BANK OF ENGLAND

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Bank capital and risk-taking: evidence from misconduct provisions

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Bank capital and risk-taking: evidence from misconduct provisions

Belinda Tracey[(1)] and Rhiannon Sowerbutts[(2)]

Abstract

Over the last decade, banks around the world have been confronted with substantial misconduct costs. We employ provisions for misconduct costs as an instrumental variable to identify the causal effect of a bank capital shock on risk-taking. Using new hand-collected data, we show that misconduct provisions have adversely affected bank capital across UK banks. Our instrumental variable approach additionally exploits an important difference in timing between current risk-taking and the past misconduct that current misconduct provisions refer to. Our main finding is that a negative bank capital shock causes an increase in risk-taking in the UK mortgage market.

Key words: Bank misconduct, risk-taking, capital shocks, instrumental variables.

JEL classification: G21, G28.

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1 Introduction

Recent investigations into bank misconduct have plagued many of the largest banks in the world. Banks have put aside substantial provisions to address misconduct costs such as fines, litigation and customer redress payments. U.K. banks alone have put aside around £87 billion in misconduct provisions since 2010; a sum equivalent to almost a third of aggregate 2017 Common Equity Tier 1 (CET1) capital. In this study, we show that provisions for misconduct costs have adversely affected U.K. banks' capital ratios. And we use this relationship to address a long-standing question in finance: what is the impact of a shock to bank capital on the risk-taking behavior of banks?

Understanding how banks respond to capital shocks is central to understanding how aggregate shocks are transmitted to credit markets and the real economy. But empirically this topic is challenging because bank capital and risk-taking form an endogenous relationship. Reverse causality is a particular concern: a change in capital is likely to alter a bank's risk-taking incentives, yet a change in risk-taking can directly affect a bank's capital ratio via a change in retained earnings or risk-weighted assets. The primary innovation of this paper is our approach to address this endogeneity, and thereby isolate the causal effect of a bank capital shock on risk-taking. We overcome this identification challenge by using provisions for misconduct costs as an instrument for bank capital.

Misconduct provisions are a timely and comprehensive measure of misconduct costs. Banks are required, in accordance with International Accounting Standards, to make adequate provisions for the periods they expect to face any likely misconduct costs. These provisions are a shock to bank capital because they reduce retained earnings, which could otherwise contribute to CET1 capital, and thereby reduce potential capital contributions. By contrast, actual misconduct penalties may not affect bank capital because they sometimes take considerable time to be finalized and so banks have often previously provisioned for them.

There are two necessary conditions for misconduct provisions to qualify as a valid instrument. First, we require misconduct provisions to have a significant effect on bank capital. There are good reasons to expect this to be the case. Misconduct provisions have been considerable in size and, as described above, they can affect the numerator of bank capital ratios. Empirically, we find that there is indeed a significant and negative relationship between misconduct provisions and changes to bank capital ratios.

We additionally require misconduct provisions to be uncorrelated with the error term of our risk-taking explanatory equation, conditional on the other covariates. One major threat to meeting this requirement is that a determinant of misconduct provisions may also be an omitted variable in our risk-taking equation, implying that misconduct provisions are correlated with the error term of this equation. We therefore review the banking literature to determine the drivers of misconduct provisions, and how they relate to asset risk-taking. While the literature contains no evidence that misconduct provisions affect asset risk-taking, other than via their impact on retained earnings and capital, there are many common factors that explain both misconduct provisions and asset risk-taking. Our main risk-taking analysis therefore carefully controls for factors that influence risk-taking and also misconduct provisions, such as governance and balance sheet strength. Of particular importance, we include bank fixed effects to capture unobserved time-invariant bank characteristics such as a bank's business model and risk culture. Such factors are likely to influence both risk-taking and misconduct, but they also tend to be very persistent over time (see, e.g., Fahlenbrach et al., 2012; Ellul and Yerramilli, 2013), implying that their influence will be controlled for by bank fixed effects. Having controlled for all of these factors, misconduct provisions would appear to be a plausible instrument.

A key strength of our identification strategy is that we use misconduct *provisions* as an instrument rather than misconduct itself. We therefore exploit the difference in timing between the two events: "bank misconduct taking place" and "misconduct provisions being made". So, a shock to some omitted misconduct determinant in period t would affect risk-taking in t and misconduct in t, but would only lead to misconduct *provisions* in some subsequent period $t + n$, where n is often at least several periods and varies randomly from case-to-case. This implies that there is no direct correlation between misconduct provisions in t and risk-taking in t, also given that our bank fixed effects will absorb any time-invariant common factors. We provide corroborating empirical evidence for these arguments. For example, we show that our results hold when we restrict our instrument to provisions related to mis-sold Payment Protection Insurance (PPI); this exercise is useful because these provisions often relate to policies that were sold more than a decade prior, making it especially likely that there is no direct correlation between misconduct provisions and risk-taking in the same period. We also show that misconduct provisions have no significant association with previous risk-taking, where several different lags of risk-taking are considered. Together these results suggest that our identification strategy is not affected by a time-varying omitted misconduct determinant.

Given the strong effect of misconduct provisions on bank capital, and the plausible assumption that misconduct provisions do not belong in the risk-taking "production function", we can employ misconduct provisions as an instrument to estimate the causal impact of a bank capital shock on risk-taking behavior. To perform our analysis, we construct a unique U.K. panel dataset. Our dataset merges new hand-collected bank-level information on misconduct provisions from published accounts with loan-level data on all regulated U.K. mortgages, which facilitates a rich analysis of bank risk-taking in the U.K. mortgage market. The granularity of our loan-level information allows us to make a serious attempt at disentangling changes in the demand for loans from changes in their supply. Following the approach of Ioannidou et al. (2015), we control for changes in the loan demand of risky borrowers by including loan and borrower characteristics in our specifications. Additionally, we control for changes in loan demand by including region-time fixed effects as done by Uluc and Wieladek (2016). In sum, our empirical specification controls for endogeneity, loan demand factors, borrower characteristics, loan characteristics, bank characteristics, and other features that may influence bank risk-taking in the mortgage market.

Our main finding is that a negative shock to bank capital causes an increase in risk-taking in the U.K. mortgage market. In particular, a one standard deviation negative shock to the CET1 ratio leads to a 1.6 percentage point increase in the average loan-to-value (LTV) ratio, holding all else constant. We also explore how banks alter their tail risk-taking behavior following capital shocks. We find that a one standard deviation negative shock to the CET1 ratio will make banks around 4 percentage points more likely to issue a new loan with an LTV of 85 or higher. These results suggest that a negative shock to capital induces lending to the most risky borrowers, in addition to an upwards shift in the average LTV ratio of all borrowers.

More generally, our findings demonstrate that bank capital is not purely a buffer to absorb shocks and protect creditors from losses: it also influences banks' risk-taking incentives. Specifically, our results support the theoretical prediction that a negative capital shock will reduce a bank's "skin-in-the game" thereby increasing risk-taking incentives. As such, these findings have important implications for financial stability. Following a decrease in bank capital, banks are likely to loosen their mortgage lending standards. This increases the vulnerability of both the household sector and the banking sector to future shocks. Additionally, these results have implications for optimal capital requirements; any determination of bank capital requirements that does not take these risk-taking consequences into account may set sub-optimal capital requirements.

We contribute to the existing literature in several ways. First and foremost, we introduce a novel way to isolate the causal impact of an exogenous change to bank capital on risk-taking. This is important in light of the fact that the previous empirical literature fails to reach a consistent conclusion about the relationship between bank capital and risk-taking. Of the 20 studies surveyed by Tanda (2015) that attempt to estimate a relationship between bank capital and risk-taking, four report a positive association between these two factors, five others a negative association, two find no relationship at all, and the remaining nine present mixed evidence. We thereby build on previous empirical research that has examined the relationship between bank capital and risk-taking often by using a simultaneous equations approach (see, e.g., Shrieves and Dahl, 1992; Jacques and Nigro, 1997; Aggarwal and Jacques, 1998; Aggarwal and Jacques, 2001; Rime, 2001; Altunbas et al., 2007).

Second, our study relates to the small but growing literature that deals with regulatory enforcement actions and their implications for banks (see, e.g., Berger et al. (2016); Delis et al., 2016; Delis et al. (2017);Nguyen et al., 2016). Our study also relates to the work of Köster and Pelster (2017) concerning the impact of financial penalties on the profitability and stock performance of banks. We are in this respect the first study to collect and summarize information about *provisions* relating to bank misconduct. And we are the first to consider the impact of these misconduct provisions on bank capital and risk-taking.

To the best of our knowledge, we are also the first study to consider the causal impact of bank capital shocks on risk-taking by utilizing granular loan-level information about lending standards and credit risk, rather than bank-level risk measures. Bank-level measures of risk-taking include Z-scores, the non-performing loans ratio and risk-weighted asset indices. There are several limitations associated with these bank-level risk measures. Of most relevance, all three are stock measures that inform us about potential bank vulnerability largely due to *previous* risk-taking. By contrast, our study utilizes information at the individual asset level, including the leverage ratio (or LTV ratio) of a new mortgage. Not only does this allow us to better control for loan demand, as discussed above, but the leverage of new loans also informs us about *current changes* to risk-taking (Geanakoplos and Pedersen, 2012).

Finally, we build on the literature that considers the impact of bank capital on bank lending (see, e.g.,Bernanke and Lown, 1991; Peek and Rosengren, 1995a; Peek and Rosengren, 1995b; Gambacorta and Mistrulli, 2004), as well as the literature on the impact of bank capital requirements on bank lending (see, e.g., Francis and Osborne, 2012; Brun et al., 2013; Aiyar et al., 2014; Bridges et al., 2014; Mésonnier and Monks, 2015; De Jonghe et al., 2016; Gropp et al., 2016; Uluc and Wieladek, 2016; Auer and Ongena, 2016; Jiménez et al., 2017; Fraisse et al., 2017). While these studies provide useful insights into the impact of bank capital on the *quantity* of lending, we provide new insights about the transmission mechanisms of changes in bank capital on the *quality* of lending.[1]

The remainder of paper is organized as follows. In Section 2, we outline the theory to motivate our hypotheses on bank capital and risk-taking. Section 3 describes the data and the institutional setting. Section 4 assesses the suitability of misconduct provisions as an instrument for bank capital. Section 5 presents our empirical results on the causal impact of bank capital on risk-taking. Section 6 concludes.

