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ORIGINAL ARTICLE

Noninterest income, macroprudential policy and bank performance

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Abstract
Macroprudential policies have become crucial tools for maintaining financial stability, but their effect on banks' noninterest income has not yet been examined. This is a paradox in light of results in the literature linking noninterest income to bank performance indicators such as risk and profitability. Using a global sample of 7395 banks over 1990–2022, we find macroprudential policies have a significant positive effect on noninterest income. Similar results are found for disaggregated samples by type of noninterest income, country development, bank size and pre and post the Global Financial Crisis, and in three robustness checks. However, stimulus from macroprudential policies to noninterest income, and especially its non-fee component, is found to adversely affect bank risk. Furthermore, while significant effects of noninterest income on profitability are generally positive, this is not the case for non-fee income. Our findings have important implications for central bankers, regulators and commercial bank management.

Keywords Macroprudential policy · Bank profitability · Noninterest income · Bank risk

JEL Classification E44 · E58 · G21 · G28

Introduction

An important aspect of the evolution of financial systems since the 1970s is a shift of banks' revenue from interest income towards a greater reliance on noninterest income.[1] DeYoung and Roland [1] and Hahm [2], among others, cite a number of factors underlying the long-term shift towards noninterest income. First, there is increased competition in loan markets due to deregulation and the rise of securities markets. Second, banks have experienced liberalisation of access to nontraditional activities such as investment banking and insurance. Third, tighter capital adequacy requirements have limited higher-risk lending. Fourth there has been growth in off-balance-sheet and securitisation activities in response to these factors, as well as technological advances. Finally, there has been greater economic volatility and banking crises affecting returns from loans.

As regards the channels of transmission of these changes, reduced scope to make profitable loans due to securities market competition and capital requirements puts downward pressure on bank profitability causing banks to seek to maintain their profitability via noninterest income generation. Measures of deregulation such as the 1999 Gramm-Leach-Bliley Act in the US enabled banks to enter new sectors such as investment banking and insurance, which gave them greater scope to generate noninterest income. Off-balance sheet activities such as securitisation tend to generate more value in terms of noninterest income than do on-balance sheet assets. Noninterest activities historically tended to require less or no regulatory capital enabling higher leverage [1], although successive Basel agreements have narrowed the scope for such arbitrage. Banks were further encouraged to seek noninterest income by increased economic volatility and banking crises since 1970, given the

[1] Noninterest income is defined as the sum of fee income, net capital gains, dividend income and other income.

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belief among bankers that there are diversification benefits in combining interest and noninterest income generation in banks' activities to reduce risk (as noted in [3]).[2]

There is an extensive literature on the effects of noninterest exposure on bank performance indicators, namely risks and profitability, such as Goddard et al. [4] and Stiroh and Rumble [5]. However, relatively few papers focus on the determinants of noninterest income (exceptions include Hahm [2] and Haubrich and Young [6]). No prior studies examine the effects of macroprudential policy on noninterest income.

This is a paradox for two reasons. First, there is the potential importance of noninterest income in affecting financial stability via its effect on bank risk and profitability, which implies that it is crucial to assess whether there are policy effects on noninterest income. And second is that macroprudential policies typically constrain the balance sheet in terms of risk and return, so any reduction in profitability is likely to be met by pressure to raise noninterest income.

We seek to fill this gap by providing an assessment of factors underlying the level of noninterest income, within which we then test how noninterest income relates to macroprudential policy. To do so, we employ a global sample of 7,395 banks over 1990–2022. This enables us to assess not only the results for a global sample of banks but also separate estimates of the effects on fees and other noninterest income, in advanced and emerging market economies, for large and small banks and for the pre and post the Global Financial Crisis. The results for noninterest income and macroprudential policy are complemented by three robustness checks on the global sample. We also undertake three additional tests. These are to consider scope for interaction of competition and regulation in the context of noninterest income, potential nonlinear responses of noninterest income to macroprudential policy and an investigation of the effects on noninterest income of the "shock" from the introduction of Basel III buffers.

Using our extensive global dataset, we provide complementary estimates of the relation of noninterest income and its components to bank risk and overall profitability. These supplementary estimates complement the existing literature by offering a more extensive and up to date dataset than existing studies, and also by focusing on the differing effects of non-fee and fee income globally and in subsamples. These features of our study enable us to assess how macroprudential policy feeds through to bank risk and profitability via the specific channel of noninterest income.

[2] Stiroh [3] notes belief among bankers that noninterest income may be less dependent on the economic cycle than traditional lending, thus reducing overall profit volatility, or that expanded product lines and cross selling may offer diversification benefits. His empirical analysis in that paper tends to disprove these assertions, however.

