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ORIGINAL ARTICLE

Risk-taking in banks: does skin-in-the-game really matter?

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Abstract

The belief that bank capital helps improve stability takes for granted the idea that increases in capital are an incentive to reduce risk-taking because bank owners would have more to lose (skin-in-the-game) if their banks fail. Nevertheless, given the higher cost of capital as compared to debt, it is also possible that increases in capital would lead to higher risk-taking due to the need for banks to boost their returns. In light of these contradictory possibilities, we exploit exogenous variations of capital to empirically investigate the actual effects of capital on risk-taking. Our analyses based on a sample of nearly 1900 US Banking Holding Companies in the 1990–2020 period indicate that increasing capital actually leads to higher risk-taking, which contradicts the skin-in-the-game hypothesis. We show evidence that this relationship could be explained by the consequent increase in funding costs that creates pressure for better returns, which is normally achieved by means of taking higher risk. Our main findings are robust to a number of alternative model and sample specifications.

Keywords Bank capital · Risk-taking · Skin-in-the-game · Funding costs

JEL Classification G21 · G28

Introduction

Bank capital is the cornerstone of international recommendations on banking regulation (e.g., [9]). One of the reasons for such regulatory requirement is because when capital increases, bank owners (shareholders in the case of listed institutions) would have more to lose (i.e., more capital) and would avoid excessive risk-taking (or monitor managers to prevent it) that could result in significant future losses (see, e.g., [8, p. 52, 11, 31, p. 146]). [1] The potential increase in risk aversion (i.e., incentives to reduce risk-taking) due to bank owners having more resources (investments) at stake is commonly referred to as a skin-in-the-game motivation. This possibility is supported by the beneficial impact of capital on risk-taking identified in a number of studies in the area (e.g., [3, 4, 19, 20, 23, 26, 32, 37, 44, 53].

However, many other authors have found evidence that increasing (reducing) bank capital would actually be related to more (less) risk-taking (e.g., [1, 5, 13, 16, 27, 28, 33, 35, 36, 39, 41, 46]). Such relationship can be explained by the high cost of newly issued capital [2] that could lead banks to take more risk to boost their returns and/or by the possibility that bank leverage and risk are substitutes in the optimization strategy followed by banks when deciding on their equity and risk levels (hence, more debt—and less capital—would lead to less risk, which is particularly claimed in [35, 36, 39].

On top of the potential opposite effects of capital on risk-taking mentioned above, a third group of studies suggest that there is no direct relationship between capital and risk (e.g., [29, 34, 45, 48]). The lack of an influence of capital on risk-taking could be due to offsetting effects of different mediators between them or the existence of latent confounders driving their association (which would be the cause of the correlation observed between them).

In view of these conflicting conclusions on the relationship between bank capital and risk-taking, the validity of

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[1] Another straightforward explanation for the importance of capital is based on the idea that the more capital a bank has the more losses it can absorb, which makes bankruptcy less likely. While this is a by-definition (therefore, valid) explanation, in this study we focus on the alleged channel (risk-taking) connecting capital to stability. Hence, our discussions will be centered on the possible changes in risk-taking as a consequence of changes in capital.

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the skin-in-the-game hypothesis with respect to bank owners could be called into question especially because, even though it is quite appealing, it lacks empirical evidence.

In this context, we use data covering the 1990–2020 period for empirically determining the practical consequences of capital changes in terms of risk-taking in US Banking Holding Companies. Apart from relying on fixed effects models, we use two-stage least square models with instrumental variables that allow us to focus on variations of capital (1) presumably not related to other issues driving both capital and risk-taking, and (2) not affected by concomitant changes in risk levels. In this way, we can identify the impact of bank capital on risk-taking rather than being limited to conclusions based on correlation measures.

We find that changes in capital lead to changes in risk in the same direction. That is, increases in capital bring about increases in risk-taking, which casts doubt on the idea of skin-in-the-game. Supplementary model and data specifications, additional proxies of capital, and different versions of the instruments used confirm our original conclusion. We interpret this result as a signal that the changes in funding costs due to variations in capital make banks adjust their risk levels in line with the return necessary to cover those costs. This explanation is supported by further analyses that reveal that changes in capital indeed affect funding costs, which in turn affect risk-taking. Therefore, in sum, we show evidence that, even if skin-in-the-game matters for risk-taking, such importance is completely dominated by other factors driving risk-taking (such as the cost of capital).

Our main contributions are threefold. First, we empirically test one of the main explanations (bank owners' skin-in-the-game) of the importance of bank capital in the promotion of stability, which many researchers and regulators have taken for granted. While issues involving skin-in-the-game in banking have already been empirically investigated in the literature, to our knowledge, none of the existing studies in the field looks into the pertinence of the skin-in-the-game to owners (e.g., shareholders) in the context of bank management (i.e., decisions on risk-taking). Billett et al. [14], for example, study the relation between skin-in-the-game of banks themselves and the design on loan contracts. Demiroglu and James [24] analyze the skin-in-the-game of loan originators (i.e., lenders) and potential losses of securities backed by the respective loans. Ashcraft et al. [7] show that financial innovation can contribute to reducing the skin-in-the-game of investors in securities based on mortgage loans. Furthermore, as indicated above, those studies focus on specific products such as mortgage-backed securities (e.g., [7, 24]) and covenant-lite loans (e.g., [14]. Our analyses, on the other hand, include all risk investments made by banks, which then leads to a more comprehensive assessment of the potential losses of shareholders.

Given the methods used (in particular, instrumental variables), we can attribute a causal interpretation to our results and then help elucidate conflicting findings in the literature focused on the impact of bank capital on risk-taking, where in some cases the conclusions may simply reflect a correlation between those variables. We show evidence that increasing capital leads to more risk-taking, which challenges the prevalent assumption that more capital would encourage less risk-taking due to skin-in-the-game motivations (bank owners' aversion to losses). Although we do not investigate capital requirements per se, our findings may suggest that rising risk-taking could be an unintended consequence of capital regulations on the occasions when banks increase their capital levels to comply with minimum ratios stipulated by regulators.

Second, while there are plenty of theoretical arguments indicating that increases in capital affect banks' funding cost (e.g., [2], to our knowledge, we contribute innovative *empirical* evidence in this regard by supporting the existence of the relationship theoretically expected.

Third, on the methodological side, we improve the instrument for bank capital changes proposed in Moreira [45], which, on some occasions, could lead to values that do not correspond with the theoretical background supporting the instrument.

Besides supplementing the academic knowledge in this field, our findings are also important to financial regulators and bank managers. The former can use our results to review the pertinence of the assumptions behind capital requirements, while the latter will see evidence of how changes in capital may affect their expenses incurred when raising funds with depositors and other investors.

Following this introductory section, this paper has another five sections. The next section presents a literature review on the relationship between bank capital and risk-taking and on skin-in-the-game in banking. In the "Data and methods" section, we describe the data and the methods used in our empirical analyses. Our main findings are reported and discussed in the "Results and discussions" section. The "Robustness tests and supporting evidence" section contains robustness tests and additional analyses aimed at checking the pertinence of our interpretation of the original results. The "Conclusions" section concludes.

Literature review

As explained earlier, the skin-in-the-game hypothesis implies that the more equity bank owners have, the more incentive they would have to reduce risk-taking. Therefore, we would expect to observe a negative relationship between bank capital and risk. A number of studies have indeed shown that more capital is linked to improved bank stability, which can be related to low risk-taking (see, e.g., [3, 4, 19, 20, 23, 26, 32, 37, 44, 53]).

Nevertheless, the extensive literature focused on that relationship has also shown other possibilities. A particular stream of empirical and theoretical studies has concluded that bank capital and risk-taking are positively related [1, 5, 13, 16, 27, 28, 33, 35, 36, 39, 41, 46]. This therefore contradicts our expectations in terms of skin-in-the-game given that higher potential losses of bank owners (more capital) would be associated with more risk-taking. Considering the relatively high cost of capital (in comparison with debt), when new capital is issued, banks may need to generate more income than what would be necessary otherwise. This is normally achieved by increasing risk. Hence, the cost of capital may dominate shareholders' motivation for keeping risk at reduced levels.

Besides the two opposite possibilities above (negative and positive relationships), some studies have indicated that bank capital does not affect risk-taking [29, 34, 45, 48]. This could be the case because mediators in channels between those two variables may counterbalance their effects or because the correlation between capital and risk is driven by unobserved factors. In this respect, it is worth noting that many studies in the area do not account for endogeneity in the relation between bank capital and risk (see discussion in [45]). This is essential to allow us to measure impact and, then, assess the possibility of skin-in-the-game. In our empirical analyses ahead, we endeavor to factor in omitted variables that could affect the association between risk and capital so that we have strong evidence that our results indicate a direct impact of the latter on the former, which, vis-à-vis correlation measures, allows us to better conclude on the possibility of skin-in-the-game.

The lack of consensus in the literature about the relationship between capital and risk is likely due to the fact that many issues can influence that association. As there are theoretical reasons for positive, negative or even no association between bank capital and risk-taking, the nature of this relationship becomes an empirical question. Therefore, we do not develop any hypotheses about it.