[1] De Jonghe et al. (2016) and Uluc and Wieladek (2016) investigate the impact of various capital requirements on credit supply, and how changes to credit supply differs across both banks with different risk-levels as well as the riskiness of their lending decisions.

2 The Theory of Bank Capital and Risk-taking

In this section, we review several theories that make predictions about the impact of bank capital on risk-taking, and use these insights to derive our hypotheses. We consider two main strands of the literature, which provide contrasting conclusions.

The first strand of the literature considers risk-taking incentives that arise due to bankruptcy costs and deposit insurance (see, e.g., Merton, 1977; Kareken and Wallace, 1978; Pyle, 1984). Depositors are not incentivized to monitor banks in this setting due to the introduction of the deposit insurance. As such, a value-maximizing bank faces incentives to increase asset risk. Furlong and Keeley (1989) build on this work to show that as a bank's capital increases, this decreases the value of any deposit insurance subsidy, and so decreases a bank's risk-taking incentives. Put another way, more capital increases a bank's "skin-in-the-game" and so reduces risk-taking incentives. Similarly, Keeley (1990) uses an alternative framework to show that a higher charter value will diminish a bank's risk-taking incentives because the bank will wish to protect the benefits of continuation. In this simple model, a negative capital shock decreases the probability of continuation and so creates risk-taking incentives. And herein lies the main finding from this first stand of the literature. As such, our first hypothesis is:

H1A. *A decrease in bank capital will lead to an* ***increase*** *in a bank's risk-taking, as measured by their mortgage lending standards.*

The second strand of the literature considers the impact of bank capital requirements on risk-taking, although the findings from this literature apply more generally to bank capital. Kahane (1977) and Koehn and Santomero (1980) find that a utility-maximizing bank will respond to an increase in capital ratio requirements by increasing asset risk. This result stems from the idea that the bank will treat leverage and risk as substitutes, and so the bank will seek to adjust risk when faced with a restriction to leverage to achieve its desired total level of risk. As a consequence, the insolvency likelihood of some banks - depending on the risk aversion of the bank - may increase rather than decrease when capital requirements are introduced. Kim and Santomero (1988) extend this work to show that appropriately chosen risk-related capital regulation can limit the insolvency. Some other authors use different frameworks to arrive at similar conclusions. Buser et al. (1981) show that implicit regulatory costs create incentives for banks to increase risk as capital increases. Overall, these findings contradict the main conclusions from the first strand of the literature, and give rise to our second hypothesis:

H1B. *A decrease in bank capital will lead to a* ***decrease*** *in a bank's risk-taking, as measured by their mortgage lending standards.*

The aforementioned literature is based on a static setup, rather than a model that considers a bank's dynamic response to a capital shock. Several more recent studies consider the impact of bank capital requirements on risk-taking within a general equilibrium framework. Gale (2010) shows that when the cost of capital is high, increased capital ratio requirements will incentivize increased risk-taking to generate additional profits. Also in a general equilibrium model with heterogeneous borrowers, Harris et al. (2017) show that an increase in capital requirements can lead to an increase in risk-taking via a reduction in lending to lower risk firms. Similar to the second strand of the literature, both of these studies look at bank capital *requirements* rather than bank capital shocks. But caution is required when applying the findings of Gale (2010) and Harris et al. (2017) to bank capital shock more generally. In both studies, the results arise due to the scarcity of capital. As such, an increase in capital requirements could be considered equivalent to a negative capital shock as these banks seek to rebuild capital, and thereby these findings rather appear to support our first hypothesis.

Given the contradictory conclusions associated with both the empirical and theoretical literature, as well as the limited applicability of earlier theoretical work to the bank capital shock context, the impact of bank capital on risk-taking is a topic that is worthwhile to consider empirically, as we do in this paper.

3 Bank Misconduct and Data

3.1 Misconduct Provisions and Bank-level Data

To test our hypotheses, we construct a panel dataset that merges bank-level data with administrative loan-level data on all regulated U.K. mortgages over the period 2010 to 2017. We hand-collect our bank-level information from published accounts because data on provisions for misconduct issues are not available in any major database. These data are semi-annual and include information about capital ratios and other bank-level variables (e.g. total assets, total loans, capital, liquid assets, return-on-assets, non-performing loans, and information about governance). Our sample comprises the 23 largest lenders by mortgage market share in the U.K., representing around 96 per cent of all U.K. mortgage lending over the sample period. Lenders include both banks and building societies, referred to hereafter simply as 'banks'.

We collect our bank-level data at the consolidated group level because decisions relating to capital management, lending and misconduct provisions are typically made at the group level (Bridges et al., 2014).[2]

[2]There are a few exceptions whereby we do not collect data for the ultimate parent company, however.

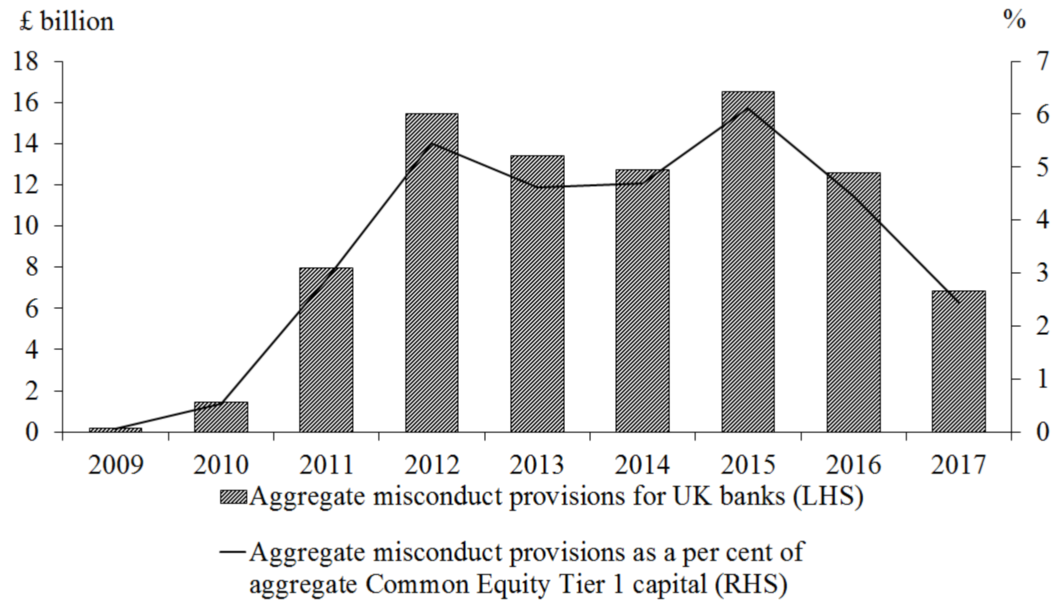

Figure 1: **Aggregate Misconduct Provisions from 2009 to 2017**
The figure plots the aggregate misconduct provisions for the 23 U.K. banks in our sample, as well as the ratio of the aggregate misconduct provisions to the aggregate Common Equity Tier 1 capital, over the period 2009 to 2017.

Of particular interest, we collect our misconduct provisions data from the notes to the financial statements contained in banks' published accounts. We take care to ensure that our collection only includes provisions that relate to misconduct costs. To do this, we strip out provisions that relate to restructuring costs, contractual commitments, sundry provisions, and the U.K. bank levy, among others. Our online Data Appendix contains detailed bank-level comments about the misconduct provisions data collection.

The start date of our sample, 2010, coincides with a substantial increase in provisions for misconduct costs. Figure 1 plots the aggregate misconduct provisions for the U.K. banks in our study, as well as the ratio of the aggregate misconduct provisions to the aggregate Common Equity Tier 1 capital, over the period 2009 to 2017. There have been several factors that are associated with the increase in bank misconduct costs, some of which reflect changes to the institutional setting. We describe these factors in turn below.

3.2 Bank Misconduct in the U.K.

The first change to the institutional setting that contributed to the increase in misconduct provisions relates to the new regime for determining financial penalties in enforcement cases, which was introduced by the Financial Services Authority (FSA) in March 2010. The Financial Conduct Authority (FCA) succeeded the FSA and is now responsible for

For example, Tesco Bank is included in our sample and we collect corresponding data for Tesco Personal Finance Group Limited (the bank) rather than the ultimate parent company Tesco Plc (the food retailer).

applying the new penalties regime. The regime aims to create a consistent and transparent framework for determining financial penalties in enforcement cases, and the approach is based on the principles of "disgorgement, discipline and deterrence" (Financial Services Authority, 2009).

Under the new regime, the FSA and FCA have applied financial penalties in relation to a number of high-profile investigations. A well-known example is the "Libor" scandal, which was described by some commentators as the biggest financial scandal in history (see, for example, Enrich, 2017). The London Interbank Offered Rate (Libor) is a benchmark interest rate, which is intended to reflect the average rate at which banks can borrow unsecured funds from other banks. Banks faced several incentives to manipulate Libor, including to benefit their trading positions (Department of Justice, 2012). In 2009, the FSA together with other international regulators began to investigate banks for misconduct relating to Libor and other benchmark rates (Wheatley, 2012). Sixteen major banks, four of which were U.K. banks, were initially accused of colluding to manipulate the Libor, and there is some evidence that Libor manipulation dated back to 2005 (Financial Services Authority, 2012). Since 2012, three U.K. banks were issued fines by the FSA and FCA for Libor manipulation. Also in relation to Libor manipulation, U.K. banks have been sued and fined by other regulators such as the FDIC, the Department of Justice and the Swiss competition regulator. Other international banks involved in the scandal have faced similar penalties by international regulators.