Among our key results are a very widespread positive and significant effect of macroprudential policies on noninterest income, including both its fee and non-fee subcomponents. We also find a significant effect of noninterest income, and especially its non-fee component, on bank-level risk as shown by the Z-score. This is in line with prior studies such as Chen et al. [7]. Non-fee income is also negatively related to overall bank profitability. These results in turn suggest that the effect of macroprudential policy on bank stability via noninterest income can be counterproductive, depending on its composition.

The paper is structured as follows. After a literature survey in "Literature" section, we introduce the methodology in "Methodology" and data in "Data" sections. Our main results are shown in "Empirical results" section. "Robustness checks" section presents three robustness checks, while "Bank performance and noninterest income" section probes the potential effect of a boost to bank noninterest income driven by macroprudential policy on bank risk and overall profitability. "Further exploratory results" section shows some further exploratory regressions, and "Conclusion" section concludes the paper.

Literature

Noninterest income and bank profitability

The bulk of work on noninterest income focuses on its link to certain bank performance indicators, notably profitability and risk. In terms of profitability, most papers suggest a positive effect. For example, Goddard et al. [4] found that banks from eight EU banks over 1992–2007 that engaged more in non-traditional lines of business, were more profitable on average, possibly due to benefits from economies of scope.

Saunders et al. [8] also found profitability was raised by noninterest income for US banks over 1984–2013. Saklain and Williams [9] using a global sample found that noninterest income raises profitability, as does a more market-based financial system. Positive effects on profitability are also found Elsas et al. [10] in nine countries over 2006–2008 and Sanya and Wolf [11], using 11 emerging economies in 2000–2007. However, Saona [12] found banks in seven Latin American during 1995–2012 showed a negative relationship between revenue diversification and the net interest margin, a component of profitability.

Noninterest income and bank risk

The balance of work on noninterest income and risk suggest that risk increases with noninterest income. For example, Stiroh and Rumble [5] found that diversification increased

exposure to risk, measured using risk-adjusted earnings and the Z-score for US financial holding companies over 1997–2002. Diversification also impacted the trade-off between risk and return, since noninterest activities are much more volatile and not necessarily more profitable than interest-generating activities. Chen et al. [7] analysing behaviour of US banks over 1992–2010 and found both trading and non-trading noninterest revenue positively and significantly boosted both idiosyncratic and systematic risks.

Brunnermeier et al. (2019) found that US banks with higher noninterest income over 1986–2017 made a higher contribution to systemic risk via its subcomponents: tail risk and interconnectedness risk. Apergis [13] examined a sample of 1725 US banks over 2000–2013 and found that high non-traditional activity, which generates noninterest income, boosts both profitability and risk, measured by the inverse of the Z-score.

Results showing a boost to risk from noninterest income are not confined to the US. Antao and Karnik [14] found income diversification raised risk (measured using the Z-Score) for Asian banks over 1996–2018. Maudos [15] found European banks over 2002–2012 with a more diversified income structures were riskier as measured by the Z-score and income volatility, and had a higher probability of insolvency, notably prior to the 2008 crisis. Kamani [16] found that over 2002–2016, European small banks' exposure to systemic risk rose with noninterest income.

There remain some studies that found income diversification reduced risk. Complementing their results for profitability, Elsas et al. [10] and Sanya and Wolf (2011) found lower risk for diversified banks. Davis et al. [17] found both the ratio of provisions/loans and non-performing loans/total loans were lower when noninterest income is higher, across over 100 national banking sectors.

Other papers suggest that there is a distinction between effects on risk of fee and non-fee income. DeYoung and Torna [18] found fee-based income is associated with a decline in failure probabilities of US banks, although non-fee income increased risk.

Determinants of noninterest income

In contrast to the extensive literature on profitability and risk, there are relatively few studies of the determination of noninterest income. Hahm [2] sampled 662 banks in 29 OECD countries over 1992–2006. Banks with larger balance sheets, lower net interest margins, higher impaired loan ratios, higher returns on assets and higher cost-income ratios tended to have higher levels of noninterest income. At a country level, lower economic growth and inflation and highly-developed stock markets tended to accompany higher noninterest income shares for banks. Higher noninterest income tended to accompany higher profit volatility.

Meng et al. [19] studied data for 88 Chinese banks over 2003–10. They found that risk (the Z-score) as well as higher cost-asset ratios, capital adequacy, bank size and foreign ownership were positively related to the noninterest income to assets ratio. Ammar and Boughrara [20] found that in MENA countries over 1998–2015, overall profitability, liquidity, credit risk, deposits/assets, the cost-asset ratio and GDP growth had a positive effect on income diversification, while capitalisation was negatively related.

