simply the annualized standard deviation, is therefore around $\sqrt{252}$ times daily volatility.

Figure 1: Time Series Plots of Equity and Implied Volatility for CEBs and Non-CEBs
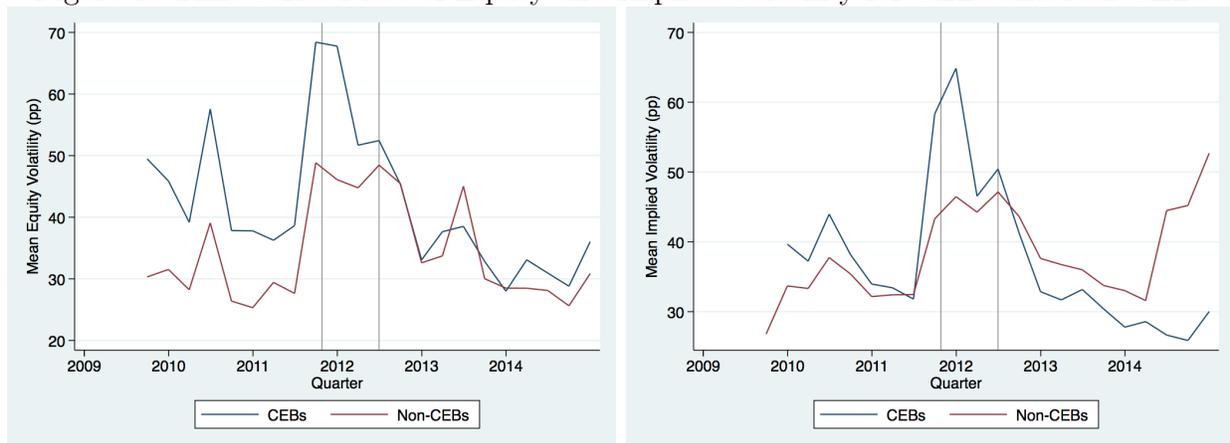
Note: These plots show mean equity volatility (left) and implied volatility (right) by quarter for CEBs and non-CEBs. The vertical grey lines mark the Capital Exercise's announcement date (October 26, 2011) and the deadline for meeting the new capital requirements (June 30, 2012).

$$r_e = r_f + \beta_e(r_m - r_f), \tag{1}$$

where r_e is the cost of equity, r_f is the risk-free rate, β_e is equity beta, and r_m is the market return. The cost of equity in turn factors into banks' weighted average cost of capital (WACC) according to the equation

$$WACC = \frac{E}{D+E}r_e + \frac{D}{D+E}r_d(1-t), \tag{2}$$

where E is the market value of equity, D is the market value of debt, r_d is the cost of debt, and t is the corporate tax rate.

In Figure 2, I plot the evolution of equity beta before, during, and after the Capital Exercise. The similarity of the trends for CEBs and non-CEBs throughout this period suggests that any channel through which higher capital requirements affect equity beta may be much weaker than predicted by standard financial theory. This is superficially consistent with Baker and Wurgler (2015), who use the lack of an empirical relationship between stock

Figure 2: Time Series Plot of Equity Beta for CEBs and Non-CEBs
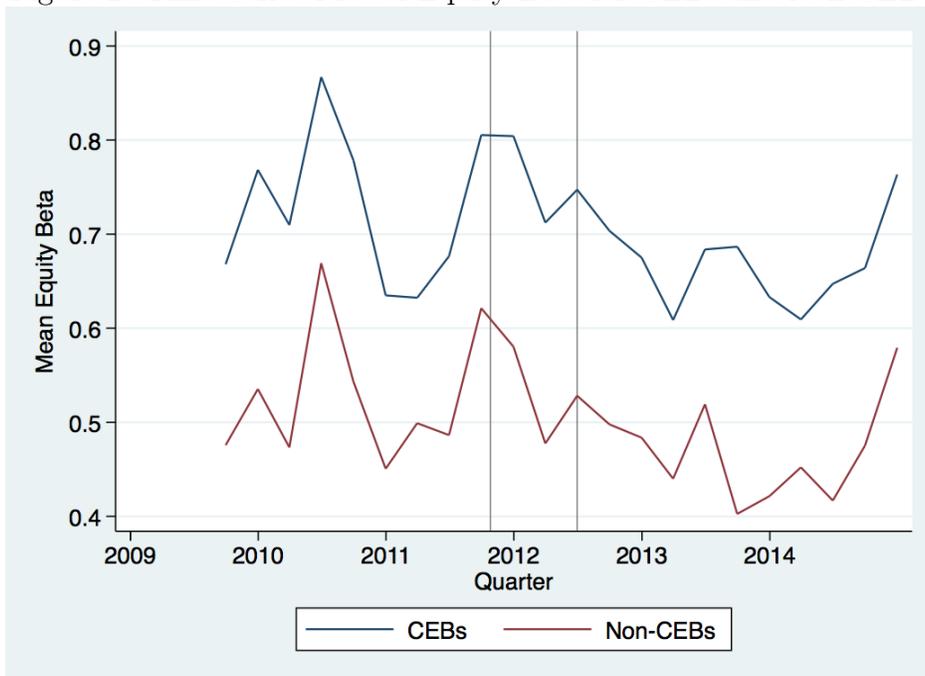
Note: This plot shows mean equity beta by quarter for CEBs and non-CEBs. The vertical grey lines mark the Capital Exercise's announcement date (October 26, 2011) and the deadline for meeting the new capital requirements (June 30, 2012).

returns and beta to cast doubt on whether higher capital ratios lower banks' cost of equity.

The implied probability of default is the most complex of the six risk measures, and has the advantage of capturing tail risk (Barro and Liao 2016). It is computed by the *Bloomberg Default Risk* (DRSK) function, which estimates a bank's default probability using inputs such as the share price, share price volatility, and total debt. The DRSK function implements the Kealhofer-McQuown-Vasicek (KMV) model (Kealhofer 1993; McQuown 1993; Vasicek 1984), which is based on the Merton (1974) structural model of default. I explain these default probability models in detail in Sections A.1 and A.2 in the Appendix. Table 2 suggests the Capital Exercise may have reduced the default probability, which fell from 0.61% to 0.53% for CEBs but remained approximately the same for non-CEBs.

The price-to-book ratio, which is the ratio of market capitalization to book value, has recently received considerable attention as a measure of banks' resilience. Market capitalization reflects not only the value of current assets less liabilities, but also the franchise value

of future profits in excess of the cost of capital, and the option value arising from implicit subsidies and shareholders' limited liability (Vickers 2019). Therefore, if the market believed banks' book valuations, banks' price-to-book ratios should substantially exceed one. However, the International Monetary Fund (IMF) *Global Financial Stability Report* published in October 2018 remarks that

> In the euro area, China, Japan, and the United Kingdom, bank aggregate price-to-book ratios are less than one. This means that the market value of equity is less than the amount of capital booked on bank balance sheets. If market valuations are used to calculate capital ratios—in place of the balance sheet value of capital used in the regulatory ratios—a number of banks would have a market-adjusted capitalization of less than 3 per cent, the minimum level in the Basel III framework.