A second factor that brought about significant misconduct provisions relates to the mis-selling of Payment Protection Insurance (PPI). The PPI saga is the largest financial services redress exercise ever undertaken in the U.K. (Financial Conduct Authority, 2014). While the Libor scandal and other similar cases affected major global banks, customer redress payments related to PPI have affected the U.K. banking system more broadly, which is one reason that our focus on U.K. banks offers a useful setting for the question at hand. PPI covers loan repayments if, for example, the borrower becomes ill or unemployed. Adding PPI to a credit product was a widespread practice and highly profitable; the PPI commission was often more profitable than the loans themselves (Upton, 2006). PPI were mis-sold across a number of dimensions. For example, some borrowers were unaware they had bought PPI alongside their credit product.[3] In 1998, a consumer magazine *Which?* first raised issues with PPI. In 2005, the FSA took over the regulation of general insurance selling including PPI. The FSA was aware of the problems with PPI from the outset, and undertook a number of reviews and actions to address these. Of particular significance, the sale of single premium PPI - the product most associated with mis-selling - was banned in 2009. And new measures for handling mis-sold Payment Pro-

[3]According to survey evidence by ComRes (2015), only one third of adults with PPI have known all along that they had bought PPI.

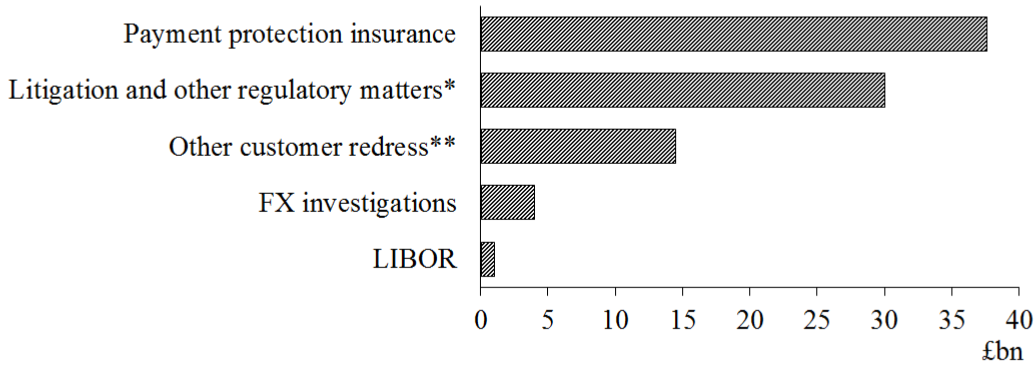

Figure 2: **Aggregate Provisions by Misconduct Issues from 2009 to 2017**
The figure shows the aggregate provisions for different misconduct issues for the 23 U.K. banks in our sample over the period 2009 to 2017. * The category "Litigation and other regulatory matters" includes: securities litigation, U.S. residential mortgage-backed securities investigations, money laundering, tax-related investigations, CDS, LIBOR, EURIBOR, foreign exchange investigations, other benchmark investigations, and other unspecified provisions for regulatory matters. ** The category "Other customer redress" includes: mis-sold interest rate hedging products, mis-sold packaged accounts, investment advice, U.K. Consumer Credit Act violations. Additionally some banks report provisions for mis-sold PPI within another customer redress category.

tection Insurance (PPI) were introduced in August 2010 and upheld by the High Court in April 2011. These new measures led to substantial provisions for customer redress payments for mis-sold PPI.

Beyond the aforementioned Libor manipulation and PPI claims, banks have been affected by costs relating to a broad range of misconduct issues over the same period, including: Euribor manipulation, foreign exchange market manipulation, money laundering, violations of the U.S. Consumer Credit Act, and U.S. residential mortgage-backed security mis-selling. Figure 2 plots the provisions categorized by different misconduct issues for our sample of 23 U.K. banks over the period 2009 to 2017. The next section describes how we merge these bank-level data on misconduct provisions, as well as other bank-level information, with administrative loan-level data for the U.K. mortgage market.

3.3 Mortgage Data

We obtain loan-level data from the Product Sales Database (PSD). The PSD is a regulatory database of all *new* regulated mortgages in the U.K., which has been collected on a quarterly basis by the FCA starting from April 2005. These data represent a flow measure of current credit conditions, and so can measure current changes to risk-taking in the mortgage market.

The PSD facilitates a rich analysis of risk-taking in the U.K. mortgage market. For each loan, we have detailed information about the mortgage contract, including the loan-to-value (LTV) ratio, the loan value, the property value, the date the mortgage was made, the mortgage term, the mortgage type (e.g. first-time buyer, home mover, re-mortgagor), and the repayment type (e.g. fixed interest rate, variable interest rate). We also have information about the borrower associated with each loan, including: age, employment status, income, whether the borrower has an impaired repayment history, and the postcode of the home address of the mortgagor. Finally, we have information about the lender for each loan, which enables us to merge the PSD with our bank-level data.

The loan-level variables allow us to control for, among others, changes in demand for mortgages from risky borrowers.[4] This is an advantage of our loan-level analysis, as an analysis of lending standards at the portfolio level may fail to detect offsetting shifts in loan-level and borrower characteristics.

The PSD is collected from banks at the individual entity level rather than the bank group level. We therefore consolidate these data so that they correspond to our misconduct provisions and bank-level data, which are at the bank group level. We do so by classifying the mortgages of each constituent entity to its relevant parent banking group. For example, for the Royal Bank of Scotland Banking Group we consider its mortgages as those made by seven bank entities (The Royal Bank of Scotland Plc, National Westminster Bank Plc, National Westminster Home Loans, Ulster Bank Ltd, Coutts & Company, Adam & Company Plc).

3.4 Summary Statistics

Table 1 presents summary statistics for the variables used in our analysis; these variables are further discussed in Sections 4 and 5.1. Most summary statistics are computed at the loan-level, but we compute the summary statistics for the bank-level variables on the bank panel only and un-weighted by the amount of loans in each period. Although the total possible number of bank-half year observations is 368, we report summary statistics for the 303 bank-half year units that are ultimately employed for our empirical specification. Of the 65 bank-half year clusters that are missing from our analysis, 43 clusters are excluded due to missing bank-level information. In these cases, the bank-level information is missing due to either no publicly available half-yearly reports, or key variables in our empirical specification that are not reported within a given half-yearly report. A further 12 clusters are excluded due to missing loan-level information. And the final 10 clusters are excluded due to missing both bank-level and loan-level information.

[4]Ioannidou et al. (2015) follow the same approach and use borrower characteristics to control for changes in loan demand of risky borrowers in their study of monetary policy and risk-taking.

Table 1: **Summary Statistics**

For all variables included in our empirical analyses, this table provides their mean, standard deviation, 5th percentile, median, and 95th percentile. The number of mortgage observations is 6,775,719. The number of bank-half year observations is 303.

Variable Name	Unit	Mean	Std. dev.	5th %tile	50th %tile	95th %tile
Bank-level Variables						
Misconduct provisions	%	0.0750	0.189	0.000	0.0114	0.352
△ Capital Ratio	%	0.447	1.619	-1.913	0.291	2.916
Capital Ratio	%	13.950	4.265	9.100	13.202	23.470
Liquidity Ratio	%	6.593	3.649	1.220	6.009	13.021
NPL Ratio	%	3.173	3.244	0.327	2.198	10.314
ROA	%	0.219	0.345	-0.375	0.226	0.764
Ln(Total Assets)	£bn	11.219	2.032	8.247	10.661	14.292
Loan Ratio	%	64.939	19.020	29.719	69.476	86.193
Governance	%	23.452	23.999	0.000	17.424	70.000
Loan-level and Borrower Variables						
Loan-to-value Ratio	%	64.356	47.725	20.426	70.107	90.217
Mortgage Rate Type:						
Fixed	0/1	0.794	0.405	0	1	1
Discount	0/1	0.0325	0.177	0	0	0
Tracker	0/1	0.136	0.343	0	0	1
Capped	0/1	0.00178	0.0422	0	0	0
Standard Variable Rate	0/1	0.0299	0.170	0	0	0
Other Mortgage Rate Type	0/1	0.00553	0.0741	0	0	0
Repayment Type:						
Capital and Interest	0/1	0.910	0.287	0	1	1
Interest Only (Endowment)	0/1	0.00347	0.0588	0	0	0
Interest Only (Pension)	0/1	0.00934	0.0962	0	0	0
Interest Only (Other)	0/1	0.0188	0.136	0	0	0
Mix of Capital and Interest Only	0/1	0.000908	0.0301	0	0	0
Unknown	0/1	0.00224	0.0472	0	0	0
Other	0/1	0.0452	0.208	0	0	0
Interest Only	0/1	0.0103	0.101	0	0	0
Maturity	Years	22.763	9.066	9	24	35
Borrower Type:						
Business	0/1	0.000666	0.0258	0	0	0
First-time Buyer	0/1	0.275	0.446	0	0	1
Home Mover	0/1	0.356	0.479	0	0	1
Re-mortgagor	0/1	0.346	0.476	0	0	1
Social Tenant	0/1	0.00818	0.0901	0	0	0
Unknown	0/1	0.000500	0.0224	0	0	0
Other	0/1	0.0136	0.116	0	0	0
Impaired	0/1	0.00282	0.0530	0	0	0
Income Verified	0/1	0.859	0.348	0	1	1
Employment Status:						
Employed	0/1	0.870	0.337	0	1	1
Self-employed	0/1	0.0160	0.125	0	0	0
Retired	0/1	0.0114	0.106	0	0	0
Other Employment	0/1	0.103	0.304	0	0	1
Age	Years	38.778	10.190	24	38	56

4 Misconduct Provisions and Bank Capital

This section outlines our strategy to identify the causal effect of a change in bank capital on risk-taking. Bank capital and risk-taking may form an endogenous relationship for several reasons. First, these factors are jointly determined because a change in asset risk will typically have a direct impact on the required risk-weighted assets, which is the denominator of the CET1 ratio. Second, there is potential measurement error in the CET1 ratio primarily due to risk-weighted assets. And third, reverse causality is another concern, as described in the introduction. We therefore propose misconduct provisions as an instrument for changes to bank capital. We evaluate the merits of our instrument below.