Haubrich and Young [6] found that larger banks in the US over 2001–2018 period were more dependent on noninterest income. Before the global financial crisis, there was a positive relation of net interest income to the share of noninterest income, whereas afterwards this relation was negative. The term spread had a positive effect but only before the crisis.

Borio et al. [21] used data on 109 major international banks from 1995–2012 to assess determinants of the ratio of noninterest income to total assets and found a positive effect of asset price growth as well as the bank liquidity ratio, and a negative effect of asset price volatility. Furthermore, the ratio was negatively affected by the short-term interest rate and the yield curve, which the authors attributed to pressure on net interest margins when interest rates are low.

Some recent work has also focused on the determination of noninterest income in low-interest rate periods such as the period from 2008 to 2021. For example, Molyneux et al. [22] reported a negative effect of the short-term interest rate on fee income for 440 Italian banks over the 2007–2016 period, along with a negative effect of size and liquidity and a positive effect of the cost to income ratio and nonperforming loans. However, Altavilla et al. [23] focusing on the profitability of 288 Eurozone banks from 2000 to 2016, reported no significant interest-rate effect on noninterest income.

Macroprudential policy and bank performance

There is an extensive literature on the effects of macroprudential policy on banks, notably on lending and risk (see for example Claessens et al. [24] and Altunbas et al. [25]). The results generally favour a decline in lending and a reduction in risk when macroprudential policy is tightened.

The research on the relation of macroprudential policy to bank income and profitability is much more limited. Davis et al. [26] studied effects of macroprudential policies on bank profitability with a global sample of banks,capital measures tended to reduce profitability whereas loan supply/demand measures had a zero or positive effect. Meuleman and Vander Vennet [27] found that while Eurozone banks reduced lending and risk in response to macroprudential

policy tightening, net interest margins tended to decline. Davis et al. [28] focused on the determination of the net interest margin by both macroprudential and monetary policy. In the short run, tightening of both types of policy tended to narrow the margin, while in the long run, monetary policy typically widens the margin while effects of macroprudential policies were mostly zero or positive, suggestive of countervailing action by banks. There were also significant interactions between macroprudential and monetary policy for several macroprudential policies.

No extant work, to our knowledge, focuses on the effects of macroprudential policy on bank noninterest income.

Potential effects of macroprudential polices on noninterest income

The absence of empirical work focused on effects of macroprudential policy on noninterest income is a paradox in the light of the work cited above highlighting links of noninterest income to profitability (such as Goddard et al. [4], Saunders et al. [8] and Saklain and Williams [9]) and risk (such as Stiroh and Rumble [5], Chen et al. [7] and Brunnermeier et al. (2019)).

This is not least because channels for such effects can be envisaged. The main components of noninterest income are net fees and commissions and net trading income. As macroprudential policy typically constrains the balance sheet in terms of risk and return, which may reduce net interest income, any such reduction in profitability is likely to be met by pressure to raise such fee and trading income. We may cite for example the positive effect of lower net interest margins on noninterest income found by Hahm [2].

An effect of macroprudential policy on noninterest income can be traced for the range of macroprudential policy categories. For example, loan-targeted macroprudential measures aim to alter portfolio decisions on earning assets, typically shifting banks towards lesser expansion of credit and often also less risk. Given the likely effect of less lending and lower risk on interest income, banks are likely to be stimulated to raise noninterest income to compensate for this loss of income. They may also raise risk related to noninterest income (growing trading income relative to fee income) to restore the balance of risk and return.

Within this category, certain loan-targeted policies operate on the demand for loans, notably loan-to-value and debt service to income ratios on mortgages. A tightening of such policies will lead to lower overall loan demand and also a reduction in the highest risk (and hence potentially profitable) loans. Such an effect would be likely to lead the bank to increase fee and trading income to compensate for income losses. A rise in trading and other forms of non-fee income by many banks[3] may again represent attempts to regain previous relations of risk and return in the light of the bank's risk appetite. We note also that a lesser expansion of housing loans may have a direct negative effect on fee income since these are typically linked to loan origination, although this may be outweighed by increased fee income from other sources.