This striking finding highlights the significant discrepancy between market and book measures of bank risk. I compare a time series plot of these aggregate price-to-book ratios (Figure 3) with the trends in price-to-book ratios for CEBs and non-CEBs over the course of the Capital Exercise (Figure 4). The US is the only country in Figure 3 for which price-to-book ratios have recovered from the crisis to levels persistently above one. However, this cannot be attributed to higher capital requirements, since Basel III was implemented across the G20.[9] On the other hand, Figure 4 appears to suggest that higher capital requirements may increase price-to-book ratios with a lag.

Finally, the price-to-earnings ratio contains an embedded risk premium, along with earnings expectations and discount rates, making it an appropriate measure of bank risk. For instance, Rajan (2005) finds that the price-to-earnings ratios of US banks had been declining relative to the market, and concludes that the market must have been discounting bank earnings with an increasing risk premium. Rajan interprets this as evidence that banks had not become less risky over the previous three decades.

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[9]The Bank of England has suggested that low price-to-book ratios can be explained by weak expected future profitability due to factors other than poor asset quality (Vickers 2019). Another possible explanation is that bank franchise values have declined more steeply outside the US (Sarin and Summers 2016).

Figure 3: Post-Crisis Trends in Bank Aggregate Price-to-Book Ratios
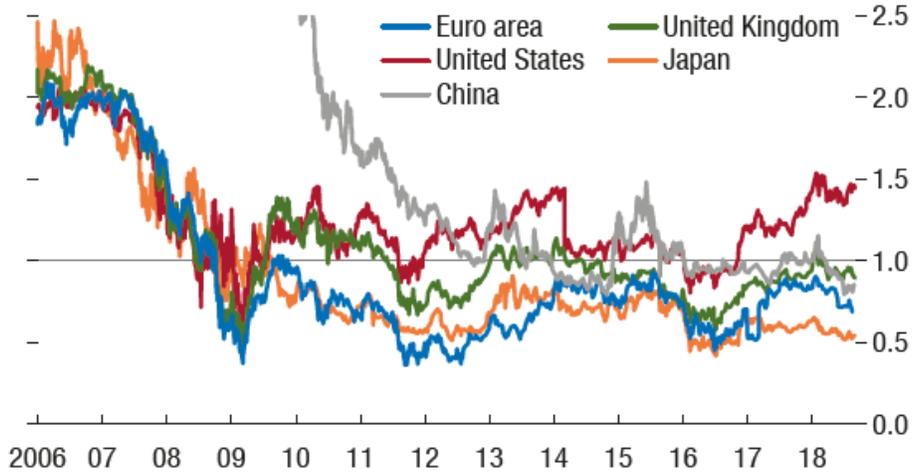
Note: This plot shows bank aggregate price-to-book ratios for the euro area, the US, China, the UK, and Japan. Only in the US have price-to-book ratios recovered to levels above one.

Source: Reproduced from Figure 1.20 in the IMF Global Financial Stability Report.

Figure 4: Time Series Plot of Price-to-Book Ratios for CEBs and Non-CEBs
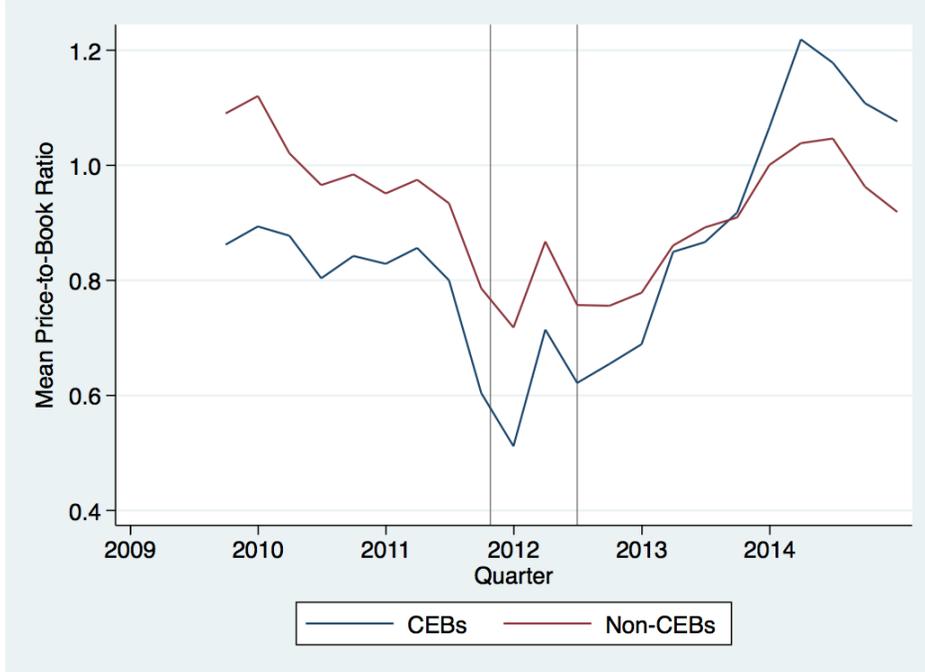
Note: This plot shows mean price-to-book ratios by quarter for CEBs and non-CEBs. The vertical grey lines mark the Capital Exercise's announcement date (October 26, 2011) and the deadline for meeting the new capital requirements (June 30, 2012).

4 Methodology

The objective of my analysis is to test whether banks that were subject to the Capital Exercise (CEBs, the treatment group) were consequently considered less risky by the market than banks that were not (non-CEBs, the control group). As noted by Gropp et al. (2019) and Schmidt (2019), the structure of the Capital Exercise lends itself to a difference-in-differences (DD) approach, in which the treatment occurs between the announcement of the Capital Exercise (October 26, 2011) and the deadline for meeting the new capital requirements (June 30, 2012). DD differences out the time-invariant confounders in each of the six market risk measures according to treatment status, thereby facilitating an estimate of the impact of the Capital Exercise on CEBs relative to non-CEBs.