When it comes to empirical investigations on skin-in-the-game in banking, the literature has not presented specific analyses focused on bank owners. The existing studies in the area have evaluated the consequences of skin-in-the-game related to other agents such as investors and financial institutions (lenders). Demiroglu and James [24] show that losses in securities based on mortgage loans are lower when loan originators have more skin-in-the-game. This would be because lenders would act more cautiously when they have more to lose. Billett et al. [14] find that bank skin-in-the-game in loans affects loan underwriting in line with banks' economic interest in the loans granted. According to Ashcraft et al. [7], the skin-in-the-game of sponsors of securities backed by mortgage loans has a positive effect on the performance of those investments as the participation of sponsors tends to encourage them to improve the quality of underlying assets.

It is important to stress that the aforementioned literature has concentrated on a few types of investments, namely mortgage-backed securities (e.g., [1, 24]) and covenant-lite loans (e.g., [14], which do not represent the range of assets seen in banks' portfolios. Hence, the existing studies are focused on different stakeholders (i.e., not bank owners) and on a few products, while the motivation for avoiding risk in the context of bank owners would refer to any asset in banks' portfolios. We overcome these limitations by analyzing the case of bank owners and considering risk related to all types of assets that may result in losses to bank owners.

Data and methods

Data

We use annual data on 1,886 active and inactive (acquired or failed) US Bank Holding Companies (BHCs, hereafter called *banks* for the sake of simplicity) spanning from 1990 to 2020, which refers to all years when the necessary data was available at the time of its collection. Our analyses are focused on American banks because the USA is the world's leading financial center with influence in many other countries. Therefore, changes in our dependent variable (risk-taking of US banks) can have consequences in other banking systems as seen during the Global Financial Crisis 2008–2009. Moreover, most of the aforementioned empirical investigations into the relationship between bank capital and risk are based on US data. Thus, our sample facilitates the comparison between our results and the findings presented in the existing literature.

The market data used for the calculation of banks' probability of default come from the Capital IQ database. Bank-specific accounting data are retrieved from call reports compiled by Standard & Poor's (Capital IQ Pro). The macroeconomic control variables are downloaded from FRED (Federal Reserve Economic Data).[2]

We use annual data due to the way our instruments are calculated (see details ahead where we show that the rationale behind our instruments relies on annual observations of data/information).

We focus on BHCs because the decisions regarding capital ratios and risk-taking in their groups are made at the BHC level (rather than at their subsidiaries). Several activities

[2] Available at https://fred.stlouisfed.org/. When the frequency of a variable is monthly or quarterly, we take its average in each year.

may involve many subsidiaries linked to a BHC, which could affect risk-taking decisions for the whole group [21].

Methods

Fixed effects

The potential influence of confounders (e.g., bank strategy or culture) is a key challenge of estimating the impact of capital on risk-taking. We then initially use a fixed effects model to control for omitted time-invariant aspects that could jointly affect banks' decisions in terms of their capital ratios and risk-taking:

$$\Delta R_{i,t} = \beta_0 + \beta_1 \Delta C_{i,t} + \beta_2 X_{i,t} + \beta_3 M_t + \mu_i + \varepsilon_{i,t}. \quad (1)$$

Because we are particularly interested in measuring the impact of bank capital ratios (C) on risk-taking (R), which can be associated with a causal interpretation, we use changes (denoted by Δ) in those variables. This leads to more intuitive results as compared to analyses based on variables in levels. The subscripts i and t mean bank i and time (year) t, respectively. μ_i represents bank fixed effects and $\varepsilon_{i,t}$ is the error term.

Risk-taking is measured as risk weighted assets (RWA [3]) divided by total assets. We consider three capital measures that can be related to the skin-in-the game (bank ownership) hypothesis: total equity (common and preferred shares), common equity Tier 1 (CET1, basically common shares + retained earnings), and Tier 1 capital (which, besides CET1, includes preferred shares alongside other items). All these three alternatives are divided by total assets so that they are measured in the same scale as the dependent variable.

X are bank-specific controls that can affect banks' decisions regarding the risk taken. *Size* (proxied by the natural logarithm of total assets) is the first control in this category because large banks could take more risk due to their too-big-to-fail status (e.g., [5, 28, 33, 47, 51]). While our focus is on the changes in capital, the *capital level* itself is also relevant in this context as a particular percentage change in capital would possibly have a stronger effect on risk-taking for banks with lower capital ratios. We therefore control for capital ratios alternatively using the three aforementioned measures and also consider how far from the minimum regulatory ratio a bank's capital is in every period given that the literature has found evidence that banks very close to the minimum requirements may gamble for resurrection [22, 47, 52, p. 448]. We do so by creating a dummy equal to 1 if a bank's *capital ratio is less than 1% above the minimum* required and 0 otherwise. *Capital ratio squared* is also included in our regressions because previous studies (e.g., [18, 27] have found a U-shaped relationship between capital and risk. *Liquidity ratio* (liquid assets divided by total liabilities) is another important factor because low liquidity levels may prevent banks from take excessive risk [5, 40]. *Profitability* (return on assets), especially when relatively low, can affect the need for banks to increase risk-taking in order to try to increase return [10, 33, 47, 53]. The *approach (standardized or advanced)* used by banks to calculate their regulatory capital could give them more or less incentives to take risk [1]. We set a dummy equal to 1 if the bank uses the advanced approach and 0 otherwise.[4]

M are macro-variables that affect risk-taking decisions of all banks at once in each period. We follow Acosta-Smith et al. [1] and include, in our regressions, the 10-year government bond yield, the ratio of total bank credit to GDP, stock price growth (all shares traded in the USA), house price growth, and changes in the official bank rate (Federal Funds rate).[5] Additionally, we take the initiative of including a dummy for the Global Financial Crisis period (equal to 1 for years 2007 to 2009, and 0 otherwise) because the events in that period (for instance, bailouts and market skepticism) may have altered the relationship between capital and risk-taking.

With a view to enhancing the credibility of our results, we test an alternative model where the macro-variables (M_t) are replaced with a dummy for time fixed effects (τ_t):

$$\Delta R_{i,t} = \alpha_0 + \alpha_1 \Delta C_{i,t} + \alpha_2 X_{i,t} + \mu_i + t_t + \varepsilon_{i,t}, \quad (2)$$

and the remaining notation follows Eq. (1). This specification helps us control for other factors (e.g., competition) pointed out in the literature (e.g., [5] that are valid for all banks in a particular period (besides the factors with the same characteristics that cannot be included in the regressions due to the lack of data or because we are not aware of their importance).

To conclude this section, we emphasize that, although many empirical studies in this area overcome the possibility of reverse causality by using lagged independent variables

[3] RWA is a regulatory measure according to which assets are given weights representing the risk of their category. These weights are then multiplied by the value of the respective assets.

[4] In additional tests ahead specific for listed banks, we include controls regarding the percentage of shares held by CEOs (which could alleviate agency problems and therefore reduce risk-taking) and the existence of major shareholders (with more than 5% or alternatively 10% of shares, which could increase the pressure on managers when deciding their banks' risk allocation).

[5] Acosta-Smith, Grill and Lang (2021) also control for the Basel Accord version (I, II or III) valid in each period. As the influence of the regulatory minimum capital ratios on risk-taking happens via the capital ratios held by banks, which we control for in our models, dummies regarding the Basel versions are not necessary in our case.

(see, e.g., [1, 12, 26, 30]), this practice not always leads to economically meaningful results. In our case, we initially opt for using concomitant observations of the dependent and independent variables because, in practice, their relationships may be formed within a single period. As risk-taking and capital are measured on a yearly basis, it would be possible that changes in capital happen earlier in a year while, as a potential response, changes in risk take place later in the same year.

However, considering that we do not observe when exactly these variables change in a particular year, we run robustness tests using ΔR in a period ahead of ΔC so that we represent situations where risk-taking responses are not immediate.[6] These additional tests are also important for another two reasons. First, they ease concerns due to the fact that RWA in year t could be a consequence of risk-taking decisions made in past periods. Hence, future (after year t) values of RWA could reflect the risk taken in the same year t when (or just after) capital changed. Second, they help rule out the possibility that the *only* direction of the relationship between changes in risk-taking and changes in capital ratios goes from the former to the latter.[7] In fact, the IV approach introduced in the next section will also prevent reverse causality given the way our instruments are calculated (besides giving more credibility to our results by extending the treatment of the omitted variables to the time-varying ones, while the previous approach, fixed effects, only controls for non-time-varying unobserved factors).

Two-stage least squares with instrumental variables

Model We supplement our analyses based on fixed effects models with a two-stage least squares (2SLS) model where the possible influence of unobserved confounders that may vary over time is taken into consideration by the use of instrumental variables (IVs) that can represent exogenous variations of bank capital:

$$\Delta C_{i,t} = q_0 + q_1 IV_{i,t-1} + q_2 X_{i,t} + q_3 M_t + \mu_i + \varepsilon_{i,t} \tag{3}$$

and

$$\Delta R_{i,t} = g_0 + g_1 + g_2 X_{i,t} + g_3 M_{i,t} + \mu_i + \varepsilon_{i,t}. \tag{4}$$

Equations (3) and (4) are the first and the second stages, respectively. Apart from $\mathrm{IV}_{i,t-1}$ and $\widehat{\Delta C}_{i,t}$, all the other terms follow the notation used in Eqs. (1) and (2). $\widehat{\Delta C}_{i,t}$ is the variation of capital estimated according to the parameters found in Eq. (3). $\mathrm{IV}_{i,t-1}$, the instrumental variables, will be explained in the next section.