Parallels can be traced between these demand-side effects of loan-targeted macroprudential policy and the historic stimulus to noninterest income from the decline in corporate loan demand with the growth of securities markets since the 1970s, as noted above and by DeYoung and Roland [1] and Hahm [2]. In that case, banks sought to increase noninterest income because the demand for loans by high-quality borrowers able to access securities markets declined. There may however be a greater impact from demand-side loan-targeted policies than from these historic patterns, since they seek to reduce lending to higher risk borrowers, for example by requiring higher deposits or lower loan/income ratios. Chan et al. [29], for example, found a reduction in bank risk for a global sample from such demand side measures. Accordingly, the effect on profitability and hence desire of banks to boost noninterest income, may be greater.

Macroprudential policies can also affect loan supply directly, with tighter credit growth limits and other loan restrictions having a similar effect of constraining the balance sheet. Claessens et al. [24], for example, found a negative effect on lending. As scope for lending declines, banks will be incentivised to seek more noninterest income to maintain profitability. Average risk may be unchanged if the bank is simply ordered to limit overall loan growth. But if the loan restrictions limit some of the higher risk categories such as commercial property lending, there may again be pressure to raise risk in the noninterest field via expansion of trading as opposed to fee income per se.

In contrast to loan-targeted measures, capital measures are primarily aimed at ensuring that banks can cope in the event of a systemic crisis by build-up of resilience, not at altering portfolio decisions on earning assets. Nevertheless, capital measures may also encourage fee and trading income, owing to the downward pressure they exert on lending via higher costs of capital, and consequent reduction in overall profitability as found by Davis et al. [26]. Again, this can be seen as comparable to the initial historic impact of capital requirements on the shift from interest to noninterest activities, which led banks to seek increased leverage via noninterest activities.

[3] We note that a large proportion of banks in our sample benefit from forms of non-fee income as well as fee income, as witness the number of banks in the regression for fees as a ratio of average assets (6274 banks) as opposed to the banks in the corresponding non-fee regression (5477 banks), see Table 5.

As in the past, capital requirements bear much less on noninterest income than on income from loans, with only operational risk capital requirements applying to fee income. Capital limits do bear on trading via the "trading book" but these have generally been less strict than for lending assets held on the "banking book", (although since the Global Financial Crisis there have been efforts to equalise the treatment (Basel Committee 2012)). Accordingly, an asymmetric effect favouring noninterest income as opposed to interest income from lending is likely to occur when tighter capital requirements are employed as a macroprudential policy tool. This includes policies such as other capital requirements (introduced throughout our sample) and the countercyclical buffer, the conservation buffer, leverage requirements (introduced after the Global Financial Crisis).[4]

Such effects on noninterest income may vary between capital adequacy policies. Tightening of unweighted macroprudential measures such as the leverage ratio may induce banks to raise balance sheet risk by boosting commercial lending and small firm loans (as found by Auer et al. (2019)) to regain previous levels of profitability and obtain sufficient reserves to build up resilience. Such effects may reduce incentives to raise noninterest activities to regain profitability and desired risk levels. Similar effects may arise from advance provisioning requirements. On the other hand, tighter risk-adjusted capital requirements may lead to a larger boost to noninterest activity as banks shift into lower risk-weighted assets with a negative impact on interest income.

Liquidity reserve-type macroprudential measures are again imposed on banks to ensure they can bolster asset resilience and cope in a systemic crisis. They oblige banks to hold more low-return assets than they would otherwise, thus enhancing their incentive to seek to restore previous levels of profitability, although this may be partly offset if they also oblige banks to shift from wholesale to cheaper retail funding (King 2013), which reduces risk and interest costs on the liabilities side. Again, assuming the bank's risk appetite is unchanged, such liquidity based macroprudential policies may induce an offsetting rise in noninterest activity, including riskier trading as well as fee income.

We note that these expected responses to macroprudential policy tightening have parallels, and indeed may occur alongside other forms of response to macroprudential policy which entail increases in non-controlled and/or riskier lending and other asset classes, to offset declines in profitability due to the macroprudential policy. For example, loan-to-value limits may reduce mortgage lending but raise corporate lending and securities holdings [30]. Further effects may be to shift financial activities to nonbank credit outside regulatory parameters [31] and increase borrowing from foreign branches [32] and cross-border [33]. These responses may entail forms of risk-shifting that may be aggravated by moral hazard generated by the safety net of deposit insurance and lender of last resort for banks that consider themselves "too big to fail".

Regulatory arbitrage or search for yield?

There are two mechanisms by which macroprudential restrictions could influence banks' decisions to focus on non-interest income as a revenue stream: firstly, from the direct balance sheet costs from the "tax" effect of greater controls and secondly via regulatory arbitrage as banks actively seek unregulated, off-balance sheet income.