DD relies on the identifying assumption that each of the market risk measures would have followed the same trend for CEBs and non-CEBs absent the Capital Exercise. Although this parallel trends assumption cannot be tested directly, it can be assessed nonparametrically for a specification without controls or fixed effects by inspecting time series plots of each of the risk measures for CEBs and non-CEBs. Figures 1, 2, and 4 show that equity volatility, implied volatility, equity beta, and price-to-book ratios indeed followed a common trend for CEBs and non-CEBs prior to the announcement of the Capital Exercise. For completeness, I include time series plots of all six market risk measures in Figure A1 in the Appendix. Default probabilities and price-to-earnings ratios, which exhibit more ambiguous dynamics, may still satisfy the parallel trends assumption conditional on suitable covariates.[10]

In my baseline specification, I include treatment interaction terms for both the treatment period (October 26, 2011–June 30, 2012) and the post-treatment period (July 1, 2012–December 31, 2014), since the Capital Exercise may have had a dynamic treatment effect. The only time-varying controls I include in this specification are time fixed effects and a linear time trend in the difference between the risk measures of CEBs and non-CEBs. Controlling for time-varying bank-level characteristics could bias my results, since they are likely to have

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[10]I examine the parallel trends assumption in detail for each of the risk measures in Section 6 (Figure 5).

been affected by the Capital Exercise. This yields the regression model

$$\rho_{i,t} = \alpha_i + \lambda_t + \gamma \cdot CEB_i * t + \delta \cdot CEB_i * Dur_t + \tau \cdot CEB_i * Post_t + \varepsilon_{i,t}, \qquad (3)$$

where: t is the number of quarters after 2011 Q4, the quarter in which the Capital Exercise was announced; $\rho_{i,t}$ is the market risk measure for bank i in quarter t; α_i denotes bank fixed effects; λ_t denotes time fixed effects; CEB_i is an indicator for whether bank i was subject to the Capital Exercise; Dur_t is an indicator for whether the end of quarter t occurred during the treatment period; $Post_t$ is an indicator for whether the end of quarter t occurred in the post-treatment period; and $\varepsilon_{i,t}$ is the error term. I interact the linear time trend t with the CEB indicator rather than individual bank indicators in order to prevent the time trend from absorbing part of the treatment effect, which is especially important because the Capital Exercise may have had a dynamic treatment effect. The coefficients of interest in this specification are δ and τ, which together capture the magnitude and timing of the treatment effect on the CEBs. In all DD specifications, I cluster standard errors at the bank level to account for autocorrelation.

An important concern with the Capital Exercise is that the treatment was not randomly assigned but correlated with bank size. In addition to constructing the overlap sample in Section 3, I address this issue using the bias-corrected matching estimator developed by Abadie and Imbens (2002). The matching estimator estimates the average treatment effect on the treated (ATET) by comparing the pre-post difference in each of the six market risk measures for CEBs against a matched control group of non-CEBs. For the matching specification, I calculate the pre-post difference in each risk measure as the difference between the means in the pre-announcement and post-announcement periods. I match on several pre-treatment bank characteristics in addition to size, since CEBs and non-CEBs also differ in their capital structures, business models, and funding strategies. Specifically, I match on log total assets, the tier 1 capital ratio, total customer deposits as a share of total assets,

net income as a share of total assets, net interest income as a share of total assets, and short-term depository funding as a share of total assets.[11] The matching estimator thereby accounts for a wide range of potential confounders in addition to bank size. The matching procedure uses four matches, which Abadie and Imbens (2011) find to be a good trade-off between bias and variance, along with standard errors that are robust to heteroskedasticity.

To understand the mechanism by which higher capital requirements affect bank risk, I further estimate a DD specification that exploits differences in CEB capital ratios prior to the Capital Exercise, using the inverse of the tier 1 capital ratio as a continuous measure of treatment intensity:

$$\rho_{i,t} = \alpha_i + \lambda_t + \delta \cdot Treat_i * Dur_t + \tau \cdot Treat_i * Post_t + \varepsilon_{i,t}, \tag{4}$$

where $Treat_i$ is the inverse of the tier 1 capital ratio of bank i in 2010 Q4.[12] I use the inverse of the tier 1 ratio—a risk-weighted measure of leverage—to ensure that higher values of the treatment variable $Treat_i$ correspond to larger capital shortfalls, and therefore larger effective increases in capital requirements as a result of the Capital Exercise.

5   Results

In this section, I present the results for the baseline specification, the Abadie and Imbens (2002) matching estimator, and the continuous treatment specification for CEBs.

Table 3 reports the results of the baseline specification for each of the six market risk measures. I find that the Capital Exercise strongly increased the average risk of CEBs relative to non-CEBs according to four of the six risk measures: equity volatility, implied volatility, the default probability, and the price-to-book ratio. During the treatment period,

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[11]This set of covariates is similar to those used by Gropp et al. (2019) and Schmidt (2019).

[12]I unfortunately do not have data on the most appropriate capital ratio—the core tier 1 ratio, which is the regulatory measure that was increased in the Capital Exercise. I therefore use the tier 1 ratio instead.

the Capital Exercise increased equity volatility by 16 percentage points, implied volatility by 18 percentage points, and the default probability by 0.58 percentage points, and decreased the price-to-book ratio by 0.35. All of these estimates are significant at the 0.1% level, and are qualitatively robust to nonparametric controls for pre-existing trends (Section 6).[13] Moreover, just under half of the effect on the price-to-book ratio during the treatment period persisted through the post-treatment period. On the other hand, for equity volatility, implied volatility, and the default probability, the effects of the Capital Exercise during the treatment period largely dissipated in the post-treatment period. These results indicate that the market rapidly priced in higher expectations of risk following the announcement of the Capital Exercise, but these expectations generally failed to materialize after the deadline for meeting the new capital requirements.[14]

Table 3: Baseline Estimates of the Impact of the Capital Exercise on Risk Measures

	(1) Vol	(2) Implied Vol	(3) Beta	(4) Default Prob	(5) P/B	(6) P/E
$CEB_i * Dur_t$	15.66***	18.19***	0.05*	0.58***	-0.35***	-2.92
	(2.22)	(1.58)	(0.02)	(0.15)	(0.03)	(1.51)
$CEB_i * Post_t$	-3.34	-0.66	-0.02	0.38	-0.16***	4.03*
	(2.43)	(0.95)	(0.03)	(0.19)	(0.04)	(1.91)
Bank FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Linear Trend	X	X	X	X	X	X
Observations	1619	926	1619	1527	1493	1124
Adjusted R^2	0.062	0.112	0.138	0.011	0.023	0.035

Note: This table reports the baseline results for equation (3), which indicate the Capital Exercise increased bank risk according to all six market risk measures. However, the coefficients for equity beta are biased by pre-existing trends (Figure 5), while the coefficients for the price-to-earnings ratio are not robust to the effects of the sovereign debt crisis (Tables 6 and A1). Standard errors are in parentheses, clustered by bank. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[13]I allow for a linear trend in the difference between the risk measures of CEBs and non-CEBs in the baseline specification, which is less flexible than a specification that includes CEB $\times$ quarter interactions.

[14]Although Table 3 also reports statistically significant coefficients for equity beta during the treatment period and the price-to-earnings ratio during the post-treatment period, I do not give much weight to these estimates as they are not robust to nonlinear pre-existing trends (Figure 5) and the sovereign debt crisis (Tables 6 and A1), respectively.