4.1 Do Misconduct Provisions affect Bank Capital?

For misconduct provisions to qualify as a valid instrument for bank capital, they need to have a strong impact on bank capital. That is, we require the instrument to be very significant in our first-stage analysis. There are reasons to anticipate either a positive or a negative association between misconduct provisions and bank capital. On the one hand, we might expect a negative association because misconduct provisions have been substantial in size (see, e.g., Figure 1) and they affect the numerator of the bank capital ratio by way of an accounting identity. Namely, misconduct provisions reduce retained earnings, which would otherwise contribute to Common Equity Tier 1 (CET1) capital, and therefore reduce potential capital contributions. On the other hand, there is evidence that banks mis-report their risk levels following a decline in equity capital (Begley et al., 2017). This mis-reporting could be considered as a type of misconduct, and suggests that we could also expect to uncover a positive relationship between misconduct provisions and bank capital shocks.

Whether misconduct provisions have a positive or negative association with bank capital shocks is an empirical question, which does not affect our identification strategy. For our instrument to be valid, we simply require that the relationship is very significant irrespective of its sign. Similarly, it also does not matter for our identification strategy if the relationship in the first-stage regression, between a change of capital and misconduct provisions, is itself endogenous.

Specification

To consider the relationship between misconduct provisions and bank capital, we estimate the following first-stage model:

$$\begin{aligned} \triangle\text{Capital Ratio}_{j,t} = \quad & \alpha_0 + \alpha_1 \text{Misconduct Provisions}_{j,t} + \boldsymbol{\alpha_2}\textbf{Bank}_{j,t-1} \\ & + \boldsymbol{\alpha_3}\textbf{Loan}_{i,j,t} + \gamma_j + \lambda_r + \theta_t + \theta_t\eta_j + u_{i,j,t}, \end{aligned} \tag{1}$$

where i indexes a mortgage, j indexes a bank and t is the period. We observe banks over time and so the bank-level variables have a panel structure indexed by j and t. In each period, there are multiple mortgages made by each bank to new borrowers i, and so their mortgage-level information has a pooled cross-sectional data structure and is indexed by i, j and t. We cluster the standard errors at the bank-half year level to control for the correlation that exists between mortgages made by the same bank within each time period, and we find that our results are robust when we cluster at the bank-level or time-level.

Capital Ratio is the ratio of CET1 capital to risk-weighted assets, and ΔCapital Ratio$_t$ is the difference between Capital Ratio$_t$ and Capital Ratio$_{t-1}$. Misconduct Provisions, our instrument for $\triangle$ Capital Ratio, is the ratio of a bank's misconduct provisions to their total assets.

Bank and **Loan** are vectors containing the control variables for the second-stage risk-taking model. We include all control variables in the first-stage model that subsequently enter the second-stage model because failure to do so would lead to inconsistent two-stage estimates. As such, these control variables control for risk-taking in the U.K. mortgage market. In particular, they include loan-level control variables that are relevant for the second-stage model, despite the fact that $\triangle$Capital Ratio and Misconduct Provisions are both bank-level variables. As an aside, our results are robust to a bank-level version of Equation 1 that excludes any loan-level variables and is conducted for the bank-level panel only.

Bank is a vector of bank characteristics that includes: the CET1 capital ratio, liquidity ratio, non-performing loans (NPL) ratio, return on assets (ROA)[5], log of assets, customer loans to assets ratio, and a governance measure. The CET1 capital ratio, liquidity ratio, NPL ratio and ROA are included to control for the financial health of the bank. The log of assets controls for too-big-to-fail factors that may affect risk-taking incentives.

[5] ROA is calculated as the ratio of net profits (before tax and misconduct provisions) to total assets. We consider net profits before tax and misconduct provisions, because net profits after misconduct provisions are strongly collinear with misconduct provisions. For some banks, the negative correlation between misconduct provisions and net profits after misconduct provisions is more than 80 per cent. We note that our results are robust when we include ROA calculated as the ratio of net profits before tax to total assets.

The loan ratio controls for differences in a bank's business model, which may affect their risk appetite and risk-management approach. The governance measure relates to board quality and is defined by Nguyen et al., 2016 as the proportion of board members appointed before the CEO takes office; this measure is included following a body of literature that demonstrates a relationship between governance and risk-taking in banks (see, e.g., Diamond and Rajan, 2009; Aebi et al., 2012; Beltratti and Stulz, 2012; Ellul and Yerramilli, 2013; Minton et al., 2014). Unlike the other variables in this specification, our bank control variables are predetermined and considered at period $t-1$. Specifically, balance sheet information is taken at the end of the previous half-year $(t-1)$ and bank performance information over the previous half-year.

Loan is a vector of loan-level and borrower characteristics that includes: the length of the mortgage term, a set of fixed effects for the repayment type (for example, if the loan is "capital and interest"), a set of fixed effects for the rate type (for example if the loan has a fixed rate), the borrower's age, a set of fixed effects for the borrower type (for example, if the borrower is a first-time borrower), a dummy variable that takes on the value one if the borrower does not have a standard credit history and zero otherwise, a dummy variable that takes on the value one if the borrower's income has been verified and zero otherwise, and a set of fixed effects for employment status. These variables allow us to control for, among others, observed changes in demand for mortgages from risky borrowers.

We also include in our specification: bank fixed effects, γ_j; regional fixed effects, λ_r; half-yearly time fixed effects, θ_t; and an interaction term with the half-yearly time fixed effects to control for differences in several banks' reporting periods, $\theta_t\eta_j$, where η_j is a bank-level dummy variable that takes the value one if a bank reports end-March and end-September, and zero otherwise.

Results

Column (1) of Table 2 reports the first-stage results from Equation 1. These results suggest that Misconduct Provisions have a negative impact on △Capital Ratio. In particular, a one standard deviation increase in Misconduct Provisions, which is equivalent to a 0.189 percentage point increase in Misconduct Provisions, is on average associated with a 0.406 percentage point decrease in △Capital Ratio, holding all else equal. The coefficient estimate of Misconduct Provisions is statistically significant at the 1 per cent level. The F-statistic for Misconduct Provisions as an instrument is 20.91, which is greater than 10 and suggests Misconduct Provisions is a strong instrument according to the "rule of thumb" described by Staiger and Stock (1997). Moreover, as we will show in Section 5, the Anderson-Rubin Wald statistic and the Stock-Wright S statistic provide strong

Table 2: **Misconduct Provisions as an Instrument for Bank Capital**

The table presents coefficient estimates for Equation 1, the first-stage regression of the change in the CET1 ratio (△Capital Ratio) on misconduct provisions scaled by total assets (Misconduct Provisions) and the relevant control variables. Column (1) presents the baseline results, with Misconduct Provisions as an instrument. Column (2) presents estimates from a specification that includes the square of Misconduct Provisions as an additional instrumental variable. Column (3) presents estimates from a specification that employs PPI provisions (scaled by total assets) as an alternative instrumental variable. Standard errors are heteroskedasticity-robust and clustered by bank-half year groups, and the standard errors of the coefficient estimates are in parentheses. ***, **, and * indicate statistical significance at the 1 per cent, 5 per cent and 10 per cent confidence level, respectively.

	(1)	(2)	(3)
Instrumental Variables			
Misconduct Provisions_t	-2.148***	-2.246**	
	(0.470)	(1.057)	
Misconduct Provisions^2_t		0.089	
		(0.640)	
PPI Provisions_t			-2.798***
			(0.592)
Bank Characteristics			
Capital Ratio_{t-1}	-0.230***	-0.230***	-0.237***
	(0.0738)	(0.0739)	(0.0732)
Liquidity Ratio_{t-1}	0.0684	0.0679	0.0682
	(0.0524)	(0.0533)	(0.0527)
NPL Ratio_{t-1}	-0.0836	-0.0835	-0.0910
	(0.0702)	(0.0703)	(0.0699)
ROA_{t-1}	-0.692	-0.689	-0.802
	(0.564)	(0.562)	(0.560)
Ln(Total $\text{Assets})_{t-1}$	0.380	0.372	0.665
	(0.753)	(0.763)	(0.767)
Loan Ratio_{t-1}	0.0150	0.0146	0.0235
	(0.0343)	(0.0343)	(0.0345)
Governance_{t-1}	0.01680***	0.0168***	0.0169***
	(0.00433)	(0.00433)	0.00433
Other Control Variables			
Loan and borrower characteristics	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes
Model Statistics			
Number of clusters	303	303	303
Number of observations	6,775,719	6,775,719	6,775,719
F-statistic for instrument	20.91***	17.33***	22.33***

support for this specification. We also note that our results are robust when we exclude bank fixed effects or the bank-level variables from the main specification.

Column (2) of Table 2 reports the results from a similar specification to that presented in Column (1), which includes the square of Misconduct Provisions as a second instrument to reflect any potential non-linearity in the relationship between Misconduct Provisions and $\triangle$Capital Ratio. The coefficient estimate of the additional instrument is not significant, although the F-statistic for both instruments is significant at 17.33. We therefore do not use the square of Misconduct Provisions as a second instrument in our main analysis, but we do use this specification in Section 4.2 to test the overidentifying restrictions.

Column (3) of Table 2 reports the results from a specification that employs PPI Provisions (scaled by assets) as an instrumental variable instead of Misconduct Provisions. The coefficient estimate of PPI Provisions is statistically significant at the 1 per cent level, and the F-statistic for the instrument is 22.33. PPI Provisions is therefore another potential instrument due to its strong impact on $\triangle$Capital Ratio. And we use PPI Provisions as an instrument in our robustness checks.

In sum, these results demonstrate there is a strong and negative association between bank capital shocks and misconduct provisions. These results suggest that misconduct provisions (scaled by assets) is a suitable instrument for bank capital shocks from a "strong first-stage" perspective.

4.2 Do Misconduct Provisions meet the Exclusion Restriction?

For misconduct provisions to be a valid instrument for bank capital, we also require these provisions to be uncorrelated with the error term of our second-stage model (the main risk-taking equation), conditional on the other covariates. There are several issues to consider in order to determine whether misconduct provisions satisfy this condition, and we consider these below.

The Drivers of Misconduct Provisions

The first issue we examine relates to omitted variables. Our instrument will not be valid if one of the determinants of misconduct provisions is also an omitted variable in our main risk-taking equation, thereby implying that misconduct provisions are correlated with the error term of the risk-taking equation. We therefore review the banking literature to determine the potential drivers of misconduct provisions, and how these relate to asset risk-taking.