Instruments We take advantage of regulatory (see, e.g., [42] and market [6, 11, 25, 31, 43] pressures faced by banks when determining their capital levels. Similar to what is done in Moreira [45], although with an improvement as explained below, and in line with the aforementioned literature, we initially consider two aspects possibly taken into account by banks when defining their capital ratios in a particular year t. One of the aspects is the distance between a bank's capital and the average capital ratio in the banking system. The lower the capital of a bank in comparison with the mean capital observed in the market, the higher the pressure on that bank to increase its capital. The second aspect concerns the distribution of capital in the banking system; the less disperse it is, the easier it is for supervisors and investors to spot banks with extremely low capital levels. Using these two arguments, our first instrument is given by:

$$\mathrm{IV}_{i,t-1}^{\mathrm{mean\_disp}} = (C_{i,t-1} - \overline{C}_{s,t-1}) * 1/\sigma_{Cs,t-1},$$

where C_i is the capital of bank i and $\overline{C}_s$ is the average capital of the banking system. $\sigma_{Cs,t-1}$ gives the dispersion (standard deviation) of the distribution of bank capital in the banking system in the period considered. The subscript $t-1$ denotes year $t-1$, which means that the instrument calculated based on data/information for $t-1$ will motivate capital variations during year t. This is the case because, when adjusting their capital during year t, banks do not have information on the capital ratios of their competitors in that year. The latest information available refers to the end of year $t-1$.

This instrument is, in fact, an improved version from that used in Moreira [45]. In order to make its value more consistent with the rationale behind it, we replace the dispersion measure used in that study ($\sigma_{Cs,t-1}$) with its inverse ($1/\sigma_{Cs,t-1}$) so that the banks with the lowest capital ratios (biggest negative differences from the system's mean) in an environment of concentrated capital (i.e., low $\sigma_{Cs,t-1}$ and therefore high $1/\sigma_{Cs,t-1}$, always positive) will be the ones facing the highest pressure to increase their capital levels (negative IV with the greatest magnitude). The use of the $1/\sigma_{Cs,t-1}$ ratio also enhances the compatibility of the instrument for banks with capital above the system's average. For example, a highly concentrated scenario in terms of capital will lead to a large term ($1/\sigma_{Cs,t-1}$) that will be multiplied by the difference between a bank's capital and the system's mean. Considering the negative relationship between the instrument and the pressure for increasing capital, this will result in a relatively

[6] This is naturally equivalent to using lagged observations of capital.

[7] In light of our objectives, we do not aim at completely precluding the possibility that changes in risk-taking can lead to changes in capital, which is expected to happen. As we are investigating whether the latter affects the former, an opposite impact does not invalidate a positive conclusion about that relationship. Therefore, here, it suffices to make sure that the association between our main variables is not *solely* driven by the effect of risk-taking on capital.

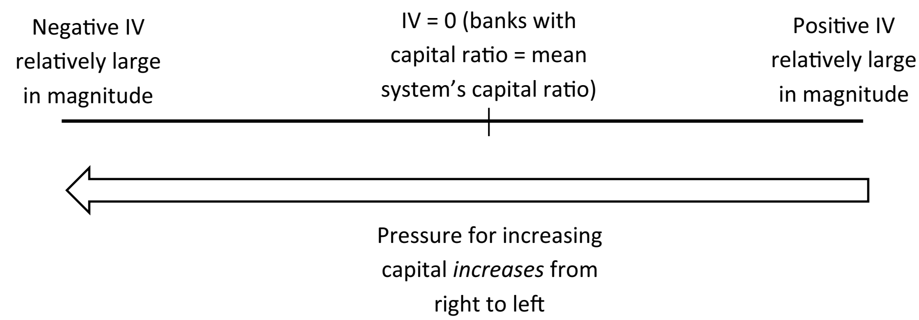

Fig. 1 Rationale behind the instrument for changes in bank capital

large instrument, which is associated with a reduced need of increasing capital. This amendment to the calculation of the instrument is one of the contributions of our study.[8]

The basic idea behind $\mathrm{IV}_{i,t-1}^{\mathrm{mean\_disp}}$ is shown in Fig. 1.

Following Moreira [45], we also estimate another three instruments for bank capital. In place of comparing a bank's capital with the mean of the banking system, it is also reasonable to assume that bank managers focus on the rank position of their banks' capital in relation to their peers. Hence, our second instrument is calculated as:

$$\mathrm{IV}_{i,t-1}^{\mathrm{perc\_disp}} = \left(C_{i,t-1}^{\mathrm{perc}}\right) * \sigma\left(C_{s,t-1}\right),$$

where $C_{i,t-1}^{\mathrm{perc}}$ is the percentile of bank i's capital ratio in the distribution of capital in the banking system in year $t-1$. Note that, given the rationale for this instrument, the first term is multiplied by $\sigma_{Cs,t-1}$ instead of $1/\sigma_{Cs,t-1}$ (the notation of which is the same as above).

To include the possibility that banks primarily pay attention to the relative size or position of their capital without worrying about the dispersion of capital in system, we also use modified versions of the two previous instruments where the standard deviation term is omitted (and the former notation applies):

$$\mathrm{IV}_{i,t-1}^{\mathrm{mean}} = \left(C_{i,t-1} - \overline{C}_{s,t-1}\right)$$

and

$$\mathrm{IV}_{i,t-1}^{\mathrm{perc}} = \left(C_{i,t-1}^{\mathrm{perc}}\right)$$

Given that the exact rules observed by banks to adjust their capital levels are not known to external agents and considering that the motivations may vary across banks, we replicate our 2SLS-IV analyses by using all the aforementioned instruments.[9]

Validity of the instruments The instruments described above comply with the main conditions regarding their exogeneity. First, in terms of inclusion restriction (i.e., the relationship between the instrument and the endogenous variable), the arguments presented in the previous section indicate that the instruments (in short, banks' capital ratios as compared to those of their peers) would impact banks' decisions on their capital levels.

Second, when it comes to exclusion restriction, our instruments are not expected to have a direct link with the dependent variable (changes in risk-taking). Adjustments in risk are a function of many factors (e.g., need to increase return, pressure from internal stakeholders, bank strategy, macroeconomic issues, etc.), while we understand that having more or less capital than competitors do would not be a key aspect driving the amount of capital held or issued by banks. That is, there would be no reasons for bank managers to increase or decrease risk-taking just because they are in a favorable or unfavorable capital position in comparison with other banks. As said above, the risk taken by a bank would primarily reflect its internal environment or other external forces such as financial or economic shocks.[10] In addition to this point, we would not expect any links between the instruments and risk-taking by means of unobserved channels.[11]

Third, none of the IVs shares common causes with risk-taking given that the instrument for each bank depends not only on the own bank's capital but also the capital of all the other banks in the same market. Hence, if we think of these

[8] We test both versions of this instrument in our empirical analyses ahead. Although, in our case, their performance in the statistical validation tests and their results are similar, we prefer our version due to its stronger theoretical background. Also, there is no guarantee that their results and statistical validity would be the same in every sample.

[9] Due to the relatively high correlation between the different measures, the instruments are used separately.

[10] This also applies to the possibility of poorly capitalized banks "gambling for resurrection". In this context, the benchmark for under-capitalization refers to regulatory requirements (e.g., [18]. Therefore, the possibility that low capital levels would lead banks to increase risk-taking (i.e., a direct link between capital levels and risk-taking) would result from each bank comparing its *own capital ratio to what is required by regulators*. Our instruments, on the other hand, are built based on the comparison of capital levels across banks.

[11] Obviously, this is a non-exhaustive conclusion but, to the best of our knowledge, no impact of the relative position of bank capital on issues (potential mediators) relevant to risk-taking has been found or suggested in the literature.

Table 1 Summary statistics of the main variables

Variable	N	Mean	Stdev	Min	25 pct	Median	75 pct	Max
Panel A. Main variables of interest								
ΔR	19,016	0.0056	0.0446	− 0.0882	− 0.0097	0.0000	0.0276	0.1013
ΔEq_ta	18,989	0.0144	0.1154	− 0.2000	− 0.0476	0.0000	0.1000	0.2500
$\Delta CET1\_ta$	1733	− 0.0021	0.0774	− 0.1627	− 0.0529	0.0071	0.0498	0.1371
$\Delta Tier1\_ta$	1733	− 0.0055	0.0736	− 0.1572	− 0.0553	0.0039	0.0443	0.1261
Panel B. Controls								
Size	21,305	14.0606	1.5086	12.0553	12.8193	13.8006	15.0107	17.3825
Eq_ta	21,305	0.0889	0.0239	0.0500	0.0700	0.0900	0.1000	0.1400
CET1_ta	2159	0.0833	0.0092	0.0022	0.0798	0.0890	0.0893	0.0893
Tier1_ta	2170	0.0899	0.0081	0.0469	0.0860	0.0951	0.0954	0.0954
Liq	21,305	0.2289	0.1236	0.0630	0.1310	0.2050	0.3030	0.5090
ROA	21,305	0.0090	0.0059	− 0.0050	0.0060	0.0100	0.0130	0.0190
Gov_bond	21,305	0.0503	0.0190	0.0089	0.0367	0.0502	0.0644	0.0855
Cred_gdp	21,305	1.7177	0.2016	1.4690	1.5228	1.6735	1.8780	2.1048
Stock_growth	21,305	0.0064	0.0128	− 0.0442	− 0.0028	0.0090	0.0151	0.0236
hp_growth	21,305	0.0031	0.0045	− 0.0106	0.0007	0.0033	0.0062	0.0107
Off_rate	21,305	0.0416	0.5529	− 0.9170	− 0.3235	− 0.0716	0.2547	1.9811