Table 4 reports the results from the Abadie and Imbens (2002) bias-corrected matching estimator. These results provide further evidence that the Capital Exercise increased bank risk. The matching estimator finds that the Capital Exercise increased equity volatility by 12 percentage points, implied volatility by 10 percentage points, and the default probability by 0.10 percentage points, and decreased price-to-book ratios by 0.22. These matching estimates are considerably smaller in magnitude than the baseline estimates but remain sizable in economic terms, comprising 32%, 30%, 16%, and 26% of CEB pre–Capital Exercise averages for equity volatility, implied volatility, the default probability, and the price-to-book ratio, respectively (Table 2).[15] This difference in magnitudes may be partly attributable to the use of a single post-announcement period in the matching specification, as opposed to the distinct treatment and post-treatment periods used in the baseline specification. I prioritize the baseline results in the remainder of the paper, since the matching estimates are computed using a small number of observations and are therefore sensitive to the choice of matching covariates.

Table 4: Matching Estimates of the Impact of the Capital Exercise on Risk Measures

	(1) Vol	(2) Implied Vol	(3) Beta	(4) Default Prob	(5) P/B	(6) P/E
Estimator (ATET)	11.93*	10.07**	0.02	0.10***	-0.22***	1.37
	(5.53)	(3.63)	(0.02)	(0.03)	(0.06)	(0.89)
Observations	58	39	58	58	55	56

Note: This table reports the results for the Abadie and Imbens (2002) bias-corrected matching estimator. The estimator uses four matches as a good trade-off between bias and variance (Abadie and Imbens 2011). Standard errors are in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Having shown that the Capital Exercise increased the risk of CEBs relative to non-CEBs, I examine the heterogeneous effects of the Capital Exercise on bank risk among CEBs by estimating equation (4). Table 5 reports the results. I find that the Capital Exercise generated larger increases in risk for more undercapitalized CEBs, which were effectively subject to larger increases in capital requirements, corroborating the main finding that higher

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[15]This comparison makes sense because the DD and matching specifications both estimate the ATET.

capital requirements can increase bank risk. These effects are significant at the 0.1% level across all six risk measures during the treatment period. Around half of the effect on the default probability remains significant at the 5% level in the post-treatment period. The steeper and largely transient deterioration in risk measures for more undercapitalized CEBs is consistent with a negative signaling effect of the announcement of the Capital Exercise.

Table 5: Within-CEBs Estimates of the Impact of the Capital Exercise

	(1) Vol	(2) Implied Vol	(3) Beta	(4) Default Prob	(5) P/B	(6) P/E
$Treat_i * Dur_t$	2.04***	1.98***	0.01***	0.04***	-0.04***	-0.46***
	(0.30)	(0.27)	(0.00)	(0.01)	(0.01)	(0.13)
$Treat_i * Post_t$	-0.06	-0.06	0.01	0.02*	-0.02	0.31
	(0.29)	(0.22)	(0.01)	(0.01)	(0.02)	(0.31)
Bank FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Observations	674	517	674	693	650	465
Adjusted R^2	0.138	0.363	0.057	0.192	0.041	0.063

Note: This table reports the results for equation (4). These results show that the Capital Exercise generated larger increases in risk for more undercapitalized CEBs across all six risk measures during the treatment period, providing further evidence that higher capital requirements can increase bank risk. Standard errors are in parentheses, clustered by bank. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6   Robustness Checks

I proceed to perform a series of robustness checks to assess the sensitivity and validity of my baseline results. To examine the parallel trends assumption more closely, I consider a dynamic DD specification that controls for pre-existing trends nonparametrically by interacting the CEB indicator with indicators for each quarter:

$$\rho_{i,t} = \alpha_i + \lambda_t + \sum_{s \neq -1} \tau_s \cdot CEB_i * \mathbb{1}(s = t) + \varepsilon_{i,t}. \tag{5}$$

This specification allows for more flexible pre-existing trends than the linear time trend in

equation (3). The interaction between the CEB indicator and the indicator for 2011 Q3 is omitted from the summation (or equivalently, the coefficient τ_{-1} is normalized to zero) in order to avoid multicollinearity, so all of the other interaction coefficients $\{\tau_s\}_{s \neq -1}$ are estimated relative to the quarter preceding the Capital Exercise.

For each of the six risk measures, I plot the sequence of estimates and 95% confidence intervals for the coefficients $\{\tau_s\}$ (Figure 5) to assess the validity of the parallel trends assumption, conditional on bank and time fixed effects. Figure 5 supports the validity of the conditional parallel trends assumption for equity volatility, implied volatility, and the price-to-book ratio.[16] Although equity volatility exhibits residual effects of the financial crisis in 2009 H2 and the onset of the sovereign debt crisis in 2010 H1, these effects disappear entirely by the end of 2010. Therefore, my estimates for equity volatility should not be biased by these effects. Figure 5 also supports the validity of the conditional parallel trends assumption for the default probability, even though the validity of the unconditional parallel trends assumption is more ambiguous (Figure A1). However, Figure 5 does undermine the validity of the conditional parallel trends assumption for equity beta, which experienced a sharp decline for CEBs relative to non-CEBs in the quarter preceding the Capital Exercise, implying that my baseline estimates of the effect on equity beta are likely to be biased.

The plots in Figure 5 also visualize the dynamic effects of the Capital Exercise on each of the risk measures. For the four risk measures that appear to satisfy the conditional parallel trends assumption—equity volatility, implied volatility, the default probability, and the price-to-book ratio—the Capital Exercise had a sharp effect immediately after the announcement date which faded over the course of the following year. This pattern substantiates the finding that the Capital Exercise primarily impacted risk measures through the announcement itself, which again is consistent with the Capital Exercise sending a negative signal about the risk of CEBs relative to non-CEBs.

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[16]Figure A1 supports the validity of the unconditional parallel trends assumption for these same three risk measures, as discussed in Section 4. However, the conditional parallel trends assumption examined here is more relevant, since all DD specifications that I use control for bank and time fixed effects.