The two main drivers of misconduct provisions are *past* misconduct and getting caught for that past misconduct. What, then, are the drivers of (past) misconduct? One important factor is bank governance: better governance prevents bank misconduct (Nguyen et al., 2016). There is also evidence that a relationship between governance and bank risk-taking exists, although the findings are mixed and nuanced (see, e.g., Diamond and Rajan, 2009; Aebi et al., 2012; Beltratti and Stulz, 2012; Ellul and Yerramilli, 2013; Minton et al., 2014). Bank performance and balance-sheet strength are also likely to influence bank misconduct. A weak bank may be more likely to commit wrongdoing, or increase asset risk, in order to inflate earnings (Nguyen et al., 2016). Additionally, a bank's business model and risk culture are factors we expect to drive both a bank's willingness to engage in misconduct, as well as its asset risk-taking appetite.

In estimating a relationship between capital shocks and risk-taking, therefore, controls are included for factors that influence risk-taking, but that also capture the aforementioned drivers of misconduct. Specifically, the vector **Bank** includes variables that capture governance, bank performance and balance sheet strength. We also include bank fixed effects to capture unobserved bank-specific characteristics such as a bank's business model and risk culture; these two factors are very likely to influence both risk taking and misconduct, but they are also very stable over time (see, for example, Fahlenbrach et al., 2012; Ellul and Yerramilli, 2013) and so can be captured by bank fixed effects.

We have so far focused on the drivers of misconduct, but we also need to understand the drivers of getting caught and thus having to make provisions for misconduct fines and customer redress payments. Here the institutional setting is important. The provisions in our sample have been the result of system-wide investigations, as outlined in Section 3. It is possible that the regulator is yet to detect some forgone misconduct in the banking sector. But for the specific cases of past misconduct considered so far, the regulator has investigated all banks and applied new policies and rules affecting the entire sector that have led to misconduct provisions. The time fixed effects in our specification should absorb the banking sector-wide regulator factors that lead to new waves of misconduct provisions.

Overall, we uncover many common factors that explain both misconduct provisions and asset risk-taking, and our main risk-taking analysis controls for these factors.

The Timing of Misconduct Provisions

Having controlled for the observed and time-invariant unobserved factors that influence risk-taking and also misconduct provisions in our main risk-taking analysis, we have diminished the risk that misconduct provisions are correlated with the error term of our risk-taking equation. Misconduct provisions therefore appears to be a plausible instrument. But what if there remains an unobserved *time-varying* omitted variable that affects both risk-taking and bank misconduct?

A key advantage of our study is that we use misconduct *provisions* as an instrument, rather than misconduct itself. We therefore make use of the time difference between the two events: "bank misconduct taking place" and subsequent "misconduct provisions being made". The time difference implies that a shock to some omitted misconduct determinant in period t would affect risk-taking in t and misconduct in t, but would only lead to misconduct provisions in some subsequent period $t+n$, where n is often at least several periods and varies randomly from case-to-case. This means that there is no direct correlation between misconduct *provisions* in t and risk-taking in t, given that our bank fixed effects will absorb any time-invariant common factors.

The often long lag between the two events "misconduct taking place" and "misconduct provisions being made" is well illustrated by the type of misconduct provisions made by U.K. banks since 2010. To best see this, we focus our attention on Payment Protection Insurance (PPI) claims, which account for around half of all misconduct provisions included in our sample.[6] Provisions for PPI claims occur because a bank previously mis-sold this product. Of course, a bank that mis-sells greater amounts of PPI may be more likely to also take on risks in other ways due to its risk culture, or other factors we have controlled for. Any time-invariant omitted variable will be captured by our bank fixed effects. But to the extent there is another unconsidered time-varying omitted variable, it is important to emphasize that provisions for PPI claims do not relate to a bank's current or recent activities but rather to claims for policies mis-sold often ten years (or more) prior; the peak of PPI sales occurred in the early 2000s with two thirds of these sales being made before 2005 (Parliamentary Commission on Banking Standards, 2013). And the most frequently mis-sold PPI product was banned in 2009, which is prior to the start of our sample when related provisions were made. Moreover, people claimed mis-sold PPI randomly, meaning that provisions made in 2013 could reflect misconduct in, for example, 1999 and 2004. If one believes that there are additional omitted time-varying variables affecting bank misconduct and risk-taking, it is unlikely that a bank's misconduct many years prior could be related to their asset risk-taking in 2010 and beyond.

We provide some corroborating evidence for the timing arguments above. The risk to our identification strategy is that a shock to some omitted misconduct determinant in period t, which affects misconduct in t and risk-taking in t, could be serially correlated and persistent in a way that our bank fixed effects do not control for. We therefore consider whether misconduct provisions relate to past measures of risk-taking, conditional on the relevant covariates. We regress lagged values of the LTV ratio on misconduct provisions as well as lagged values for the loan-level controls and bank-level controls as follows:

$$\begin{aligned} \text{Risk}_{i,j,t-n} = \;& \delta_0 + \delta_1 \text{Misconduct Provisions}_{j,t} + \boldsymbol{\delta_2} \mathbf{Bank}_{j,t-n-1} \\ & + \boldsymbol{\delta_3} \mathbf{Loan}_{i,j,t-n} + \gamma_j + \lambda_r + \theta_{t-n} + \theta_{t-n}\eta_j + \upsilon_{i,j,t-n} \end{aligned} \tag{2}$$

where i indexes a mortgage, j indexes a bank and t is the period. The variables included

[6] PPI claims are customer redress payments, not financial penalties. But customer redress payments are similar to financial penalties; they occur because a bank has previously mis-sold a specific product and must therefore provide customer compensation such that the customer is in the same financial position as if they had not bought the product.

Table 3: **Do Misconduct Provisions meet the Exclusion Restriction?**

The table presents coefficient estimates for Equation 2, the regression of the lagged values of the LTV ratio (Risk) on misconduct provisions scaled by total assets (Misconduct Provisions) and other equivalently (to the LTV ratio) lagged control variables. Columns (1), (2), (3), (4) and (5) consider a two period (one year), four period (two year), six period (three year), eight period (four year) and 10 period (five year) lag, respectively, for the LTV ratio and respective control variables. The standard errors of the coefficient estimates are in parentheses. ***, **, and * indicate statistical significance at the 1 per cent, 5 per cent and 10 per cent confidence level, respectively.

	(1)	(2)	(3)	(4)	(5)
	LTV_{t-2}	LTV_{t-4}	LTV_{t-6}	LTV_{t-8}	LTV_{t-10}
Main Explanatory Variable					
Misconduct Provisions_t	-0.0224	-1.563	-0.625	0.396	0.174
	(0.982)	(1.101)	(0.914)	(1.247)	(0.784)
Bank Characteristics					
Capital Ratio_{t-n-1}	-0.284***	-0.314***	-0.116	0.0178	0.0247
	(0.0839)	(0.115)	(0.150)	(0.0986)	(0.190)
Liquidity Ratio_{t-n-1}	0.341***	0.324***	0.243**	0.108	-0.00141
	(0.0809)	(0.0824)	(0.0947)	(0.0994)	(0.0926)
NPL Ratio_{t-n-1}	0.222*	0.205	0.0341	0.0839	-0.385
	(0.131)	(0.136)	(0.143)	(0.198)	(0.232)
ROA_{t-n-1}	0.800	1.536*	1.141	1.496	0.172
	(0.681)	(0.778)	(0.854)	(1.220)	(1.265)
Ln(Total $\text{Assets})_{t-n-1}$	0.548	1.509	1.659	4.535*	5.039***
	(1.442)	(1.409)	(1.389)	(1.838)	(1.830)
Loan Ratio_{t-n-1}	-0.0206	0.00419	0.125*	0.209**	0.159*
	(0.0638)	(0.0690)	(0.0668)	(0.0735)	(0.0899)
$\text{Governance}_{t-n-1}$	-0.00498	0.00470	0.000777	-0.0104	0.00461
	(0.00747)	(0.00713)	(0.00865)	(0.0105)	(0.00942)
Control Variables					
Loan and borrower characteristics	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes
Model Statistics					
Number of clusters	279	238	199	158	118
Number of observations	6,205,816	5,311,201	4,520,793	3,613,078	2,754,393
R-square	0.405	0.406	0.407	0.406	0.400

in Equation 2 are outlined in Section 2 and Section 5. We consider up to $n = 10$ lags, which is equivalent to a five year lag. Table 3 presents the corresponding results. We do not find that misconduct provisions are significantly associated with previous bank risk-taking, where several different lags of risk-taking are considered. These results are highly suggestive that there is no omitted variable in our main risk-taking analysis that somehow relates to misconduct provisions.

Misconduct Provisions and Reputational Effects

An argument could be that detected misconduct leads to reputational effects that encourage a bank to change their business model and culture. In this scenario, misconduct provisions could affect risk-taking via reputational effects, in addition to their impact via bank capital. But there is little empirical evidence to support this claim. Köster and Pelster (2017) find that misconduct penalties do not affect the stock performance of European banks, where stock performance is an indicator of potential reputation costs. One explanation for their findings, which is relevant to our own data and identification strategy, is that any potential change to a bank's culture caused by reputational costs is likely to be a one-off level effect occurring after a bank's first significant misconduct case. But most banks in our sample have made misconduct provisions in every period over the last eight years; these misconduct provisions do not represent just a few one-off shocks, thereby suggesting that our instrument will affect risk-taking only via the bank capital channel.

Standard Test of Overidentifying Restrictions

Finally, we apply a standard test of overidentifying restrictions to our instrument. We apply the Sargan-Hansen test to the specification presented in Column (2) of Table 2, in which the number of instruments exceeds the number of endogenous variables in this specification. The null hypothesis of the Sargan-Hansen test is that the over-identifying restrictions are valid, which implies that the instruments satisfy the exclusion restriction and are uncorrelated with the error process of the second-stage model. We find that we cannot reject the null hypothesis (p-value = 0.9066), which provides additional support for the exclusion restriction assumption.