N is the number of observations. Stdev is standard deviation. Min and Max are the minimum and maximum values, respectively. 25 pct and 75 pct are the 25th and the 75th percentiles. ΔR *is* the percentage variation of *RWA* (the ratio of risk weighted assets to total assets) from the end of year $t-1$ to the end of year t. ΔEq_ta, $\Delta CET1\_ta$ and $\Delta Tier1\_ta$ are, respectively, the percentage variations (from the end of year $t-1$ to the end of year t) of total equity divided by total assets (*Eq_ta*), Common Equity Tier 1 divided by total assets (*CET1_ta*), and Tier1 divided by total assets (*Tier1_ta*). *Size* is measured by the natural logarithm of total assets. *Liq* is the liquidity ratio (liquid assets divided by total liabilities). *ROA* is return on assets. *Gov_bond* is the 10-year US government bond yield. *Cred_gdp* is the ratio of total bank credit to GDP. *Stock_growth* is the variation in price (from year $t-1$ to year t) of all stocks traded in the USA, while *hp_growth* is the variation in house price from year $t-1$ to year t. *Off_rate* represents changes in the Federal Funds rate from year $t-1$ to year t

potential common causes as each bank's internal factors, we can preclude their effect on the IVs because the instruments' values are determined by what happens in all the other banks. On the other hand, if we consider the possible influence of macroeconomic or financial common causes, they would likely affect many (possibly most) banks in the same way and this would have a small effect on the instrument value for each bank as the capital of all or most banks would move in the same direction (hence, their relative position would remain—almost—the same). Therefore, although macro-factors could affect risk-taking of each bank, their impact on the IVs would tend to be small, which means that those factors could hardly be seen as a common cause of risk-taking and the instruments.

In addition to the theoretical arguments above, the validity of all instruments is corroborated by the results of relevant statistical tests reported in the next section.

As a final note, we emphasize that our instruments allow us to be more confident about the direction of relationship between capital holdings and risk-taking. Considering that the variations of capital at time t (our endogenous variable) are determined by events (reflected in the IVs) taking place at $t-1$, we can safely assume that the dependent variable (variations in risk-taking) could not have affected the main independent variable (variations in capital).

Results and discussions

As explained in the "Methods" section, we initially investigate the relationship between changes in capital on changes in risk-taking by controlling for omitted factors that do not vary over time. We then advance our analyses by employing instruments to avoid the impact of time-varying omitted factors as well. With a view to eliminating the influence of extreme, unusually seen, values all bank-specific continuous variables are winsorized at the 5th and 95th percentiles.

The summary statistics in Table 1 indicate that the ranges of all variables analyzed are consistent. As shown in Table 2, the correlations across the independent variables do not raise any concerns about multicollinearity. The only correlations relatively high refer to alternative measures of capital (Common Equity Tier 1 and Tier 1) and their variations, which are not used together in our regressions (i.e., they are used alternately). This conclusion is supported by the variance inflation factor (VIF) values of the independent variables,

Table 2 Correlation across continuous independent variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) Δ*Eq_ta*	1.0000													
(2) Δ*CET1_ta*	0.6681	1.0000												
(3) Δ*Tier1_ta*	0.6841	0.9270	1.0000											
(4) *Size*	− 0.0087	− 0.1023	− 0.041	1.0000										
(5) *Eq_ta*	0.1869	0.1323	0.1440	0.1931	1.0000									
(6) *CET1_ta*	− 0.0294	0.2145	0.1644	0.3382	0.3070	1.0000								
(7) *Tier1_ta*	− 0.0295	0.2595	0.2359	0.3398	0.3032	0.9960	1.0000							
(8) *Liq*	0.0556	− 0.1020	− 0.0571	− 0.1614	0.0259	− 0.0991	− 0.0958	1.0000						
(9) *ROA*	0.1597	0.1134	0.0959	0.0871	0.2586	0.0648	0.0638	0.0227	1.0000					
(10) *Gov_bond*	0.0733	0.3686	0.3516	− 0.4092	− 0.3456	− 0.5206	− 0.5236	0.2853	0.0116	1.0000				
(11) *Cred_gdp*	− 0.0701	0.3955	0.3678	0.3202	0.1796	0.1976	0.1980	− 0.3879	− 0.1368	− 0.7420	1.0000			
(12) *Stock_growth*	0.0537	− 0.0667	− 0.0704	− 0.0463	0.0360	− 0.0500	− 0.0507	0.1113	0.1123	0.0754	− 0.2337	1.0000		
(13) *hp_growth*	− 0.0443	− 0.3791	− 0.3509	− 0.0046	0.0755	0.1220	0.1231	− 0.0292	0.2716	− 0.1954	− 0.1101	0.2701	1.0000	
(14) *Off_rate*	0.0126	0.2814	0.2542	0.1299	0.1479	0.4262	0.4270	− 0.0919	0.1622	− 0.1750	0.1251	0.1527	0.3062	1.0000

Δ*Eq_ta*, Δ*CET1_ta* and Δ*Tier1_ta* are, respectively, the percentage variations (from the end of year $t-1$ to the end of year t) of total equity divided by total assets (*Eq_ta*), Common Equity Tier 1 divided by total assets (*CET1_ta*), and Tier1 divided by total assets (*Tier1_ta*). *Size* is measured by the natural logarithm of total assets. *Liq* is the liquidity ratio (liquid assets divided by total liabilities). *ROA* is return on assets. *Gov_bond* is the 10-year US government bond yield. *Cred_gdp* is the ratio of total bank credit to GDP. *Stock_growth* is the variation in price (from year $t-1$ to year t) of all stocks traded in the USA, while *hp_growth* is the variation in house price from year $t-1$ to year t. *Off_rate* represents changes in the Federal Funds rate from year $t-1$ to year t. Most of the pairs have correlations statistically significant at the 1% level. The exceptions are Δ*Tier1_ta-Liq* (5%), Δ*Eq_ta-Off_rate*, Δ*Tier1_ta-Size* and *ROA-Gov_bond* (10%), and Δ*Eq_ta-Size* and *Size-hp_growth* (not significant)

Table 3 Relationship between variations in capital and variations in risk-taking (fixed effects)

Dependent variable	ΔR					
	Eq_ta		*CET1_ta*		*Tier1_ta*	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔC	0.02857**	0.03540**	0.13278**	0.13278**	0.12719**	0.12719**
	0.00386	0.00382	0.01890	0.01890	0.01913	0.01913
No. obs	18060	18060	1711	1711	1711	1711
No. banks	1886	1886	406	406	406	406
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes
Macro-controls	Yes	No	Yes	No	Yes	No
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes
R-squared	0.0512	0.1237	0.1004	0.1004	0.0999	0.0999

The results in this table are based on the models represented in Eqs. (1) and (2). ΔR is the percentage variation of the ratio of risk weighted assets to total assets from year $t-1$ to year t. ΔC is the percentage change in bank capital. Three measures of capital are tested: *Eq_ta* (total equity divided by total assets), *CET1_ta* (Common Equity Tier 1 divided by total assets), and *Tier1_ta* (Tier1 divided by total assets). No. obs. is the total number of bank-year observations. Bank controls (X in the aforementioned equations) are variables specifically related to each bank, while Macro-controls, M in Eq. (1), are variables that simultaneously affect all banks in a given period. FE stands for fixed effects. Numbers in parenthesis are robust standard errors clustered by banks. ** indicates coefficients statistically significant at the 1% level (note that * is not used in this table to maintain our notation consistent across all tables)

which range from 1.05 and 3.07 (therefore, below the minimum cutoff value, 5, that would suggest the existence of multicollinearity).

Our baseline fixed effects results in Table 3 reveal that changes in any of the three capital measures considered (as described in the "Fixed effects" section) have a positive impact on changes in risk-taking. The regression coefficients are highly significant. Hence, when banks increase their capital, they take more risk. A causal interpretation is only valid if we assume that the pertinent unobserved confounders are constant. In order to give more credibility to our conclusion, we turn to our 2SLS-IV analyses where the variations of capital can be seen as exogenous (i.e., in principle, not led by other issues that could be driving changes in both capital and risk-taking).

All scenarios tested in Table 4 indicate that the relationship is indeed causal. As before, three measures of capital are analyzed (one in each panel) and for each of them the four instruments explained in the "Instruments" section are used. The results of the first stage (statistically significant negative IV coefficients and relatively large F statistics) and the results of the Kleibergen–Paap rk Lagrange Multiplier and the Kleibergen–Paap rk Wald F tests support the validity of all instruments.[12] In the second stage, the coefficient of the main variable of interest ($\widehat{\Delta C}$) is positive and statistically significant at the 1% level in all specifications. Because this variable represents exogenous variations in capital at time t (triggered by the instruments measured at $t-1$), we can conclude that the changes in risk-taking are due to the changes in capital. In other words, whenever banks increase capital, they tend to consequently increase risk-taking. This provides empirical support to the conclusions in Kahane [35], Koehn and Santomero [39], and Kim and Santomero [36], which are primarily based on theoretical analyses.