Figure 5: Dynamic DD Estimates of the Impact of the Capital Exercise on Risk Measures
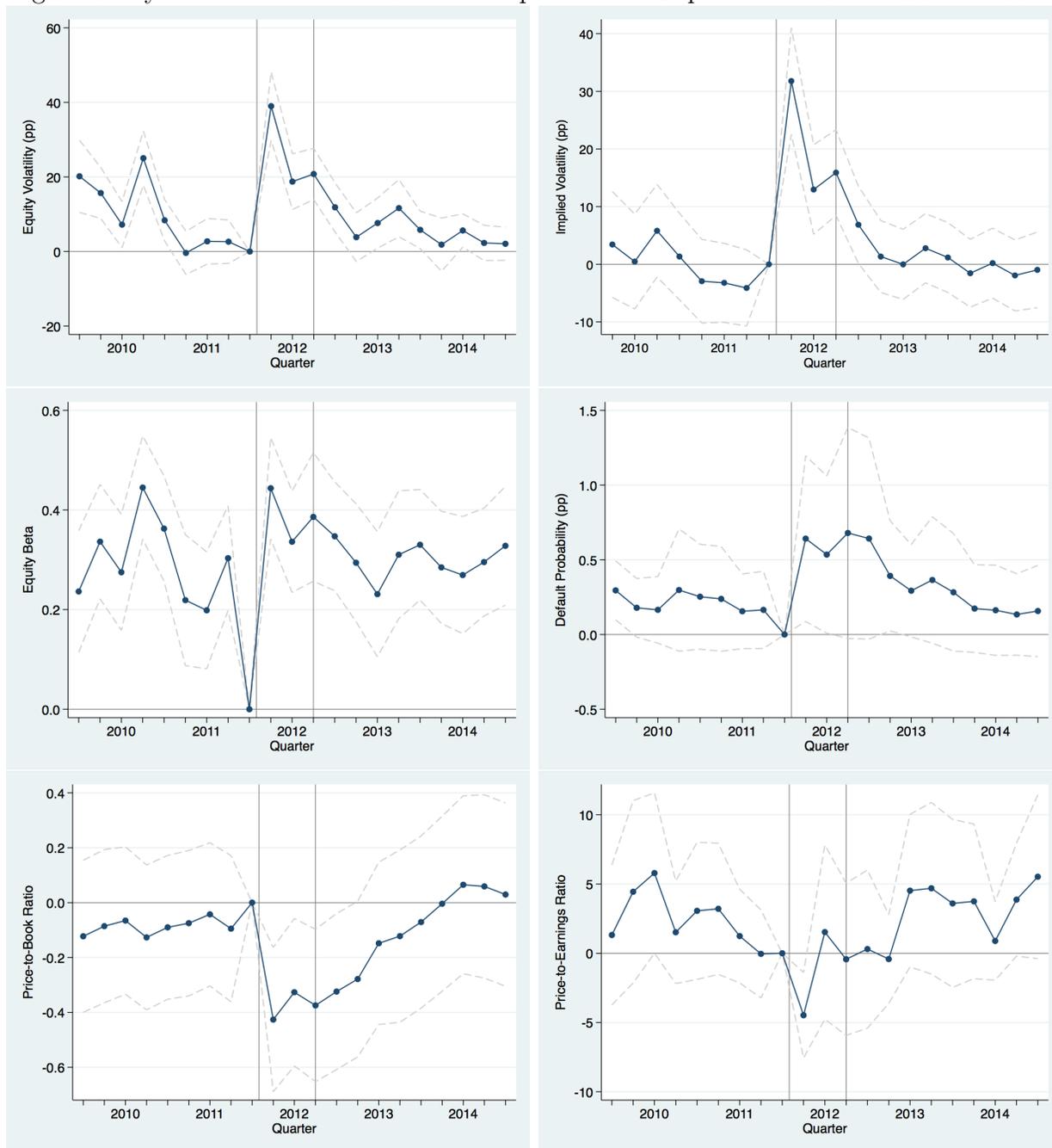
Note: These plots show the evolution of the effect of the Capital Exercise on each of the risk measures. The blue dots represent the sequence of estimates for the coefficients $\{\tau_s\}$ in equation (5). The coefficient τ_{-1} corresponding to 2011 Q3 is normalized to zero across all risk measures, so all other coefficients are estimated relative to the quarter preceding the Capital Exercise. The coefficient τ_{-9} corresponding to 2009 Q3 is omitted for implied volatility, since there are no observations available for implied volatility in this quarter. The dashed grey lines trace the 95% confidence interval for τ_s in each quarter s. The solid vertical grey lines mark the Capital Exercise's announcement date (October 26, 2011) and the deadline for meeting the new capital requirements (June 30, 2012).

I now turn to address potential confounders specifically associated with the European sovereign debt crisis, such as moral suasion by governments and the launch of the European Central Bank's longer-term refinancing operations (LTROs) in December 2011. If the events of the sovereign debt crisis affected larger banks disproportionately, my baseline results in Table 3 are likely to be biased. I tackle this issue in two ways.

First, I control for the differential effects of the sovereign debt crisis across countries in both the baseline and within-CEBs specifications, using the volatility of the national benchmark index of the country in which each bank is headquartered:

$$
\rho_{i,t} = \alpha_i + \lambda_t + \gamma \cdot CEB_i * t + \delta \cdot CEB_i * Dur_t
$$
$$
+ \tau \cdot CEB_i * Post_t + \beta \cdot \text{IndexVol}_{i,t} + \varepsilon_{i,t} \tag{6}
$$

$$
\rho_{i,t} = \alpha_i + \lambda_t + \delta \cdot Treat_i * Dur_t + \tau \cdot Treat_i * Post_t + \beta \cdot \text{IndexVol}_{i,t} + \varepsilon_{i,t}, \tag{7}
$$

where $\text{IndexVol}_{i,t}$ is the volatility in quarter t of the national benchmark index of the country corresponding to bank i.

Table 6 reports the results for equation (6), which unsurprisingly show that index volatility is a significant predictor for each of the risk measures. I find that the effects of the Capital Exercise on equity volatility, implied volatility, default probabilities, and price-to-book ratios are robust to country-specific risk factors. While the effects on equity and implied volatility are smaller than the baseline estimates—at 9 and 13 percentage points respectively—they still comprise substantial proportions of CEB pre–Capital Exercise averages, at 24% for equity volatility and 38% for implied volatility. Moreover, the effect on the default probability shifts from the treatment period to the post-treatment period when controlling for index volatility, providing evidence that the Capital Exercise generated a large and persistent increase in bank risk that cannot be explained by the sovereign debt crisis. The estimated coefficients for the price-to-book ratio remain similar to the baseline estimates in both the treatment and post-treatment periods. On the other hand, the effects of the Capital Exer-

cise on equity beta and the price-to-earnings ratio in the baseline specification are no longer significant when controlling for country-specific risk factors. The effects on implied volatility and the price-to-book ratio remain significant at the 0.1% level, while the effects on equity volatility and the default probability are significant at the 1% level.

Similarly, Table 7 reports the results for equation (7), which again show that index volatility is a significant predictor for each of the risk measures. I find that the larger effects of the Capital Exercise on more undercapitalized CEBs are robust to country-specific risk factors across all six risk measures. That said, the treatment effects are somewhat smaller in magnitude in this specification, and the effect on equity beta shifts from the treatment period to the post-treatment period.