5 Bank Capital and Risk-taking

The previous section presented a range of evidence to confirm that provisions for misconduct costs represent a valid instrument for bank capital. This section examines whether bank capital shocks affect risk-taking in a reduced-form sense, as well as in an instrumental variable sense.

5.1 The Reduced-form Impact of Misconduct Provisions on Risk-taking

We first consider the reduced-form relationship between misconduct provisions and risk-taking, which is obtained via an ordinary least squares regression of our main dependent variable of interest, Risk, on our instrument Misconduct Provisions and the other covariates. The reduced-form specification is an important auxiliary equation in the context of 2SLS for several reasons. In particular, a combination of the first-stage and reduced-form estimates can provide useful insights to motivate a causal story for our instrumental variable estimates (Angrist and Krueger, 2001). In the context of this study, our first-stage estimates show that misconduct provisions reduce the CET1 ratio. If, in addition, a reduced-form relationship between misconduct provisions and risk-taking exists, then we can expect shocks to the CET1 ratio to affect risk-taking.

We estimate the following reduced-form specification:

$$\begin{aligned} \text{Risk}_{i,j,t} = \quad & \delta_0 + \delta_1 \text{Misconduct Provisions}_{j,t} + \boldsymbol{\delta_2} \textbf{Bank}_{j,t-1} \\ & + \boldsymbol{\delta_3} \textbf{Loan}_{i,j,t} + \gamma_j + \lambda_r + \theta_t + \theta_t \eta_j + v_{i,j,t} \end{aligned} \tag{3}$$

where i indexes a mortgage, j indexes a bank and t is the period. The independent variables included in Equation 3 are outlined in Section 4.1, and our risk-taking measure is discussed below.

Risk is our dependent variable, which is represented by the loan-to-value (LTV) ratio of each loan. The LTV ratio embodies the most important measure of bank risk-taking in the U.K. mortgage market for several reasons. First, it is an important gauge of credit risk; a higher LTV ratio is associated with a higher probability of negative home equity and mortgage default (Campbell and Cocco, 2015). Second, it provides a model-free measure that is directly observable, in contrast to other measures of risk that require estimation (Geanakoplos and Pedersen, 2012).[7] Third, it provides a timely measure of risk, which is observable at the time of loan origination. That is, the LTV ratio is a *flow* measure that informs us about *current* credit conditions and *current changes* to risk-taking (Geanakoplos and Pedersen, 2012). By contrast, other bank-level measures of risk-taking, including Z-scores, the non-performing loans ratio and risk-weighted asset indices, are stock measures that inform us about potential bank vulnerability largely due to *previous* risk-taking. Finally, U.K. banks offer quoted interest rates for mortgages that are largely based on LTV buckets.[8] The quoted rate for a given LTV bucket has a large impact on market share, and thus banks actively target LTV ratios to achieve the desired new mortgage lending flows.

The "reduced-form effect" of our instrument represented by δ_1 in Equation 3 can be interpreted as the impact of a direct shock to bank capital, brought about by misconduct

[7] For example, a net present value measure requires an estimate of the probability of default. Aside from the fact that we do not have default information in our data, this estimate can be inaccurate due to the reliance on *ex ante* data. Accurate *ex post* information about default is not available at the time of origination, and moreover, this information pertains to credit *events* rather than credit *risk*.

[8] See Best et al. (2015) for more information about the mortgage schedules based on LTV buckets.

Table 4: **The Reduced-form Impact of Misconduct Provisions on Risk-taking**
The table presents coefficient estimates for Equation 3, the reduced-form regression of the LTV ratio (Risk) on misconduct provisions scaled by total assets (Misconduct Provisions) and the relevant control variables. Column (1) presents the baseline results. Column (2) presents estimates from a specification that includes PPI provisions (scaled by total assets) as an alternative to the Misconduct Provisions variable. Standard errors are heteroskedasticity-robust and clustered by bank-half year groups, and the standard errors of the coefficient estimates are in parentheses. ***, **, and * indicate statistical significance at the 1 per cent, 5 per cent and 10 per cent confidence level, respectively.

	(1)	(2)
Main Explanatory Variable		
Misconduct Provisions$_t$	2.185**	
	(0.960)	
PPI Provisions$_t$		2.536**
		(1.251)
Bank Characteristics		
Capital Ratio$_{t-1}$	-0.1450	-0.142*
	(0.162)	(0.0787)
Liquidity Ratio$_{t-1}$	0.314***	0.314***
	(0.0785)	(0.0815)
NPL Ratio$_{t-1}$	0.265	0.272**
	(0.225)	(0.121)
ROA$_{t-1}$	0.590	0.706
	(1.146)	(0.767)
Ln(Total Assets)$_{t-1}$	0.499	0.200
	(2.232)	(1.370)
Loan Ratio$_{t-1}$	0.0344	0.0256
	0.0840	(0.0578)
Governance$_{t-1}$	-0.0174	-0.0174**
	(0.0177)	(0.00731)
Other Control Variables		
Loan and borrower characteristics	Yes	Yes
Bank fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Region fixed effects	Yes	Yes
Model Statistics		
Number of clusters	303	303
Number of observations	6,775,719	6,775,719
R-squared	0.410	0.410

provisions, on risk-taking. Thus, the reduced-form estimates are interesting in their own right and can provide us with a "natural experiment" set-up to consider the impact of a shock to bank capital on risk-taking.

Column (1) of Table 4 presents the results of estimating Equation 3. The estimate of δ_1 suggests that a 1 percentage point increase in Misconduct Provisions, the misconduct provisions to assets ratio, will lead to a 2.185 percentage point increase in the LTV ratio. And this result is significant at the 5 per cent level. Column (2) of Table 4 reports the results from a specification that employs PPI provisions scaled by assets instead of Misconduct Provisions. The main result is robust to this alternative specification. Additionally, the results are robust when we exclude bank fixed effects or the bank-level variables from the main reduced-form specification. Overall, these findings suggest that misconduct provisions, due to their impact on bank capital, bring about an increase in risk-taking in the U.K. mortgage market.

In sum, our results demonstrate a strong and negative relationship between misconduct provisions and bank capital shocks, as well as a positive relationship between misconduct provisions and risk-taking. The combination of these results suggest that misconduct provisions bring about a negative shock to bank capital, which in turn causes a shift in lending to riskier borrowers by banks. And we examine this instrumental variable channel below.

5.2 The Impact of Bank Capital on Risk-taking

We now investigate whether bank capital shocks, triggered by misconduct provisions, *cause* a change in bank risk-taking. To do this, we estimate the following two-stage panel data model:

$$\begin{aligned} \triangle\text{Capital Ratio}_{j,t} = \; & \alpha_0 + \alpha_1 \text{Misconduct Provisions}_{j,t} + \boldsymbol{\alpha_2}\mathbf{Bank}_{j,t-1} \\ & + \boldsymbol{\alpha_3}\mathbf{Loan}_{i,j,t} + \gamma_j + \lambda_r + \theta_t + \theta_t\eta_j + u_{i,j,t}, \end{aligned} \tag{4}$$

$$\begin{aligned} \text{Risk}_{i,j,t} = \; & \beta_0 + \beta_1 \widehat{\triangle\text{Capital Ratio}}_{j,t} + \boldsymbol{\beta_2}\mathbf{Bank}_{j,t-1} \\ & + \boldsymbol{\beta_3}\mathbf{Loan}_{i,j,t} + \gamma_j + \lambda_r + \theta_t + \theta_t\eta_j + e_{i,j,t} \end{aligned} \tag{5}$$

The variables included in Equations 4 and 5 are defined in Sections 4 and 5.1. The change in the capital ratio, ΔCapital Ratio, is our key explanatory variable of interest in Equation 5; the corresponding coefficient estimate (β_1) will indicate the impact of a change in bank capital on risk-taking and so directly tests our core hypotheses. Hypothesis **H1A** implies $\beta_1 < 0$. That is, that a negative shock to the bank capital ratio will lead to an *increase* in a bank's risk-taking. Hypothesis **H1B** implies $\beta_1 > 0$. That is, that a negative shock to the bank capital ratio will lead to a *decrease* in a bank's risk-taking.

Equation 5 estimated by itself represents the "naïve OLS specification" that does not account for the endogenous relationship between changes in risk-taking and bank capital. Prior to a discussion of our main results, Column (1) of Table 5 presents the results from the naïve OLS specification. Here we estimate Equation 5, where we employ the variable ΔCapital Ratio rather than the instrumented version of ΔCapital Ratio. The coefficient estimate of ΔCapital Ratio β_1 for the naïve specification is not statistically different from zero. These results suggest there is no relationship between changes to bank capital and our measure of risk-taking.

Due to the inherent endogeneity between changes to bank capital and risk-taking, the results from the OLS specification are likely to be biased and inconsistent and should be considered with caution. For this reason, we now consider the results from our 2SLS approach that uses misconduct provisions as an instrument for changes to bank capital. By employing instrumental variable techniques, this model links exogenous variation in bank capital to actual variation in risk-taking.

Column (2) of Table 5 presents the results for the second-stage of our 2SLS estimation of Equation 5, where ΔCapital Ratio is instrumented by scaled misconduct provisions. We first consider the impact of a *change* (or shock) to bank capital, the main focus of this study. The coefficient estimate of ΔCapital Ratio is negative, suggesting that a negative capital shock will cause an increase in risk-taking. Specifically, a 1.619 percentage point decrease in the change in the CET1 ratio - which is equivalent to one standard deviation for ΔCapital Ratio - will lead to a 1.647 percentage point increase in the LTV, holding all else constant. This relationship is significant at the 5 per cent level. The second-stage results are also robust when we exclude bank fixed effects or the bank-level variables from the 2SLS estimation. Overall, these results provide support for our first hypothesis, **H1A**, outlined in Section 2 that a negative bank capital shock will cause an increase in a risk-taking. This result supports the theory that a decline in bank capital increases the value of the debt subsidy (or, put another way, reduces a bank's "skin-in-the-game") and therefore increases risk-taking incentives.