Our results are clearly against the hypothesis that skin-in-the-game acts as a mechanism explaining why capital would contribute to keeping risk-taking under control (and, thus, improving bank stability). In sum, this is our main finding. But, given that the skin-in-the-game idea is so appealing and has been evoked in many studies (e.g., [8, 11, 15, 23, 31]), how can we explain our results?

In our view, the increase in risk-taking as a response to increases in capital (regardless of the reasons for such capital growth) is due to the combination of at least three key factors. First, capital is costly to banks. As pointed out by Admati and Hellwig [2], capital is more expensive than debt. Therefore, higher capital ratios lead to higher overall funding costs. As a consequence, banks end up investing in assets with higher profitability potential (than those in their previous portfolio), which in turn, tend to be riskier.

12 Recall that a negative relationship between any of the instruments and changes in capital was expected. As for the Kleibergen–Paap rk tests, their statistics are high enough to reject their respective null hypotheses, which are against the validity of the instruments.

Table 4 Relationship between variations in capital and variations in risk-taking (2SLS-IV)

	Panel A—ΔEq_ta				Panel B—$\Delta CET1\_ta$				Panel C—$\Delta Tier1\_ta$			
	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
First stage												
Dep var	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$
IV	− 0.169**	− 24.361**	− 7.734**	− 0.550**	− 0.095**	− 27.825**	− 9.537**	− 0.269**	− 0.075**	− 30.524**	− 9.773**	− 0.238**
	(0.002)	(0.230)	(0.091)	(0.005)	(0.004)	(0.981)	(0.464)	(0.009)	(0.003)	(1.079)	(0.416)	(0.008)
F statistic	720.41	870.20	673.19	941.70	106.30	133.64	103.86	126.68	109.49	134.71	106.88	130.58
Second stage												
Dep var	ΔR											
$\widehat{\Delta C}$	**0.0447****	**0.0464****	**0.0456****	**0.0458****	**0.1586****	**0.1467****	**0.1536****	**0.1539****	**0.1691****	**0.1561****	**0.1644****	**0.1651****
	(0.0048)	**(0.0049)**	**(0.0049)**	**(0.0048)**	**(0.0321)**	**(0.0305)**	**(0.0325)**	**(0.0300)**	**(0.0326)**	**(0.0305)**	**(0.0321)**	**(0.0304)**
No. obs	17,887	17,887	17,887	17,887	1,669	1,669	1,669	1,669	1,669	1,669	1,669	1,669
No. banks	1,713	1,713	1,713	1,713	364	364	364	364	364	364	364	364
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
K–P LM	3,855.75	3,949.80	3,799.98	4,012.45	188.71	208.47	187.89	210.81	187.91	223.59	190.95	224.39
K-P W F	7,486.60	11,000.00	7,205.64	12,000.00	638.13	803.88	422.82	825.67	607.78	800.86	551.02	809.90

This table reports the results of the 2SLS-IV model presented in Eqs. (3) and (4). In Panel A, ΔEq_ta is the year-on-year percentage variation of total equity divided by total assets. In Panel B, $\Delta CET1\_ta$ is the year-on-year percentage variation in Common Equity Tier 1 divided by total assets. In Panel C, $\Delta Tier1\_ta$ is the year-on-year percentage variation in Tier 1 divided by total assets. In each panel, the four instruments described in Sect. "Instruments" are tested. ΔR (the dependent variable, Dep var) is the year-on-year percentage variation of the ratio of risk weighted assets to total assets. $\widehat{\Delta C}$ is the ΔC estimated in the first stage. N. obs. is the total number of bank-year observations. FE stands for fixed effects. K–P LM and K-P W F stand for the Kleibergen–Paap rk LM (Lagrange Multiplier) and the Kleibergen–Paap rk Wald *F* statistics, respectively. Numbers in parenthesis are robust standard errors clustered by banks. **Indicates coefficients statistically significant at the 1% level (to maintain consistency with all the other tables, *is not used in this table). For convenience, the values of main interest (regarding $\widehat{\Delta C}$) are presented in bold

Table 5 Relationship between variations in capital and variations in risk-taking (fixed effects, data winsorized at the 1st and 99th percentiles)

Dependent variable	ΔR					
	Eq_ta		*CET1_ta*		*Tier1_ta*	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔC	0.02140**	0.02820**	0.12923**	0.12923**	0.13574**	0.13574**
	(0.00452)	(0.00446)	(0.02108)	(0.02108)	(0.02206)	(0.02206)
No. obs	18060	18060	1711	1711	1711	1711
No. banks	1886	1886	406	406	406	406
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes
Macro-controls	Yes	No	Yes	No	Yes	No
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes
R-squared	0.0409	0.1063	0.0698	0.0698	0.0729	0.0729

The results in this table are based on the models represented in Eqs. (1) and (2) using data winsorized at the 1st and 99th percentiles. ΔR is the percentage variation of the ratio of risk weighted assets to total assets from year $t-1$ to year t. ΔC is the percentage change in bank capital. Three measures of capital are tested: *Eq_ta* (total equity divided by total assets), *CET1_ta* (Common Equity Tier 1 divided by total assets), and *Tier1_ta* (Tier1 divided by total assets). No. obs. is the total number of bank-year observations. Bank controls (X in the aforementioned equations) are variables specifically related to each bank, while Macro-controls, M in Eq. (1), are variables that simultaneously affect all banks in a given period. FE stands for fixed effects. Numbers in parenthesis are robust standard errors clustered by banks. **Indicates coefficients statistically significant at the 1% level (note that * is not used in this table to maintain our notation consistent across all tables)

Second, increases in capital mean larger loss absorption capacity. Hence, higher level of capitalization would allow banks to increase risk-taking to pursue higher profitability. If their investment strategy does not work as expected, banks would have buffers that would reduce the possibility of insolvency.

Third, even when banks issue more capital, the responsibilities of their owners in case of bankruptcy do not represent incentives for them (owners) to carefully monitor managers and put pressure for a reduction in risk. This is because the law in most countries dictates that bank owners are not responsible for paying for losses beyond their personal investment—ownership—in banks. In this respect, our results are in line with Saunders, Strock and Travlos [49], who conclude that limited liability of shareholders can actually lead to higher risk-taking as it may be beneficial for bank owners to try to increase their return, while their potential losses are capped at their personal investment in their bank.

Thus, the three aforementioned aspects combined would mean that the need or opportunity for increasing profitability is not counterbalanced by incentives for bank owners to reduce risk-taking. Especially because our results might be seen as counterintuitive by some readers, we run several robustness tests in the next section besides searching for additional evidence of the possibility that capital growth leads to higher funding cost, which in turn makes banks increase risk-taking.

Robustness tests and supporting evidence

Robustness tests

To test whether the winsorization process has affected our results, we re-run our regressions using alternative winsorization levels (1st and 99th percentiles). In these analyses, the results of all specifications of the fixed effects and the instrumental variables regressions corroborate our original findings. As shown in Table 5, changes in any of the three capital measures considered are highly statistically significant and positively related to changes in risk-taking for both specifications in the fixed effects model (with macro-variables or replacing them with time fixed effects). In Table 6, this conclusion remains valid for the four instruments used, emphasizing that all of them pass the necessary validation tests.

Given that the ownership structure of financial institutions can affect the owners' motivations to take more or less risk, we split our sample into private and public BHCs. For example, it could be the case that agency problems in public institutions mitigate the effect of changes in capital on risk (that is, managers' decisions may not necessarily follow owners' preference in terms of risk-taking).

Except for one scenario—column (1)—in Table 7, our results in Table 7 (fixed effects) and 8 (2SLS-IV) indicate that the direction of the influence (i.e., positive) of capital on risk-taking is the same for publicly and privately held

Table 6 Relationship between variations in capital and variations in risk-taking (2SLS-IV, data winsorized at the 1st and 99th percentiles)

	Panel A—ΔEq_ta				Panel B—$\Delta CET1\_ta$				Panel C—$\Delta Tier1\_ta$			
	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
First stage												
Dep var	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$
IV	− 0.238**	− 24.243**	− 8.669**	− 0.709**	− 0.180**	− 32.578**	− 10.950**	− 0.537**	− 0.162**	− 30.727**	− 10.593**	− 0.471**
	(0.003)	(0.208)	(0.113)	(0.006)	(0.004)	(0.685)	(0.253)	(0.011)	(0.003)	(0.653)	(0.167)	(0.010)
F statistic	729.43	998.55	696.78	1096.85	261.61	263.03	263.26	261.24	513.40	291.97	500.56	293.50
Second stage												
Dep var	ΔR											
$\widehat{\Delta C}$	**0.0372****	**0.0434****	**0.0389****	**0.0432****	**0.1362****	**0.1282****	**0.1320****	**0.1321****	**0.1421****	**0.1379****	**0.1395****	**0.1412****
	(0.0053)	**(0.0051)**	**(0.0055)**	**(0.0048)**	**(0.0232)**	**(0.0240)**	**(0.0233)**	**(0.0239)**	**(0.0220)**	**(0.0230)**	**(0.0219)**	**(0.0230)**
No. obs	17887	17,887	17,887	17,887	1,669	1,669	1,669	1,669	1,669	1,669	1,669	1,669
No. banks	1713	1,713	1,713	1,713	364	364	364	364	364	364	364	364
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
K–P LM	2026.04	2,532.12	1,963.96	2,595.97	194.96	200.95	194.38	200.92	222.20	238.25	222.64	237.42
K-P W F	5782.16	14,000.00	5,892.04	15,000.00	1,892.24	2,263.83	1,865.80	2,274.24	3,943.18	2,216.72	4,020.41	2,208.66