Table 6: DD Estimates Controlling for Country-Specific Risk Factors

	(1) Vol	(2) Implied Vol	(3) Beta	(4) Default Prob	(5) P/B	(6) P/E
$CEB_i * Dur_t$	8.92**	12.96***	0.00	0.24	-0.30***	-1.92
	(2.46)	(1.91)	(0.03)	(0.18)	(0.04)	(2.03)
$CEB_i * Post_t$	4.43	4.03	0.04	0.86**	-0.27***	2.80
	(3.48)	(2.01)	(0.04)	(0.24)	(0.04)	(1.80)
Index Vol	1.59***	1.09***	0.01***	0.07*	-0.01***	-0.15**
	(0.25)	(0.14)	(0.00)	(0.03)	(0.00)	(0.05)
Bank FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Linear Trend	X	X	X	X	X	X
Observations	1619	922	1619	1487	1464	1109
Adjusted R^2	0.375	0.333	0.291	0.207	0.082	0.054

Note: This table reports the results for equation (6). These results are broadly similar to those in Table 3. In this specification, the main differences are that the effect on the default probability is shifted from the treatment period to the post-treatment period, while the coefficients for equity beta and the price-to-earnings ratio are no longer significant. Standard errors are in parentheses, clustered by bank. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The sovereign debt crisis and the ensuing LTROs primarily affected banks in Greece, Ireland, Italy, Portugal, and Spain (the GIIPS countries), which increased their exposures to domestic sovereign debt (Ongena et al. 2016) and accounted for around two thirds of the take-up in LTROs (Van Rixtel and Gasperini 2013). Therefore, I also address concerns about

Table 7: Within-CEBs Estimates Controlling for Country-Specific Risk Factors

	(1) Vol	(2) Implied Vol	(3) Beta	(4) Default Prob	(5) P/B	(6) P/E
$Treat_i * Dur_t$	0.96***	1.22***	0.00	0.03***	-0.03**	-0.30*
	(0.26)	(0.23)	(0.00)	(0.01)	(0.01)	(0.14)
$Treat_i * Post_t$	0.22	0.11	0.01*	0.03*	-0.03	0.23
	(0.26)	(0.23)	(0.00)	(0.01)	(0.02)	(0.33)
Index Vol	1.48***	1.01***	0.01***	0.01*	-0.01***	-0.23***
	(0.08)	(0.08)	(0.00)	(0.00)	(0.00)	(0.06)
Bank FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Observations	674	513	674	653	621	450
Adjusted R^2	0.243	0.591	0.198	0.201	0.213	0.089

Note: This table reports the results for equation (7). These results are broadly similar to those in Table 5. In this specification, the main differences are that the coefficients for the treatment period are somewhat smaller in magnitude, and the effect on equity beta is shifted from the treatment period to the post-treatment period. Standard errors are in parentheses, clustered by bank. Standard errors are in parentheses, clustered by bank. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

the sovereign debt crisis by excluding banks in GIIPS countries from the original overlap sample and re-estimating the baseline and within-CEBs specifications.

I include the results for the baseline specification in Table A1 in the Appendix, which are very similar to those in Table 3 except without any significant effect of the Capital Exercise on the price-to-earnings ratio. I also include the results for the within-CEBs specification in Table A2, which are essentially identical to those in Table 5.

In both the baseline results in Table 3 and the within-CEBs results in Table 5, the number of observations varies considerably across each of the risk measures. This variation arises primarily from missing observations for implied volatility and price-to-earnings ratios. To ensure that my results are not driven by differences in sample composition, I modify the original overlap sample by dropping all observations for which either implied volatility or the price-to-earnings ratio is missing. I then re-estimate both the baseline and within-CEBs specifications using this subsample.

I include the results for the baseline specification in Table A3 in the Appendix, which are

very similar to those in Table 3 except with a persistent effect on the default probability in the post-treatment period and without any significant effect on the price-to-earnings ratio. I also include the results for the within-CEBs specification in Table A4, which are essentially identical to those in Table 5. These results confirm that neither the baseline estimates nor the within-CEBs estimates are biased by differences in sample composition.

7   Conclusion

In this paper, I exploit the 2011 EBA Capital Exercise as a quasi-natural experiment to assess the impact of higher capital requirements on market measures of risk. I find evidence that the Capital Exercise strongly increased the market's perception of bank risk according to four risk measures: equity volatility, implied volatility, the default probability, and the price-to-book ratio. Moreover, among Capital Exercise banks (CEBs), I find that the Capital Exercise generated larger increases in risk for more undercapitalized banks, which were effectively subject to larger increases in capital requirements.

The market's rapid response to the announcement of the Capital Exercise implies the announcement itself sent a strong negative signal about the health of CEBs. In particular, the persistent decline in price-to-book ratios suggests the Capital Exercise actually exacerbated bank risk, by lowering franchise values or reducing expectations of government guarantees. Policymakers could mitigate these unintentional signaling effects by changing capital requirements across the entire banking sector instead of a subset of banks.

At the same time, increases in the other risk measures largely dissipated after the deadline for meeting the new capital requirements, indicating that in some cases the market's higher expectations of risk failed to materialize. This fact highlights a limitation of market-based stress tests: the market may provide a misleading view of bank risk precisely when policymakers look to it for guidance. Policymakers should therefore not use market measures in isolation, but rather in conjunction with existing regulatory measures.

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References

Abadie, A., Angrist, J. D., & Imbens, G. (2002). "Instrumental Variables Estimates of the Effect of Subsidized Training on the Quantiles of Trainee Earnings." *Econometrica*, 70(1), 91-117.

Abadie, A., & Imbens, G. (2002). "Simple and Bias-Corrected Matching Estimators for Average Treatment Effects." *NBER Working Paper No. 283.*

Abadie, A., & Imbens, G. (2011). "Bias-Corrected Matching Estimators for Average Treatment Effects." *Journal of Business and Economic Statistics*, 29(1), 1-11.

Acharya, V. V., Pedersen, L. H., Philippon, T., & Richardson, M. (2017). "Measuring Systemic Risk." *Review of Financial Studies*, 30, 2-47.

Adrian, T., & Brunnermeier M. K. (2016). "CoVaR." *American Economic Review*, 106(7), 1705–41.

Baker, M., & Wurgler, J. (2015). "Do Strict Capital Requirements Raise the Cost of Capital? Banking Regulation and the Low Risk Anomaly." *American Economic Review*, 105(5), 315-320.

Barro, R. J., & Liao, G. Y. (2016). "Options-Pricing Formula with Disaster Risk." *NBER Working Paper No. 21888.*

Basel Committee on Banking Supervision. "History of the Basel Committee." Bank for International Settlements Website.

Bostandzic, D., Irresberger, F., Juelsrud, R., & Weiss, G. N. F. (2017). "Bank Capital Requirements and Systemic Risk: Evidence from a Quasi-Natural Experiment." *Leeds University Business School Working Paper No. 18-02.*

Brownlees, C. T., & Engle, R. F. (2017). "SRISK: A Conditional Capital Shortfall Measure of Systemic Risk." *Review of Financial Studies*, 30(1), 48–79.

Cao, C., Fan, Y., and Zhong, Z., (2010). "The Information Content of Option-Implied Volatility for Credit Default Swap Valuation." *Journal of Financial Markets*, 13(3): 321–43.

Croen, D. (2018). "Assessing and Incorporating Credit Default Risk Analytics into Investment Analysis." *Bloomberg Professional Services.*

Davila, E., & Korinek, A. (2018). "Pecuniary Externalities in Economies with Financial Frictions." *Review of Economic Studies*, 85(1), 352-395.