We note that the coefficient estimates from our 2SLS results strongly differ in their significance and magnitude to the corresponding biased OLS counterparts. Why? Our 2SLS estimates demonstrate that a negative capital shock causes an increase in risk-taking. But if an increase in risk-taking simultaneously causes an increase in bank capital, as may be the case because increased risk may bring about increased profits that will feed into capital via retained earnings, then the OLS estimates will face a positive bias. This bias will misleadingly offset the true impact of bank capital shocks on risk-taking. The 2SLS results are free of this type of bias, and thus reveal the causal impact of bank capital on risk-taking.

In terms of the economic significance of the results, we observe for the "average" bank in our sample[9] that a negative shock to the CET1 ratio of one standard deviation would cause the average LTV ratio for new loans to increase from around 64 per cent to around 66 per cent. The magnitude of this effect is difficult to interpret. A portfolio with a higher average LTV ratio will be more risky, and experience higher rates of loan non-

[9]The "average" bank is defined as having a mortgage portfolio with the average LTV equal to our sample average.

Table 5: **The Impact of Bank Capital on Risk-taking**

The table presents coefficient estimates for Equation 5, the regression of the LTV ratio (Risk) on the change in the CET1 ratio (△Capital Ratio) and the relevant control variables. Column (1) presents the results estimated by ordinary least squares. Column (2) presents the results estimated by two stage least squares, where △Capital Ratio has been instrumented by misconduct provisions scaled by total assets (Misconduct Provisions). Standard errors are heteroskedasticity-robust and clustered by bank-half year groups, and are presented in parentheses. ***, **, and * indicate statistical significance at the 1 per cent, 5 per cent and 10 per cent confidence level, respectively.

	OLS	2SLS Second-Stage Results
	(1)	(2)
Main Explanatory Variable		
△Capital Ratio$_t$	-0.0197	-1.017**
	(0.116)	(0.435)
Bank Characteristics		
Capital Ratio$_{t-1}$	-0.143*	-0.384***
	(0.0850)	(0.146)
Liquidity Ratio$_{t-1}$	0.317***	0.383***
	(0.0835)	(0.109)
NPL Ratio$_{t-1}$	0.267**	0.180
	(0.123)	0.142
ROA$_{t-1}$	0.718	-0.114
	(0.781)	(1.0653)
Ln(Total Assets)$_{t-1}$	0.135	0.886
	(1.401)	(1.372)
Loan Ratio$_{t-1}$	0.0248	0.0496
	(0.0583)	(0.0684)
Governance$_{t-1}$	-0.0171**	-0.000279
	(0.00791)	(0.0115)
Control Variables		
Loan and borrower characteristics	Yes	Yes
Bank fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Region fixed effects	Yes	Yes
Model Statistics		
Number of clusters	303	303
Number of observations	6,775,719	6,775,719
F-statistic for instrument (first-stage)	n.a.	20.91***
Anderson-Rubin test	n.a.	5.17**
Stock-Wright S statistic	n.a.	10.73***
Centered R2	0.409	0.407

performance. But default rates are relatively low for a given loan with an LTV ratio below 75 per cent. By contrast, Campbell and Cocco (2015) predict that default risk becomes particularly large for loans with an LTV ratio above 90 per cent. As such, in the next section we consider whether this increase in the average LTV ratio of new loans is driven by increases in the upper tail of the distribution for the LTV ratio.

We also report a number of model statistics in Table 5, which provide support for our results regarding the impact of bank capital on risk-taking. We first consider the Anderson-Rubin test. The Anderson-Rubin test statistic is cluster-robust and is also robust in the presence of weak instruments. The results from the Anderson-Rubin test therefore dominate the first-stage inferences about instrument strength based on the F-statistic that we discussed in Section 4.1. The Anderson-Rubin test examines the joint null hypothesis that both the coefficient estimate of our endogenous variable ΔCapital Ratio in Equation 5 is equal to zero and that our over-identifying restrictions are valid (if there is more than one instrument). We reject the null hypothesis of the Anderson-Rubin test at the 5 per cent level for our results relating to the LTV ratio. We also consider the Stock-Wright S statistic, which is a generalized version of the Anderson-Rubin test with the same null hypothesis, and is similarly a cluster-robust and weak instrument-robust test. Here we can reject the null hypothesis at the 1 per cent level, which provides support for our results about the impact of bank capital on risk-taking reported in Column (2).

We have so far focused on the impact of bank capital on risk-taking in the U.K. mortgage market. Table 5 also reports the coefficient estimates for all other bank-level characteristics. We first consider the level effect of capital. The coefficient estimate of Capital Ratio_{t-1} is negative, suggesting that a bank with a lower level of capital will take relatively more risk. Specifically, a bank with a CET1 ratio that is 4.265 percentage points lower - which is equivalent to one standard deviation for the CET1 ratio - will make loans with an average LTV ratio that is 1.636 higher, holding all else constant. This result is significant at the 1 per cent level, and is consistent with theoretical predictions as well as previous empirical results (see, e.g., Shrieves and Dahl, 1992). In particular, Kim and Santomero (1988) show that utility-maximizing banks with relatively low risk-aversion will choose to hold relatively low capital combined with relatively high asset risk. The observed negative cross-sectional correlation between bank capital and risk could, therefore, be attributed to cross-sectional variation in banks' risk preferences.

The only other significant bank-level coefficient estimate in our baseline specification, reported in Column (2), is for the Liquidity Ratio_{t-1} variable. The coefficient estimate is positive and significant at the 1 per cent level, suggesting that a bank with a higher level of cash and central bank reserves will make relatively more risky loans. This result is consistent with recent empirical findings. In particular, one important driver for banks' central bank reserves holdings - and so the Liquidity Ratio_{t-1} variable - over our sample period is quantitative easing (Kandrac and Schlusche, 2017). Kandrac and Schlusche (2017) show that banks with higher central bank reserves are more likely to take on risk in their loan portfolios, which is consistent with the theoretical predictions relating to the impact of central bank reserves (see, e.g., Bernanke and Reinhart, 2004).

5.3 The Impact of Bank Capital on High-LTV Lending

The preceding section demonstrates that the average LTV ratio of a loan increases when banks face a negative capital shock. In this section, we examine whether a capital shock leads to a shift towards lending to the most risky types of borrowers. To do this, we transform the LTV ratio into several dummy variables according to the following definition: loans with an LTV ratio equal to or greater than 85 per cent (or 80 per cent or 90 per cent) are equal to one and zero otherwise. These thresholds are chosen to represent loans with a significantly higher default risk, and as such, a shift in new lending to these riskier borrowers would represent a meaningful shift in the riskiness of new lending.

Table 6 presents the results for the instrumental variable probit estimation with our transformed LTV ratio dummy variables as the dependent variable. We find that a negative shock to bank capital will bring about an increase in the probability of making a loan with an LTV ratio that is equal or greater than 85 per cent, and this is statistically significant at the 1 per cent level. We also find a corresponding statistically significant average marginal effect: a one standard deviation decrease in ΔCapital Ratio (equivalent to 1.619 percentage points) will lead to about a 4 percentage point increase in the probability of the bank issuing new loans with an LTV ratio equal or greater than 85 per cent.

We also find that the coefficient estimate and marginal effect for the probability of making a loan with an LTV ratio that is equal or greater than 90 per cent is significant at the 10 per cent level. And the coefficient estimate and marginal effect for the probability of making a loan with an LTV ratio that is equal or greater than 80 per cent is significant at the 1 per cent level.[10] Overall, the findings associated with the high LTV ratio thresholds provide further support for our hypothesis **H1A** that a negative bank capital shock will cause an increase in a risk-taking. Specifically, these findings suggest that a negative capital shock will induce further lending to the most risky borrowers.

5.4 Further Robustness

Our findings on the causal impact of a change in bank capital on risk-taking rely upon our instrumental variable approach. We have presented a range of evidence that confirm misconduct provisions are an appropriate instrument for bank capital. In this section, we show that our empirical analysis is robust to a number of alternative modeling strategies. Table 7 presents the results for the second-stage of our 2SLS estimation of Equation 5, where bank capital is instrumented by Misconduct Provisions, for several alternative specifications.

[10]We find no significant result for the probability of making a loan with an LTV ratio that is greater than 95 per cent. But these loans represent less than 2 per cent of the market over our sample period.

Table 6: **The Impact of Bank Capital on High-LTV Lending**

The table presents coefficient estimates and average marginal effects for Equation 5, the second-stage regression of Risk on the change in the CET1 ratio (△Capital Ratio) and the relevant control variables, where △Capital Ratio has been instrumented by misconduct provisions scaled by total assets (Misconduct Provisions). The Risk measures are dummy variables that take the value one (and zero otherwise) when: LTV ≥ 80, LTV ≥ 85 and LTV ≥ 90, which are reported in Columns (1) to (3). The presented results are estimated by an instrumental variable probit model. Standard errors are heteroskedasticity-robust and clustered by bank-half year groups, and are presented in parentheses. ***, **, and * indicate statistical significance at the 1 per cent, 5 per cent and 10 per cent confidence level, respectively.

	(1)	(2)	(3)
	LTV ≥ 80	LTV ≥ 85	LTV ≥ 90
Δ Capital Ratio$_t$			
Coefficient estimate	-0.113***	-0.108***	-0.0478*
	(0.0316)	(0.0302)	(0.0265)
Average marginal effect	-0.0284***	-0.0223***	-0.00648*
	(0.00794)	(0.00627)	(0.00360)
Bank Characteristics			
Capital Ratio$_{t-1}$	-0.0363***	-0.0399***	-0.0204**
	(0.0127)	(0.0119)	(0.00926)
Liquidity Ratio$_{t-1}$	0.0207**	0.0136	-0.000850
	(0.00967)	(0.00850)	(0.00726)
NPL Ratio$_{t-1}$	-0.00222	-0.00687	-0.0188*
	(0.0127)	(0.0118)	(0.00964)
ROA$_{t-1}$	-0.111	-0.0985	-0.0843
	(0.0943)	(0.0896)	(0.0761)
Ln(Total Assets)$_{t-1}$	0.0511	0.00550	0.293***
	(0.112)	(0.108)	(0.108)
Loan Ratio$_{t-1}$	0.0159***	0.0183***	0.0242***
	(0.00563)	(0.00565)	(0.00608)
Governance$_{t-1}$	0.00155*	0.00204**	0.00146*
	(0.000915)	(0.000889)	(0.000764)
Other Control Variables			
Loan and borrower characteristics	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes
Model Statistics			
Number of clusters	303	303	303
Number of observations	6,775,719	6,775,719	6,775,719
Wald statistic	57,159.60***	64,429.21***	9,963.86***

Additional Controls for Loan Demand

One concern with our analysis is that changes in risk-taking are driven by loan demand rather than loan supply. In our main specification, we disentangle these effects by including detailed loan and borrower characteristics to control for the changes in the loan demand of risky borrowers, as done by Ioannidou et al. (2015). Here we consider an additional control for changes to the loan demand of borrowers by including regional-time fixed effects in our specifications, similar to the approach of Uluc and Wieladek (2016). The results from this specification are in Column (1) of Table 7. With our additional regional time fixed effects to control for loan demand, we find that the coefficient estimates for △Capital Ratio and their significance levels for the results in Panel A are similar to our main results in Table 5.