In general, more conservative macroprudential regulation—through instruments such as capital requirements and leverage ratios, constrains banks' balance sheets reducing the profitability of traditional lending. When regulation compresses margins on traditional lending, banks may actively seek higher-yielding activities to sustain profitability. As discussed by Rajan [34], financial institutions respond to changing incentives by taking on new forms of risk in pursuit of yield, while Adrian and Shin [35] show that balance-sheet management and risk-taking are highly responsive to regulatory and market conditions. Many non-interest income activities—such as trading, underwriting, and fee-based services—offer higher or more flexible returns, making them attractive both as capital-light and yield-enhancing alternatives.

Acharya et al. [36] show that tighter regulatory scrutiny leads banks to contract loan supply and reconstitute their asset mix[5] because of two contradictory forces: risk management or moral hazard incentives. Banks under greater regulatory scrutiny may rebalance portfolios away from risky lending and thus search for yield from increased non-interest income. In contrast, banks' search for yields may encourage morally hazardous lending to more risky borrowers. However, these authors find the risk management incentives dominate in the US banking system, thus explaining the rise in non-interest income generating activities.

In the UK banking sector, Aiyar et al. [32] demonstrate that macroprudential tools directly restrict credit growth and shift activity across sectors whereby domestic banks that are subject to increases in UK capital requirements respond by reducing lending. This could incentivise movements into

[4] Note that we divide the sample at the time of the Global Financial Crisis in Tables 18, 19 and 20, reported in "Three further breakdowns of the data—summary of main results" section.

[5] A UK study Raja [37] shows that the balance sheet effects of capital requirements may change over time. Before the subprime crisis banks response to capital tightening was through capital accumulation and loan quantities. But since the crisis the effect has been to change the risk composition of assets.

non-interest income product lines to maintain competitiveness since foreign banks, unfettered by UK regulations, are able to expand their lending. In parallel, DeYoung and Roland [1] highlight that lending becomes relatively less attractive when balance-sheet costs rise. Using a sample of 472 commercial US banks, they show that non-interest income generation has moved beyond traditional services (e.g. checking services, trust and letters of credit) into entirely new product lines (e.g. insurance and mutual fund sales). Simultaneously, off-balance sheet valuations have increased as banks increasingly focus on securitization of mortgages, credit card debt and other origination and servicing activities.

Balance sheet costs are also related to the level of bank supervision and the compliance costs for banks who must demonstrate their fulfilment of regulatory requirements. For banks with riskier loan books, these costs are higher since they are subject to stricter and more frequent scrutiny. Moreover, managers of large banks may display more risk-averse behaviour. Stiroh [3] suggests these factors also contribute to higher balance sheet costs and explain the expansion of non-interest income.

Whilst the literature shows that macroprudential tightening lowers the returns to traditional intermediation, creating binding constraints on bank expansion through interest-generating activities, these factors also generate incentives for capital arbitrage. As argued by Jones [38], banks respond to regulatory pressure by restructuring activities to minimise capital usage per unit of return. This includes shifting toward off-balance-sheet exposures, securitisation, and activities with lower risk weights.

As shown in models of shadow banking by Acharya et al. [39] who examined the increasing use of conduits for asset-backed commercial paper origination by US banks, these practices allowed banks to retain balance sheet risk but with a lower capital cost. Mariathasan and Merrouche [40] show that banks using internal risk-based models to quantify their credit risk, systematically reported lower risk weights, providing a channel for capital arbitrage. Mayordomo et al. [41] identifies another example of regulatory capital arbitrage through the overvaluation of real estate collateral in the Spanish mortgage market. As mortgage risk weights depend on loan-to-value (LTV) ratios, inflating property appraisals reduces measured risk weights by as much as 9%. Since residential mortgages form a substantial component of balance sheet assets and, as the authors note, two thirds of real estate is over-valued by appraisers in Spain and the US, there are significant incentives for banks to engage in this type of capital arbitrage.

Brunnermeier et al. [42] note that the rise in non-interest income creation by banks is significant enough to negatively impact systemic risk in US banking sectors. Whilst banks compete with intermediaries in the capital markets (e.g. mutual funds and insurance companies), they have the subsidy advantage of deposit insurance. This explains the rapid rise of non-interest income since the late 1990s with both investment and retail banks taking advantage of these revenue streams.

Hence, macroprudential regulation, by inducing both capital arbitrage and yield-seeking behaviour, may reconfigure rather than eliminate risk, shifting it from traditional lending into more off-balance sheet income generation.