Degryse, H., De Jonghe, O., Jakovljevic, S., Mulier, K., & Schepens, G. (2019). "Identifying Credit Supply Shocks with Bank-Firm Data: Methods and Applications." *Journal of Financial Intermediation*, 40.

European Banking Authority (2011). "EU Capital Exercise." European Banking Authority Website.

Gao, Y., Liao, S., & Wang, X. (2018). "Capital Markets' Assessment of the Economic Impact of the Dodd Frank Act on Systemically Important Financial Firms." *Journal of Banking and Finance*, 86, 204-223.

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Gropp, R., Mosk, T. C., Ongena, S., & Wix, C. (2019). "Banks' Response to Higher Capital Requirements: Evidence from a Quasi-Natural Experiment." *Review of Financial Studies*, 32(1): 266-399.

Haldane, A., & Madouros, V. (2012). "The Dog and the Frisbee." *Revista de Economía Institucional*, 14, 13–56.

International Monetary Fund (2018). "A Decade after the Global Financial Crisis: Are We Safer?" Global Financial Stability Report.

Jenkins, P. (2012). "EBA Hails Banks' Capital Strengthening." *Financial Times*, July 11.

Jones, D. (2000). "Emerging Problems with the Basel Capital Accord: Regulatory Capital Arbitrage and Related Issues." *Journal of Banking and Finance*, 24(1-2), 35-58.

Kealhofer, S. (1993). "Portfolio Management of Default Risk." KMV Corporation.

Lintner, J. (1965). "The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets." *Review of Economics and Statistics*, 47, 13-37.

McQuown, J. A. (1993). "Market vs. Accounting Based Measures of Default Risk." KMV Corporation.

Merton, R. C. (1974). "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates." *Journal of Finance*, 29(2), 449-470.

Mésonnier, J., & Monks, A. (2015). "Did the EBA Capital Exercise Cause a Credit Crunch

in the Euro Area?" *International Journal of Central Banking.*

Myers, S. C. (1977). "Determinants of Corporate Borrowing." *Journal of Financial Economics*, 5(2), 147-175.

Myers, S. C., & Majluf, N. S. (1984). "Corporate Financing and Investment Decisions When Firms Have Information that Investors Do Not Have." *Journal of Financial Economics*, 13(2), 187-221.

Ongena, S., Popov, A., & Van Horen, N. (2016). "The Invisible Hand of the Government: 'Moral Suasion' During the European Sovereign Debt Crisis." CEPR Discussion Papers No. 11153.

Rajan, R. G. (2005). "Has Financial Development Made the World Riskier?" Speech at the Federal Reserve Bank of Kansas City Economic Policy Symposium in Jackson Hole.

Sarin, N., & Summers, L. H. (2016). "Understanding Bank Risk through Market Measures." *Brookings Papers on Economic Activity*, Fall, 57-109.

Schäfer, A., Schnabel, I., & Weder di Mauro, B. (2016). "Financial Sector Reform after the Subprime Crisis: Has Anything Happened?" *Review of Finance*, 20(1), 77–125.

Schmidt, C. (2019). "Bank Leverage, Capital Requirements and the Implied Cost of (Equity) Capital." Working Paper.

Schwert, G. W. (1989). "Why Does Stock Market Volatility Change Over Time?" *Journal of Finance*, 44(5): 1115-53.

Sharpe, W. F. (1964). "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk." *Journal of Finance*, 19, 425-442.

Tarullo, D. K. (2011). "The Evolution of Capital Regulation." Speech given at the Clearing House Business Meeting and Conference, New York, New York.

Van Rixtel, A., & Gasperini, G. (2013). "Financial Crises and Bank Funding: Recent Experience in the Euro Area." BIS Working Paper No. 406.

Vasicek, O. A. (1984). "The Philosophy of Credit Valuation: The Credit Valuation Model." KMV Corporation.

Vickers, J. (2019). "The Case for Market-Based Stress Tests." Speech at the 19th Annual International Conference on Policy Challenges for the Financial Sector, International Monetary Fund, Washington DC.

A Appendix

A.1 The Merton Model

The Merton (1974) structural model of default sets a default trigger based on certain assumptions about the dynamics of a firm's capital structure. This trigger is activated when a firm's assets reach a sufficiently low level relative to its liabilities. The Merton model then computes the expected default frequency to estimate the firm's probability of default. The default trigger threshold is set by viewing equity as a European call option on the firm's assets and applying the standard Black-Scholes call option formula. The Merton model assumes that the total value of a firm's assets follows a geometric Brownian motion:

$$dA_t = \mu A_t dt + \sigma_A A_t dW_t, \tag{8}$$

where A_t denotes the firm's total assets, μ is the mean rate of return on those assets, and σ_A is the volatility of total assets.

A.2 The KMV Model

The KMV model largely follows the approach of the Merton model, inferring the value of the firm's assets from the value of its debt and market capitalization (E_t) using

$$E_t = \text{BSCall}(A_t, T - t, r, \sigma, K), \tag{9}$$

where BSCall denotes the Black-Scholes call option formula. The KMV model then computes the firm's distance to default (DD_t) using

$$DD_t = \frac{\log(A_t/K)}{\sigma}, \tag{10}$$

where K is the default trigger level of assets and σ is the one-year standard deviation of the probability density function $\log A_{t+1}$. However, KMV diverges from strict structural models by using a proprietary function to map the distance to default to the expected default frequency, based on a large internal database of historical defaults, which has resulted in a particularly successful practical implementation of structural default modeling.

A.3 Tables and Figures

Table A1: DD Estimates Excluding GIIPS Countries

	(1) Vol	(2) Implied Vol	(3) Beta	(4) Default Prob	(5) P/B	(6) P/E
$CEB_i * Dur_t$	16.79***	18.33***	0.07**	0.51**	-0.38***	-2.65
	(2.31)	(1.91)	(0.02)	(0.17)	(0.03)	(1.85)
$CEB_i * Post_t$	0.38	0.16	-0.03	0.31***	-0.20***	1.90
	(1.95)	(1.10)	(0.03)	(0.05)	(0.03)	(1.95)
Bank FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Linear Trend	X	X	X	X	X	X
Observations	1066	601	1066	1005	965	798
Adjusted R^2	0.282	0.369	0.332	0.064	0.040	0.030