This table reports the results of the 2SLS-IV model presented in Eqs. (3) and (4). In Panel A, ΔEq_ta is the year-on-year percentage variation of total equity divided by total assets. In Panel B, $\Delta CET1\_ta$ is the year-on-year percentage variation in Common Equity Tier 1 divided by total assets. In Panel C, $\Delta Tier1\_ta$ is the year-on-year percentage variation in Tier 1 divided by total assets. In each panel, the four instruments described in the "Instruments" section are tested. ΔR (the dependent variable, Dep var) is the year-on-year percentage variation of the ratio of risk weighted assets to total assets. $\widehat{\Delta C}$ is the ΔC estimated in the first stage. N. obs. is the total number of bank-year observations. FE stands for fixed effects. K–P LM and K-P W F stand for the Kleibergen–Paap rk LM (Lagrange Multiplier) and the Kleibergen–Paap rk Wald *F* statistics, respectively. Numbers in parenthesis are robust standard errors clustered by banks. **Indicates coefficients statistically significant at the 1% level (to maintain consistency with all the other tables, * is not used in this table). For convenience, the values of main interest (regarding $\widehat{\Delta C}$) are presented in bold

Table 7 Relationship between variations in capital and variations in risk-taking (fixed effects, publicly and privately owned banks)

Dependent variable	ΔR					
	Eq_ta		*CET1_ta*		*Tier1_ta*	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A—Public banks						
ΔC	0.01578	0.03201**	0.09283**	0.11206**	0.08921**	0.11082**
	(0.01145)	(0.00539)	(0.03064)	(0.02129)	(0.03136)	(0.02154)
No. obs	8523	8523	1219	1219	1219	1219
No. banks	491	491	281	281	281	281
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes
Macro-controls	Yes	No	Yes	No	Yes	No
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes
R-squared	0.0993	0.1583	0.1132	0.1325	0.1235	0.1361
ΔC	0.03233**	0.03948**	0.18291**	0.18291**	0.16952**	0.16952**
	(0.00525)	(0.00534)	(0.03826)	(0.03826)	(0.03919)	(0.03919)
No. obs	9537	9537	492	492	492	492
No. banks	1395	1395	125	125	125	125
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes
Macro-controls	Yes	No	Yes	No	Yes	No
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes
R-squared	0.0415	0.0953	0.0610	0.0610	0.0572	0.0572

The results in this table are based on the models represented in Eqs. (1) and (2). ΔR is the percentage variation of the ratio of risk weighted assets to total assets from year $t-1$ to year t. ΔC is the percentage change in bank capital. Three measures of capital are tested: *Eq_ta* (total equity divided by total assets), *CET1_ta* (Common Equity Tier 1 divided by total assets), and *Tier1_ta* (Tier1 divided by total assets). No. obs. is the total number of bank-year observations. Bank controls (X in the aforementioned equations) are variables specifically related to each bank, while Macro-controls, M in Eq. (1), are variables that simultaneously affect all banks in a given period. FE stands for fixed effects. Numbers in parenthesis are robust standard errors clustered by banks. **Indicates coefficients statistically significant at the 1% level (note that * is not used in this table to maintain our notation consistent across all tables)

banks (keeping in mind that the magnitude of the coefficients of equity ratio are fairly similar for both types of institutions, while the magnitude of the coefficients concerning CET1 and Tier 1 is considerably larger for private banks). In Table 8, all the instruments remain statistically valid. It is worth noting that in the regressions regarding the public financial institutions we include controls regarding the presence of major shareholders (who could exert more pressure on managers as compared to minority shareholders)[13] and the percentage of shares held by top managers, which could affect the risk aversion of those individuals (in particular, the CEO who plays a key role in the final decisions made on behalf of their institutions). The former aspect is in line with discussions in, for example, Saunders et al. [49], while the latter is also addressed in Brewer III et al. [17], Laeven and Levine [40], Shehzad et al. [50], and Klomp and Haan [38].[14]

In order to check whether the increase in risk-taking is concentrated on particular asset risk levels, we run our fixed effects and IV analyses splitting risk into three categories: low (risk weights < 50%, medium (risk weights between 50 and 100%) and high (risk weights equal to or greater than 100%) according to the classification used in the calculations of regulatory capital. We use total equity to total assets as a proxy of capital but the (unreported) results for Common Equity Tier 1 and Tier 1 capital measures are in line with the results shown in Table 9 (fixed effects) and 10 (2SLS-IV). If we consider that the level of risk should normally be

[13] This is controlled by means of a dummy equal to 1 if the BHC has at least one shareholder who owns at least 10% of the institution's capital. An alternative percentage (5%) is also tested and this does not affect our results.

[14] The total number of observations and banks in Table 8 is smaller than those in the baseline IV results Table 4 because data regarding managers' ownership and major shareholders is not available for all listed banks in our sample.

Table 8 Relationship between variations in capital and variations in risk-taking (2SLS-IV, publicly and privately owned banks)

Panel A—Public banks

	Panel A.1				Panel A.2				Panel A.3			
	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
First stage												
Dep var	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$
IV	− 0.157**	− 21.013**	− 6.811**	− 0.517**	− 0.101**	− 27.074**	− 9.956**	− 0.264**	− 0.080**	− 30.881**	− 10.199**	− 0.243**
	(0.005)	(0.549)	(0.213)	(0.013)	(0.006)	(1.734)	(0.614)	(0.017)	(0.005)	(1.804)	(0.684)	(0.014)
F statistic	99.45	114.58	96.45	114.73	63.84	60.84	60.3	56.35	48.92	56.18	47.54	53.58
Second stage												
Dep var	ΔR											
$\widehat{\Delta C}$	**0.0545****	**0.0658****	**0.0552****	**0.0627****	**0.1503****	**0.1496****	**0.1331****	**0.1643****	**0.1276****	**0.1032***	**0.1266****	**0.1107***
	(0.0144)	**(0.0151)**	**(0.0144)**	**(0.0146)**	**(0.0463)**	**(0.0486)**	**(0.0468)**	**(0.0481)**	**(0.0481)**	**(0.0475)**	**(0.0483)**	**(0.0467)**
No. obs	2,104	2,104	2,104	2,104	495	495	495	495	495	495	495	495
No. banks	190	190	190	190	106	106	106	106	106	106	106	106
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
K–P LM	474.12	455.31	467.46	475.73	68.10	68.80	65.88	70.98	66.17	69.05	65.34	70.14
K-P W F	1,100.20	1,465.46	1,023.68	1,480.34	275.36	243.84	262.65	251.46	256.11	293.18	222.57	293.95

Panel B—Private banks

	Panel B.1				Panel B.2				Panel B.3			
	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
First stage												
Dep var	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta CET1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$	$\Delta Tier1\_ta$
IV	− 0.172**	− 26.365**	− 8.061**	− 0.576**	− 0.093**	− 26.740**	− 9.912**	− 0.267**	− 0.067**	− 28.645**	− 8.457**	− 0.227**
	(0.003)	(0.354)	(0.143)	(0.008)	(0.006)	(2.288)	(0.741)	(0.022)	(0.005)	(2.165)	(0.732)	(0.017)
F statistic	389.95	494.72	370.24	533.12	51.68	32.48	48.15	34.57	52.99	42.62	52.06	44.33
Second stage												
Dep var	ΔR											
$\widehat{\Delta C}$	**0.0477****	**0.0485****	**0.0490****	**0.0469****	**0.2378****	**0.2564****	**0.2456****	**0.2486****	**0.2956****	**0.3283****	**0.2987****	**0.3264****
	(0.0068)	**(0.0069)**	**(0.0070)**	**(0.0067)**	**(0.0701)**	**(0.0797)**	**(0.0702)**	**(0.0765)**	**(0.0666)**	**(0.0695)**	**(0.0664)**	**(0.0687)**
No. obs	9,373	9,373	9,373	9,373	476	476	476	476	476	476	476	476
No. banks	1,231	1,231	1,231	1,231	109	109	109	109	109	109	109	109
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 8 (continued)

Panel B—Private banks

	Panel B.1				Panel B.2				Panel B.3			
	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
K–P LM	1,877.03	1,965.66	1864.87	1969.81	45.99	48.26	49.68	48.49	54.38	57.32	54.41	58.13
K-P W F	3,151.34	5,554.81	3,185.36	5,837.15	213.52	136.62	179.02	146.31	157.83	175.03	133.53	186.17

This table reports the results of the 2SLS-IV model presented in Eqs. (3) and (4). Panels A and B refer to publicly can privately owned banks, respectively. In Panels A.1 and B.1, ΔEq_ta is the year-on-year percentage variation of total equity divided by total assets. In Panels A.2 and B.2, $\Delta CET1\_ta$ is the year-on-year percentage variation in Common Equity Tier 1 divided by total assets. In Panels C.1 and C.2, $\Delta Tier1\_ta$ is the year-on-year percentage variation in Tier 1 divided by total assets. In each panel, the four instruments described in the "Instruments" section are tested. ΔR (the dependent variable, Dep var) is the year-on-year percentage variation of the ratio of risk weighted assets to total assets. $\widehat{\Delta C}$ is the ΔC estimated in the first stage. N. obs. is the total number of bank-year observations. FE stands for fixed effects. K–P LM and K-P W F stand for the Kleibergen–Paap rk LM (Lagrange Multiplier) and the Kleibergen–Paap rk Wald F statistics, respectively. Numbers in parenthesis are robust standard errors clustered by banks. * and **Indicate coefficients statistically significant at the 5% and 1% levels, respectively. For convenience, the values of main interest (regarding $\widehat{\Delta C}$) are presented in bold

low, the results in Table 9 would indicate that, when this is not the case (medium and high levels), more capital would push banks to increase their risk-taking (possibly due to higher loss absorption capacity). Nevertheless, taking all results together, we can only draw consistent conclusions for medium-risk assets (Panel B in both tables), which according to the two methods used increase as a consequence of capital increases (and vice versa).