Hypotheses for testing

In light of the sections above, we suggest the following testable hypotheses:

Hypothesis 1 *Tightening of macroprudential policy leads to increases in bank noninterest income.*

To assess the potential impact of noninterest income on bank performance, we also test the following hypotheses with our dataset, considering the balance of results in the existing literature summarised above:

Hypothesis 2 *Increases in noninterest income raise bank risk.*

Hypothesis 3 *Increases in noninterest income raise bank profitability.*

Assessing the combination of outcomes of Hypothesis 1 alongside 2 and 3 will then enable us to assess whether there is an identifiable channel of transmission from macroprudential policies to bank risk and profitability via its impact on noninterest income, and whether this differs by type of noninterest income and across subsamples (by country development, time period and bank size).

Methodology

Our baseline noninterest income model, within which we will test macroprudential policy effects, is derived from the references above, such as Hahm [2] and Molyneux et al. [22]:

$$\begin{aligned}\mathrm{NIIAA}_{it}\ or\ \mathrm{NIR}_{it} &= \alpha_{it} + \beta_1 \mathrm{NIIAA}_{it-1}\ or\ \beta_1\,\mathrm{NIR}_{it-1} + \beta_2\,\mathrm{Internal}_{it-1} \\ &\quad + \beta_3 \mathrm{Industry}_{ijt} + \beta_4 \mathrm{Macro}_{jt} + \varepsilon_{it}\end{aligned} \tag{1}$$

where i indicates an individual bank, j refers to the country and t indicates time-period. We employ two measures of noninterest income as dependent variables, the ratio of non-interest income to average total assets (NIIAA) and the ratio

of noninterest income to gross operating income (NIR). Whereas the former shows the contribution of noninterest income to profitability (the other components being net interest income, noninterest costs and provisions), the latter shows the degree of income diversification. In a subsequent section, we subdivide total noninterest income into fee and non-fee components, a division that is not undertaken by most of the earlier work on noninterest income determination cited above.

Internal indicates bank-specific controls. These are the log of total assets (denoted BANK SIZE in the results tables), the unadjusted capital ratio of equity/assets (CAPITAL RATIO), provisions/gross loans (CREDIT RISK), portfolio balance of gross loans/total assets (LOAN/ASSET RATIO), management efficiency as shown by the cost-income ratio (COST/INCOME) and a proxy for liquidity risk, namely deposits/total liabilities[6] (LIQUIDITY RISK). In line with previous studies such as Beck et al. [44], we consider this bank level vector of independent variables to characterize aspects of a bank's business model which contribute to profitability as well as risk. We add profitability measures, namely the return on average assets (ROAA) and the net interest margin of net interest income/average assets (NET INTEREST MARGIN), as in Hahm [2].

Industry variables are twofold. First there is a banking crisis dummy (BANKING CRISIS) which is set at 1 for ongoing periods of crisis and 0 otherwise, from the Laeven and Valencia [45] crisis dataset, updated to 2022. Second, we have the Lerner Index (LERNER INDEX) showing bank-level market power.[7] We note that both factors are typically omitted from existing studies. *Macro* controls comprise real GDP growth (GDP GROWTH) and CPI Inflation (INFLATION).

In line with prior studies, all continuous variables are winsorised at 1% and 99%. Estimation is by panel OLS with bank-level and time fixed effects. Bank-level variables including the Lerner index were lagged to reduce the risk of endogeneity. We clustered standard errors by country, since the effects of macroprudential policy are also country-specific [25].

Given use of lags for bank-specific variables to mitigate issues of endogeneity, and clustering at country level to mitigate violations of the OLS assumptions, we prefer to use OLS since it allows use to relate our results to previous studies and conceptually, its underlying principles are more straightforward compared to GMM. Also, as argued by Mirzaei et al. [47], the use of lagged instrumental variables for GMM would imply further loss of degrees of freedom that would vitiate our results by markedly reducing the size of the unbalanced panel dataset. Furthermore, Kok et al. [48] argue that dynamic panel data models which use GMM estimators are only asymptotically efficient and have poor finite sample properties when the time-dimension T is small. The first difference-GMM also suffers in terms of estimation precision when the instruments are weak [49]. Due to the loss of information from the level variables on first differencing, first differencing causes substantial loss in estimation efficiency when differenced models contain instruments in levels (Areliano and Bover 1995). Hence, we prefer to retain two-step difference GMM as a robustness check only, to assess whether endogeneity is a major issue in the baseline estimates.[8]