Alternative Instrumental Variable Specifications

In Section 4, we presented the first-stage results in which we included Misconduct Provisions[2] as an additional instrumental variable to cater for potential nonlinearities in the relationship between capital and misconduct provisions. Column (2) presents the second-stage results for this specification. The coefficient estimates for △Capital Ratio and their significance levels are similar to our main results in Table 5 for the LTV ratio.

Section 4 also presented the first-stage results in which the PPI provisions to assets ratio was included as an alternative instrumental variable. PPI provisions are an attractive alternative instrument due to the especially long lag between the associated misconduct event and misconduct provisions, which should diminish the risk that our specification is suffering from any omitted variable bias. Column (3) presents the second-stage results for this specification. The coefficient estimate for △Capital Ratio is similar but slightly smaller than our main results in Table 5 for the LTV ratio. Overall, these results largely confirm our main findings.

Alternative Measures of the Capital Ratio

As a robustness check for our capital ratio measure, the CET1 ratio, we also consider two alternative measures. We consider the (first-differenced) Tier 1 capital ratio as well as a (first-differenced) leverage ratio, and these results are reported in Columns (4) and (5), respectively, of Table 7. The Tier 1 capital ratio is the ratio of CET1 capital combined with Additional Tier 1 (AT1) capital to risk-weighted assets, whereby AT1 capital includes preferred shares and contingent convertible capital instruments. Here we use a measure of the leverage ratio defined as the ratio of CET1 capital to total assets.

It remains the case that a negative change in the bank capital ratio will lead to an increase in risk-taking, as measured by the mortgage lending standards, for our two alternate measures of the capital ratio. Here we find that a one percentage point negative shock to the Tier 1 ratio will lead to a 1.355 percentage point increase in the LTV ratio, *ceterus paribus*. A one percentage point decrease in the leverage ratio will lead to a 3.158 percentage point increase in the LTV ratio, *ceterus paribus*.

Table 7: **Robustness Checks for the Impact of Bank Capital on Risk-taking**

The table presents coefficient estimates for the change in the CET1 ratio (△Capital Ratio) in Equation 5, the second-stage regression of the LTV ratio (Risk) on △Capital Ratio and the relevant control variables, where △Capital Ratio has been instrumented by Misconduct Provisions. The presented results are estimated by two-stage least squares. Five robustness checks are reported. Column (1) presents estimates from a model that includes region-time fixed effects in the specification. Column (2) presents estimates from a model that includes Misconduct Provisions^2 as an additional instrument for △Capital Ratio. Column (3) presents estimates from a model that includes PPI provisions scaled by assets (PPI Provisions) as an alternative instrument for △Capital Ratio. Column (4) presents estimates from a model that employs the Tier 1 capital ratio instead of the CET1 capital ratio. And Column (5) presents estimates from a model that employs a leverage ratio instead of the CET1 capital ratio. Standard errors are heteroskedasticity-robust and clustered by bank-half year groups, and are presented in parentheses. ***, **, and * indicate statistical significance at the 1 per cent, 5 per cent and 10 per cent confidence level, respectively.

	(1)	(2)	(3)	(4)	(5)
Main Explanatory Variable					
△Capital Ratio$_t$	-0.979**	-1.016**	-0.906*	-1.355**	-3.158**
	(0.436)	(0.445)	(0.450)	(0.637)	(1.378)
Bank Characteristics					
Capital Ratio$_{t-1}$	-0.397***	-0.383***	-0.357**	-0.599**	-0.386**
	(0.142)	(0.1479)	(0.149)	(0.305)	(0.180)
Liquidity Ratio$_{t-1}$	0.368***	0.383***	0.376***	0.3713**	0.341***
	(0.101)	(0.109)	(0.103)	(0.156)	(0.127)
NPL Ratio$_{t-1}$	0.240*	0.181	0.190	0.107	0.263*
	(0.143)	(0.142)	(0.143)	(0.215)	(0.142)
ROA$_{t-1}$	-0.376	-0.112	-0.0215	-0.214	0.699
	(1.059)	(1.0672)	(1.083)	(1.370)	(0.997)
Ln(Total Assets)$_{t-1}$	0.888	0.885	0.803	0.668	-0.613
	(1.383)	(1.372)	(1.342)	(3.290)	(2.429)
Loan Ratio$_{t-1}$	0.0526	0.0496	0.0469	-0.0195	-0.0589
	(0.0670	(0.0685)	(0.0669)	(0.117)	(0.102)
Governance$_{t-1}$	0.00203	-0.000304	-0.00215	0.00606	-0.00855
	(0.0113)	(0.0116)	(0.0121)	(0.0153)	(0.00888)
Control Variables					
Loan and borrower characteristics	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes
Region × time fixed effects	Yes	No	No	No	Yes
Model Statistics					
Instrument	Misconduct Provisions	Misconduct Provisions & Misconduct Provisions^2	PPI Provisions	Misconduct Provisions	Misconduct Provisions
Number of clusters	303	303	303	214	216
Number of observations	6,775,719	6,775,719	6,775,719	6,143,307	6,159,565
F-statistic for instrument (first-stage)	21.12***	17.33***	22.33***	14.05***	39.15***
Anderson-Rubin test	4.83**	3.61**	4.11**	5.73**	5.78**
Stock-Wright S statistic	n.a.	17.03***	7.86***	13.22***	13.27***
Centered R2	0.411	0.408	0.408	0.402	0.406

6 Conclusion

This paper examines the impact of a negative shock to bank capital on risk-taking, using a newly constructed U.K. panel dataset that combines hand-collected bank-level information on misconduct provisions and capital with detailed mortgage-level information on lending standards.

The main contribution of this study is our novel approach to determine the causal impact of a negative shock to bank capital on risk-taking. Namely, we use provisions for misconduct costs as an instrument for bank capital. The U.K. offers a useful setting to address this question because U.K. banks were significantly affected by misconduct provisions during the period 2010 to 2017. Our analyses suggest that misconduct provisions are a valid instrument for capital. First, we show that misconduct provisions have a statistically significant and negative relationship with changes in bank capital. Second, we provide a strong case in support of the assumption that misconduct provisions are not correlated with the error term of the main risk-taking equation.

Our core finding is that a negative shock to bank capital leads to an increase in risk-taking in the U.K. mortgage market. In particular, we find that a decrease in bank capital will lead to an increase in the average LTV ratio of new mortgages. We also find that a decrease in capital makes a bank more likely to issue a new mortgage with a high LTV ratio. These results are consistent with theories that a decline in bank capital reduces a bank's skin-in-the-game and therefore increases risk-taking incentives.

These findings have important implications from the perspective of financial stability and optimal capital requirements. First, the fact that a negative capital shock causes banks to engage in riskier mortgage lending means that such shocks expose both the household sector and the banking sector to increased risk. This in turn makes both sectors more vulnerable in the event of future economic adversity. Second, regulators setting capital requirements should also take note of our findings. Indeed, our results suggest that a failure to take into account the risk-taking consequences of changes to bank capital may translate into capital requirements that are set sub-optimally.

There is finally a caveat to our findings worth noting. In particular, we only observe how banks respond to an exogenous shock to capital by altering risk-taking via their *mortgage* lending standards. Our dataset does not include business loans, and so we cannot observe the potential effects of changes in bank capital on lending standards to non-financial firms. Similarly, we do not consider the potential effects on risk-taking in non-retail banking activities. Given that we find in this paper that a negative shock to bank capital leads to an increase in risk-taking, our hypothesis is that the effect of a negative shock to bank capital on these other activities might be even more pronounced. This is because these activities are in general more risky than secured lending to households. Further research could attempt to analyze how capital shocks affect the risk-taking across different banking activities.

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A Appendix

Table 8: **Definitions of Variables used in Empirical Analyses**

Variable Name	Variable Description
Bank-level Variables	
Misconduct Provisions	The ratio of misconduct provisions over total assets
PPI Provisions	The ratio of PPI provisions over total assets
$\triangle$ Capital Ratio	Difference between the Capital Ratio in period t and t-*1*
Capital Ratio	The ratio of Common Equity Tier 1 capital over risk-weighted assets
Liquidity Ratio	The ratio of cash and balances at central banks over total assets
NPL Ratio	The non-performing loans ratio
ROA	The ratio of net profits (before tax and misconduct provisions) over total assets
Ln(Total Assets)	The log of total assets
Loan Ratio	The ratio of gross customer loans over total assets
Governance	Index of board quality defined as the proportion of independent board members appointed before the CEO takes office
Loan-level and Borrower Variables	
Loan-to-value Ratio	Loan-to-value ratio of a mortgage
Mortgage Rate Type	Categories: fixed; discount; capped; standard variable rate; other
Repayment Type	Categories: capital and interest; interest only (endowment); interest only (pension); interest only (other); mix of capital and interest only; unknown; other
Maturity	Remaining years until mortgage maturity
Borrower Type	Categories: business; first-time buyer; home mover; re-mortgagor; social tenant
Impaired	Takes the value 1 if the borrower has any credit history and 0 otherwise
Income Verified	Takes the value 1 if the borrower had their income verified and 0 otherwise
Employment Status:	Categories: employed; self-employed; retired; other
Age	Age of the borrower