Note: This table reports the estimates for equation (3) using a subsample that excludes all observations from banks in Greece, Ireland, Italy, Portugal, and Spain. These estimates are broadly unchanged from those in Table 3. For this subsample, the main differences are that the Capital Exercise now has a persistent effect on the default probability and no longer increases the price-to-earnings ratio in the post-treatment period. Standard errors are in parentheses, clustered by bank. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure A1: Time Series Plots of Market Risk Measures for CEBs and Non-CEBs
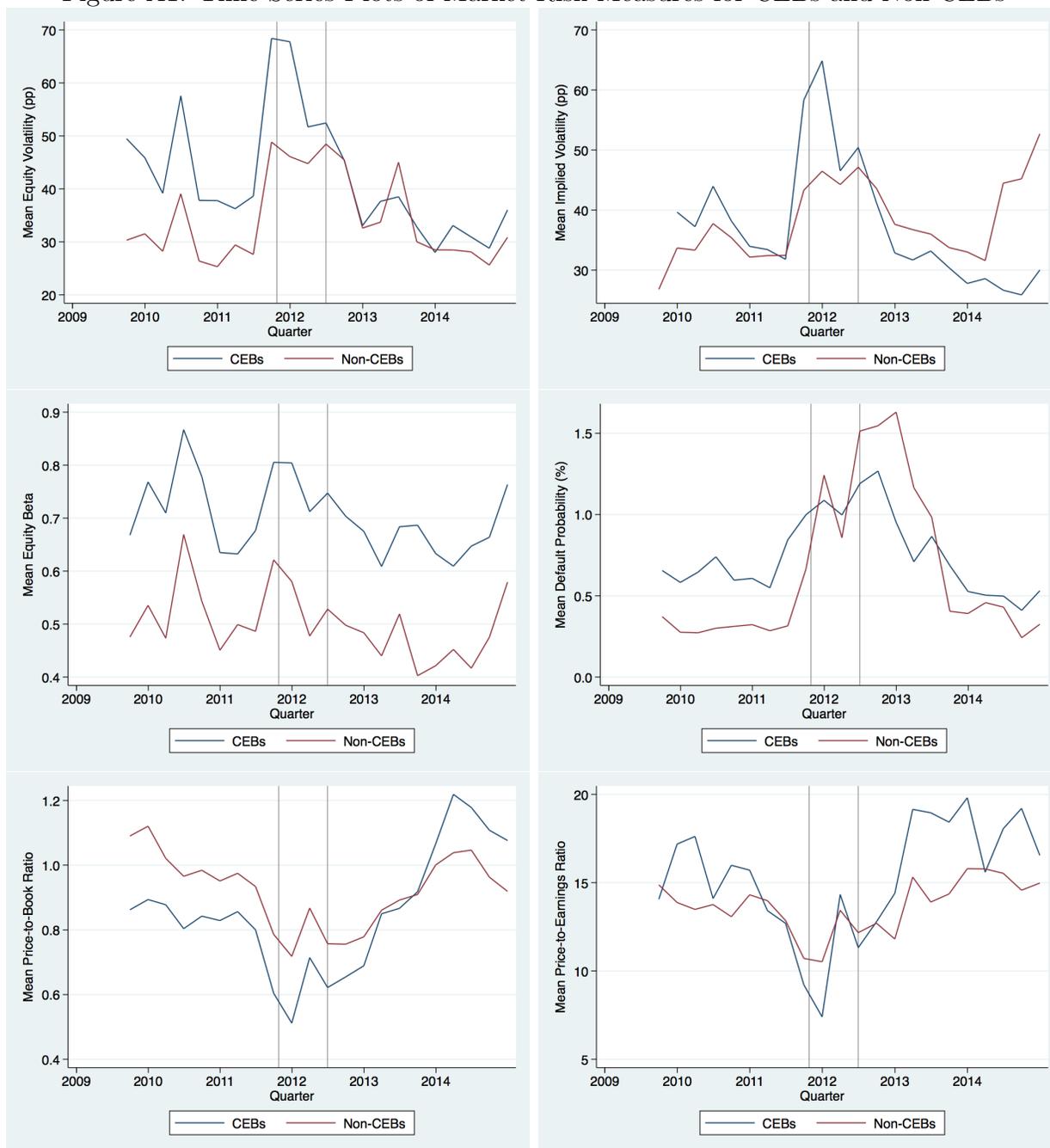
Note: These plots show the mean values of each of the risk measures by quarter for CEBs and non-CEBs. The vertical grey lines mark the Capital Exercise's announcement date (October 26, 2011) and the deadline for meeting the new capital requirements (June 30, 2012).

Table A2: Within-CEBs Estimates Excluding GIIPS Countries

	(1) Vol	(2) Implied Vol	(3) Beta	(4) Default Prob	(5) P/B	(6) P/E
$Treat_i * Dur_t$	2.16***	2.23***	0.01**	0.04***	-0.04***	-0.65***
	(0.32)	(0.29)	(0.00)	(0.01)	(0.01)	(0.13)
$Treat_i * Post_t$	0.28	0.12	-0.00	0.04**	-0.02	-0.22
	(0.35)	(0.24)	(0.01)	(0.01)	(0.02)	(0.32)
Bank FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Observations	478	397	478	504	461	364
Adjusted R^2	0.305	0.436	0.078	0.320	0.272	0.029

Note: This table reports the estimates for equation (4) using a subsample that excludes all observations from banks in Greece, Ireland, Italy, Portugal, and Spain. These estimates are essentially identical to those in Table 5. Standard errors are in parentheses, clustered by bank. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A3: DD Estimates Ex. Obs. with Missing Implied Vol or P/E Ratio

	(1) Vol	(2) Implied Vol	(3) Beta	(4) Default Prob	(5) P/B	(6) P/E
$CEB_i * Dur_t$	16.28***	16.16***	0.07***	0.31***	-0.31***	-3.13
	(2.33)	(1.98)	(0.01)	(0.05)	(0.04)	(1.75)
$CEB_i * Post_t$	-3.71	-2.91	0.04	0.15**	-0.15*	4.09
	(2.08)	(1.57)	(0.03)	(0.06)	(0.06)	(2.16)
Bank FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Linear Trend	X	X	X	X	X	X
Observations	641	643	641	624	625	643
Adjusted R^2	0.192	0.101	0.185	0.208	0.065	0.049

Note: This table reports the estimates for equation (3) using a subsample that excludes all observations for which either implied volatility or the price-to-earnings ratio is missing. These estimates are broadly unchanged from those in Table 3. For this subsample, the main differences are that the Capital Exercise now has a persistent effect on the default probability and no longer increases the price-to-earnings ratio in the post-treatment period. Standard errors are in parentheses, clustered by bank. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A4: Within-CEBs Estimates Ex. Obs. with Missing Implied Vol or P/E Ratio

	(1) Vol	(2) Implied Vol	(3) Beta	(4) Default Prob	(5) P/B	(6) P/E
$Treat_i * Dur_t$	2.09***	1.99***	0.01***	0.04***	-0.04***	-0.48***
	(0.32)	(0.27)	(0.00)	(0.01)	(0.01)	(0.11)
$Treat_i * Post_t$	-0.01	-0.05	0.01	0.02	-0.03	0.38
	(0.29)	(0.22)	(0.00)	(0.01)	(0.02)	(0.29)
Bank FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Observations	378	380	378	380	363	380
Adjusted R^2	0.256	0.364	0.087	0.147	0.124	0.068

Note: This table reports the estimates for equation (4) using a subsample that excludes all observations for which either implied volatility or the price-to-earnings ratio is missing. These estimates are essentially identical to those in Table 5. Standard errors are in parentheses, clustered by bank. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$