Having estimated baseline models for noninterest income as in Eq. (1), we test the additional effect of the cumulative stance of macroprudential policies as shown in Eq. (2):

$$\begin{aligned}\mathrm{NIIAA}_{it} \text{ or } \mathrm{NIR}_{it} = {} & \alpha_{it} + \beta_1 \mathrm{NIIAA}_{it-1} \text{ or } \beta_1 \mathrm{NIR}_{it-1} + \beta_2 \mathrm{Internal}_{it-1} \\ & + \beta_3 \mathrm{Industry}_{ijt} + \beta_4 \mathrm{Macro}_{j} + \beta_5 \mathrm{Macroprudential}_{jt-1} + \varepsilon_{it}\end{aligned} \tag{2}$$

Macroprudential denotes the stance of macroprudential policy, measured as discussed below by cumulation of individual policy measures. These are introduced into the baseline model one by one, in line with the standard approach in the literature on macroprudential policy such as Cerutti et al. [33], Akinci and Olmstead-Rumsey [50], Carreras et al. [51] and Gaganis et al. [52]. They are also lagged to allow for gradual adjustment of banks' behaviour to macroprudential measures. Lags also ensure the risk of endogeneity and reverse causality is not present, in case macroprudential authorities may react to bank-level developments. The remaining variables are already defined. The dataset used and the measure of cumulation are discussed in the following section.

Data

Empirical testing of the model used data from 7395 banks from a range of advanced and developing countries sourced from the Fitch-Connect database. As shown in Appendix Table 15, our sample is drawn from banks operating in

[6] Mergaerts and Vander Vennet [43] suggest that this shows the degree of dependence on non-deposit funding, that are more subject to runs than deposit funding in the presence of deposit insurance. As noted by Altunbas et al. [25], this is also a measure of a bank's contractual strength. "Banks with a large amount of deposits will adjust their deposit rates by less (and less quickly) than banks whose liabilities are mainly composed of variable rate bonds that are directly affected by market movements" (ibid, p411).

[7] The Lerner index is a measure of the price–cost margin; it can be seen as a proxy for current and future profits stemming from pricing power, and it varies at the level of the individual bank. It is derived by estimation of a translog cost function as in Beck et al. [44] and Davis and Karim [46].

[8] In further exploratory results we also include a Difference-in Difference estimation.

100 countries, of which 35 are advanced countries and 65 are emerging market and developing economies (EMDE). There are 3661 banks from advanced countries and 3734 from emerging market and developing economies. The types of banks included are universal commercial banks and retail and consumer banks. Investment banks and private banks are excluded due to different balance sheet and income structures, as are bank holding companies, to avoid double counting.

As in Claessens et al. [24], the number of banks for each country is generated from a sample of up to 100 largest banks based on total assets in 1995, 2005 and 2015.[9] This avoids the sample being dominated by countries with many banks (such as the US, Germany, Japan and Austria). The banking data collected are unconsolidated (where available), which also allows for the reporting of foreign bank subsidiaries in each country. All financial statement data are annual and in US dollars. The period of coverage for the banking data is 1990 to 2022, annually, in line with the iMaPP database introduced below. As noted by Altunbas et al. [25], a global sample of countries with different macroprudential policy experiences should reduce the risk of omitted-variables bias.

Data for GDP growth and inflation are from the World Bank's World Development Indicators database, while that for interest rates is from the IMF International Financial Statistics database and the OECD. The data for banking crises is from Laeven and Valencia [45], updated to 2022.

Statistical analysis (Table 1) shows that the ratio of non-interest income to average assets is around half the size of the net interest margin. Of the total, around half is fee and

Table 1 Descriptive statistics for global sample 1990–2022

	Mean	Median	Maximum	Minimum	Std. Dev	Observations
NIIAA	2.210	1.080	26.628	-1.212	3.863	103,195
NIR	32.728	28.880	123.167	-49.176	27.550	110,895
NIFEEAA	1.135	0.619	12.780	-0.540	1.865	95,673
NIFEER	19.419	16.324	90.666	-27.541	18.833	101,610
NINON-FEEAA	0.841	0.282	13.366	-1.811	1.935	95,673
NINON-FEER	12.892	7.934	101.972	-42.760	20.281	101,610
Bank size	21.218	21.178	27.170	15.948	2.324	112,971
Capital ratio	0.132	0.090	0.908	0.003	0.148	112,936
Credit risk	1.371	0.580	16.981	-2.790	2.667	92,137
Cost/income	64.490	61.660	250.734	1.650	32.719	111,144
Loan/asset ratio	0.575	0.605	0.998	0.004	0.234	109,869
Return on average assets	1.221	0.950	13.080	-11.150	2.742	102,550
Net interest margin	4.128	2.840	28.850	-1.720	4.490	101,854
Lerner index	0.229	0.240	0.657	-0.908	0.207	94,431
Liquidity risk	0.679	0.753	0.993	0.002	0.266	104,144
GDP growth	3.024	3.071	11.795	-10.000	3.713	241,386
Inflation	9.853	3.079	299.510	-0.923	32.956	235,225
Banking crisis	0.090	0.000	1.000	0.000	0.287	244,068
Central bank rate	6.659	4.229	69.97	0.000	9.811	180,379
Log Z score	3.432	3.472	6.486	-8.972	1.280	92,763
NPL/loans	6.277	2.940	59.158	0.000	9.533	65,341