As the fixed effects and the instrumental variable methods deliver conflicting results for low- and high-risk assets (Panels A and C in Tables 9 and 10), we run additional analyses using random effects and Generalized Method of Moments (GMM) models with a view to identifying the relationship that is more likely to be correct. The new results corroborate the findings based on the fixed effects models.[15] That is, when capital increases, investments in low-risk assets fall, while investments in high-risk assets go up.

Thus, overall, these results indicate that increments in risk following increases in capital are concentrated on assets with intermediate- and high-risk levels. On the other hand, possibly to release resources for those new investments, banks reduce the value invested in low-risk assets. In general, this supports our main conclusions.

As mentioned in the "Fixed effects" section, we re-run our analyses by replacing $\Delta R_{i,t}$ with future changes in risk ($\Delta R_{i,t+1}$) to allow for the possibility that our risk measure regarding a particular year could reflect past risk-taking decisions and to add further evidence against reverse causality. This is done for the fixed effects and the 2SLS-IV regressions and does not alter our baseline conclusions. Robustness tests based on three alternative measures of risk-taking (loan loss provisions, impaired loans to total loans ratio, and nonperforming assets to total assets ratio) are also run. In general, the results based on fixed effects models and 2SLS-IV support our original conclusions, according to which increases in capital lead to increases in risk-taking. For the sake of brevity, we do not report these additional results here but they are available upon request.

The impact of capital on funding costs

In the interpretation of our main results in the "Results and discussions" section, we suggest that risk-taking tends to go up as a response to capital increases because adding capital to banks would raise their overall funding costs. This would be the case because capital is known to be more expensive

[15] Although the GMM results are not statistically significant, the signs of all key coefficients support the direction of the relationships implied in the fixed and random effects analyses. Due to space constraints, the additional results are not reported in the paper but are available upon request.

Table 9 Relationship between variations in capital and variations in risk-taking (fixed effects, different risk levels)

Dependent variable	ΔR					
	Panel A Low risk		Panel B Medium risk		Panel C High risk	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔC	− 0.02466*	− 0.02743**	0.02541**	0.02266**	0.00020**	0.00021**
	(0.01001)	(0.01015)	(0.00325)	(0.00323)	(0.00006)	(0.00005)
No. obs	18060	18060	18060	18060	18060	18060
No. banks	1886	1886	1886	1886	1886	1886
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes
Macro-controls	Yes	No	Yes	No	Yes	No
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes	No	Yes
R-squared	0.0264	0.0501	0.0513	0.1287	0.1433	0.5280

The results in this table are based on the models represented in Eqs. (1) and (2) where asset risk is split into three categories: low (risk weight < 50%), medium (risk weight from 50 to 100%) and high (risk weight ≥ 100%). ΔR is the percentage variation of the ratio of risk weighted assets to total assets from year $t-1$ to year t. ΔC is the percentage change in bank capital, which is proxied by *Eq_ta* (total equity divided by total assets). No. obs. is the total number of bank-year observations. Bank controls (X in the aforementioned equations) are variables specifically related to each bank, while Macro-controls, M in Eq. (1), are variables that simultaneously affect all banks in a given period. FE stands for fixed effects. Numbers in parenthesis are robust standard errors clustered by banks. * and **Represent coefficients statistically significant at the 5% and 1% levels, respectively

than debt such as deposits. Hence, if our reading is correct, we would expect that increases in capital do affect banks' funding costs. To check this possibility, we regress changes in funding costs on changes in capital plus controls using the two methods used before and assuming that it takes one period (year in this case) for funding costs to react to changes in capital. The two specifications of the fixed effects model are given by:

$$\Delta \mathrm{WACC}_{i,t} = \beta_0 + \beta_1 \Delta C_{i,t-1} + \beta_2 X_{i,t} + \beta_3 M_t + \mu_i + \varepsilon_{i,t}. \quad (6)$$

and

$$\Delta \mathrm{WACC}_{i,t} = \alpha_0 + \alpha_1 \Delta C_{i,t-1} + \alpha_2 X_{i,t} + \mu_i + t_t + \varepsilon_{i,t}. \quad (7)$$

The notation above follows Eqs. (1) and (2), the most relevant difference[16] being the dependent variable, ΔWACC (changes in banks' weighted average cost of capital[17]), which is our measure of funding cost, calculated as:

$$eq\_ta * cost\_cap + (1 - eq\_ta) * cost\_debt,$$

where *eq_ta* is capital ratio as defined in our baseline models, *cost_cap* is the cost of capital (total dividends paid) divided by total equity, and *cost_debt* is the cost of debt (expenses related to non-equity funding) divided by the total value of debt. We test two proxies of *cost_debt*: the costs of interest-bearing deposits and the total costs of all non-equity liabilities (including those that do not pay interest rates). The weighted average costs of capital calculated using these two measures of debt cost are denoted by WACC-dep and WACC-fund, respectively.

The two stages of the IV model are:

$$\Delta C_{i,t-1} = q_0 + q_1 IV_{i,t-2} + q_2 X_{i,t} + q_3 M_t + \mu_i + \varepsilon_{i,t} \quad (8)$$

and

16 In terms of bank-specific controls, X, we drop the dummy regarding the approach used by banks to calculate their regulatory capital as this does not appear to be a key determinant of funding costs. On the other hand, we include a new dummy representing the period when bail-ins became a possibility in the USA (2010 onwards in line with the Dodd-Frank Wall Street Reform and Consumer Act of January 2010). The macro-controls, M, in Eq. (6) are the same as before.

17 We recognize that the term 'cost of capital' may be misleading in the context of this paper as, despite being called 'cost of capital' it includes not only capital (equity) but also the other sources of bank funding (e.g., deposits). Even though, we opt for using WACC given its widespread use in the banking literature. Hence, readers are urged to bear in mind that, here, WACC refers to all funding sources.

Table 10 Relationship between variations in capital and variations in risk-taking (2SLS-IV, different risk levels)

	Panel A—low risk				Panel B—medium risk				Panel C—high risk			
	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
First stage												
Dep var	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta	ΔEq_ta
IV	− 0.084**	− 12.484**	− 3.808**	− 0.279**	− 0.084**	− 12.484**	− 3.808**	− 0.279**	− 0.084**	− 12.484**	− 3.808**	− 0.279**
	(0.002)	(0.281)	(0.094)	(0.006)	(0.002)	(0.281)	(0.094)	(0.006)	(0.002)	(0.281)	(0.094)	(0.006)
F statistic	1636.82	1978.83	1625.51	1936.13	1636.82	1978.83	1625.51	1936.13	1636.82	1978.83	1625.51	1936.13
Second stage												
Dep var	ΔR											
$\widehat{\Delta C}$	**− 0.0110**	**− 0.0255**	**− 0.0163**	**− 0.0041**	**0.0155***	**0.0278****	**0.0175***	**0.0148***	**< 0.0001**	**− 0.0009****	**− 0.0001**	**< 0.0001**
	(0.0222)	**(0.0230)**	**(0.0231)**	**(0.0221)**	**(0.0071)**	**(0.0073)**	**(0.0074)**	**(0.0071)**	**(0.0002)**	**(0.0002)**	**(0.0002)**	**(0.0002)**
No. obs	17887	17887	17887	17887	17887	17887	17887	17887	17887	17887	17887	17887
No. banks	1713	1713	1713	1713	1713	1713	1713	1713	1713	1713	1713	1713
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
K–P LM	1732.54	1777.95	1699.70	1767.74	1732.54	1777.95	1699.70	1767.74	1732.54	1777.95	1699.70	1767.74
K-P W F	1636.82	1978.83	1625.51	1936.13	1636.82	1978.83	1625.51	1936.13	1636.82	1978.83	1625.51	1936.13

This table reports the results of the 2SLS-IV model presented in Eqs. (3) and (4) where asset risk is split into three categories: low (risk weight < 50%, Panels A), medium (risk weight from 50 to 100%, Panel B) and high (risk weight ≥ 100%, Panel C). ΔEq_ta is the year-on-year percentage variation of total equity divided by total assets. In each panel, the four instruments described in Sect. "Instruments" are tested. ΔR (the dependent variable, Dep var) is the year-on-year percentage variation of the ratio of risk weighted assets to total assets. $\widehat{\Delta C}$ is the ΔC estimated in the first stage (proxied by ΔEq_ta). N. obs. is the total number of bank-year observations. FE stands for fixed effects. K–P LM and K-P W F stand for the Kleibergen–Paap rk LM (Lagrange Multiplier) and the Kleibergen–Paap rk Wald F statistics, respectively. Numbers in parenthesis are robust standard errors clustered by banks. * and **Indicate coefficients statistically significant at the 5% and 1% levels, respectively. For convenience, the values of main interest (regarding $\widehat{\Delta C}$) are presented in bold

Table 11 Relationship between variations in capital and variations in funding costs (fixed effects)

Dependent variable	ΔWACC$_t$			
	Panel A WACC-dep		Panel B WACC-fund	
	(1)	(2)	(3)	(4)
$\Delta C\ t-1$	0.02080	0.04867**	0.01258	0.04118**
	(0.01511)	(0.01168)	(0.01407)	(0.01156)
No. obs	18060	18060	18060	18060
No. banks	1886	1886	1886	1886
Bank controls	Yes	Yes	Yes	Yes
Macro-controls	Yes	No	Yes	No
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	Yes
R-squared	0.2803	0.7182	0.2902	0.6924

The results in this table are based on Eqs. (6) and (7). $\Delta WACC_t$ is the percentage variation in the Weighted Average Cost of Capital (WACC) from the end of year $t-1$ to the end of year t. Two debt measures are used to calculate WACC: in Panel A, the debt cost is calculated based on the cost of interest-bearing deposits; in Panel B, debt cost is based on non-equity liabilities in general. $\Delta C\ t-1$ is the percentage change in bank capital (here, total equity divided by total assets, *Eq_ta*) from the end of year $t-2$ to the end of year $t-1$. No. obs. is the total number of bank-year observations. Bank controls (X in the aforementioned equations) are variables specifically related to each bank, while Macro-controls, M in Eq. (1), are variables that simultaneously affect all banks in a given period. FE stands for fixed effects. Numbers in parenthesis are robust standard errors clustered by banks. **Represents coefficients statistically significant at the 1% level (note that * is not used in this table to maintain our notation consistent across all tables)

$$\Delta\text{WACC}_{i,t} = g_0 + g_1 + g_2 X_{i,t} + g_3 M_{i,t} + \mu_i + \varepsilon_{i,t}, \tag{9}$$

where the notation follows the previous models.[18]

The fixed effects results in Table 11 show conflicting conclusions when we compare the specifications with macro-controls but without time fixed effects (columns (1) and (3)) with the specifications without macro-controls but with time fixed effects (columns (2) and (4)). While the former indicate that changes in capital are not associated with changes in funding costs the latter imply that changes in capital do have an effect on funding costs. In this case, we initially favor the results based on the use of time fixed effects dummies (rather than specific macro-variables) because the time dummies take into account the influence of *any* time-invariant factors (i.e., not only the macro-variables included in the model) that may be jointly driving the association between changes in capital and changes in funding cost.

To shed further light in this decision and settle the matter, we refer to the 2SLS-IV results in Table 12, which suggest that, for all the four instruments and the two WACC measures, capital impacts funding cost. Considering the statistical validity of the instruments and their theorical reasoning discussed in the "Validity of the instruments" section, our IV analyses support the fixed effects results based on time dummies (instead of macro-variables). Therefore, most of our results point toward a positive impact of capital ratios on funding cost. That is, as we initially assumed, an increase in bank capital tends to lead to higher funding costs.

Conclusions

The idea that bank capital helps improve stability takes for granted the idea that increases in capital are an incentive to reduce risk-taking given that shareholders would have more to lose if their bank fails. Nevertheless, given the higher cost of capital as compared to debt, it is also possible that increases in capital would lead to higher risk-taking due to the need for banks to increase their returns.

In light of these conflicting possibilities, we empirically test which of them is more reasonable in practice. By considering exogenous variations of capital in the form of instrumental variables, we are able to disentangle the actual impact of changes in capital on risk-taking from the effects of unobserved confounders and the reverse relationship (i.e., impact of risk-taking on capital levels).

Contrary to the widespread belief that more bank capital leads to a reduction in risk-taking, our results show that increasing capital makes banks take more risk. This suggests that the skin-in-the-game hypothesis is not plausible (or at least that the incentives for bank owners to reduce risk-taking in the event of capital increases are not strong enough to dominate other factors such as the need for

[18] Note that, because the IV precedes changes in capital, which is lagged one period in terms of $\Delta WACC$, it (IV) is measured in *t-2*.

Table 12 Relationship between variations in capital and variations in funding costs (2SLS-IV)

	Panel A—WACC-dep				Panel B—WACC-fund			
	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}	IV^{mean_disp}	IV^{perc_disp}	IV^{mean}	IV^{perc}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
First stage								
Dep var								
IV	ΔEq_ta_{t-1}	ΔEq_ta_{t-1}	ΔEq_ta_{t-1}	ΔEq_ta_{t-1}	ΔEq_ta_{t-1}	ΔEq_ta_{t-1}	ΔEq_ta_{t-1}	ΔEq_ta_{t-1}
	− 0.102**	− 15.035**	− 4.625**	− 0.340**	− 0.102**	− 15.035**	− 4.625**	− 0.340**
	(0.002)	(0.241)	(0.077)	(0.005)	(0.002)	(0.241)	(0.077)	(0.005)
F statistic	284.34	298.93	275.89	306.09	284.34	298.93	275.89	306.09
Second stage								
Dep var	$\Delta WACC_t$							
$\widehat{\Delta C}_{t-1}$	**0.1543****	**0.1901****	**0.1535****	**0.1548****	**0.1091****	**0.1404****	**0.1109****	**0.1117****
	(0.0276)	**(0.0281)**	**(0.0277)**	**(0.0274)**	**(0.0256)**	**(0.0259)**	**(0.0257)**	**(0.0254)**
No. obs	15984	15984	15984	15984	15984	15984	15984	15984
No. banks	1529	1529	1529	1529	1529	1529	1529	1529
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
K–P LM	2150.73	2146.31	2102.67	2180.55	2150.73	2146.31	2102.67	2180.55
K-P W F	3722.87	3881.97	3629.73	3984.95	3722.87	3881.97	3629.73	3984.95

This table reports the results of the 2SLS-IV model presented in Eqs. (8) and (9). $\Delta WACC_t$ is the percentage variation in the Weighted Average Cost of Capital (WACC) from the end of year $t-1$ to the end of year t. Two debt measures are used to calculate WACC: in Panel A, the debt cost is calculated based on the cost of interest-bearing deposits; in Panel B, debt cost is based on non-equity liabilities in general. ΔC_{t-1} is the percentage change in bank capital (here, total equity divided by total assets, Eq_ta_{t-1}) from the end of year $t-2$ to the end of year $t-1$. In each panel, the four instruments described in Sect. "Instruments" are tested. $\widehat{\Delta C_{t-1}}$ is the ΔC_{t-1} estimated in the first stage (proxied by ΔEq_ta_{t-1}). N. obs. is the total number of bank-year observations. FE stands for fixed effects. K–P LM and K-P W F stand for the Kleibergen–Paap rk LM (Lagrange Multiplier) and the Kleibergen–Paap rk Wald *F* statistics, respectively. Numbers in parenthesis are robust standard errors clustered by banks. * and **Indicate coefficients statistically significant at the 5% and 1% levels, respectively. For convenience, the values of main interest (regarding $\widehat{\Delta C_{t-1}}$) are presented in bold

higher returns to pay the additional funding costs resulting from capital newly raised). Overall, our baseline findings are corroborated by analyses based on alternative versions of the instruments, different proxies of capital, risk-taking measured in a future period, and a different approach (fixed effects, which explores different specifications).

We then present further empirical evidence confirming that changes (increases) in capital affect (increase) bank funding costs. This supports our initial interpretation claiming that the increase in risk-taking following increases in capital can be (at least partially) explained by the expectation of higher funding costs (resulting from higher capital ratios), which leads to the pursuit of higher returns. We stress that these relationships have already been mentioned in the literature but, in many cases, they are based on theoretical models and facts observed in the banking sector rather than on systematic empirical analyses, which are provided by our study.

We therefore contribute to a better understanding of the relationship between bank capital, funding costs and risk-taking, which can help policy-makers when designing regulatory requirements on banks and bank managers when deciding the capital level of their institutions.

In terms of future research, data on other countries could be used in which case the instruments employed in our study could also be used given that their foundation is applicable to any banking sector facing regulatory requirements and/or market pressure, which happen in virtually any country. Also, recalling that our study is focused on the capital levels endogenously decided by banks, it would be important to investigate the impact of capital requirements imposed on banks given that our results could indicate that an increase in risk-taking is an unintended effect of capital regulations (i.e., the requirement of higher capital levels could make banks raise their capital ratios, which in turn would trigger more risk-taking as shown in our analyses). Additionally, our study tackles reverse causality by preventing the possibility that the effect of risk-taking on bank capital would be the *only* direction of the relationship between these two variables. In other words, we show evidence that changes in capital affect risk-taking but do not preclude the possibility that risk could also affect capital levels (e.g., due to risk-based regulatory rules).

Thus, further investigations could assess the net effect of the association between capital and risk-taking.

Declarations

Conflict of interest The author states that there is no conflict of interest.

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