Data Sources: Fitch-Connect, IMF, World Bank and author calculations

Notes: NIIAA is noninterest income as a proportion of average assets, NIR is noninterest income as a proportion of total income, NIFEEAA is fee income as a proportion of average assets, NIFEER is fee income as a proportion of total income, NINON-FEEAA is non-fee noninterest income as a proportion of average assets, NINON-FEER is non-fee noninterest income as a proportion of total income, BANK SIZE is the logarithm of total assets, LOAN/ASSET RATIO is bank loans as a proportion of total assets, CAPITAL RATIO is the unadjusted capital ratio (equity/total assets), CREDIT RISK is provisions/gross loans, COST/INCOME is management efficiency (total operating expenses/ total income), RETURN ON AVERAGE ASSETS is bank profits as a proportion of average assets, NET INTEREST MARGIN is interest received minus interest paid as a proportion of average assets, LERNER INDEX is the Lerner Index calculated using a translog cost function as in Davis et al. [26], LIQUIDITY RISK is the ratio of deposits to liabilities, BANKING CRISIS is a dummy variable for banking crises and it is coded one in the year the crisis starts until the year it was over and is otherwise zero Laeven and Valencia [45], updated to 2022), GDP GROWTH is economic growth, the real GDP growth rate (annual %), INFLATION is the CPI inflation rate (annual %),CENTRAL BANK RATE is the policy rate (annual %), LOG Z SCORE is the log of the bank Z-score measured as the return on average assets plus unadjusted capital ratio)/ standard deviation of return on average assets, NPL/LOANS is the ratio of nonperforming loans to gross loans. The values are a ratio unless otherwise stated. Max – maximum, Min – minimum, StdDev—standard deviation. The variables other than banking crisis are winsorised at 99% and in levels

[9] We retained all the chosen banks for each base year through the full sample, which is why some countries have more than 100 banks.

half is non-fee income. The noninterest share in total income is an average of 33%. The Lerner Index at 0.229 is in line with comparable samples. The cost-income ratio averages 64.5%, while the return on average assets is just over 1.2%. Estimated correlations show none of the variables are highly correlated except for the correlation between management efficiency and the Lerner Index at -0.68.

For macroprudential data, we used the IMF iMaPP database of policy actions for 1990–2021 [53] as introduced in Alam et al. [54].[10] The database of individual macroprudential tools is in the form of dummy-style instruments. These dummy indices are based on the effective date whenever it differs from the announcement date, because the effective date is more widely available. The dummies show tightening (+1), no-change (0) and loosening (-1) and has accordingly only categorical as opposed to numerical values for the macroprudential policies. In other words, they show simply whether the policy is tightened, unchanged or loosened, not the severity of application or easing. They are summed for calculating the summary instruments. The fact that we have categorical measures means we are estimating the impact of an average policy action, in line with the rest of the literature on macroprudential policy.

The data were annualised and cumulated (to show the policy stance) following the approach of Bergant et al. [56] and Davis et al. [26]. As noted by Meuleman and Vander Vennet [57], cumulation is important since macroprudential measures can have effects not just initially but also in the longer term, and the specific point at which the policy becomes binding is not observable.

In iMaPP, there are 17 individual instruments, as detailed in Table 16 namely the countercyclical buffer, the conservation buffer, capital requirements, leverage requirements, provisioning requirements, credit growth limits, loan restrictions, limits on foreign currency loans, loan to deposit limits, loan to value limits, debt to income limits, levy/tax on financial institutions, liquidity measures, limits on FX operations, reserve requirements, other macroprudential measures and SIFi surcharges. As in Alam et al. [54] these are aggregated into 7 summary instruments (all measures, loan-targeted measures, demand-targeted measures, all supply-targeted measures, loan-supply-targeted measures, general supply-targeted measures and capital-related supply measures), as detailed in Table 17. In our estimates, we use both individual and aggregated summary measures (as in [54]).

Empirical results

Baseline equation for the global sample

Table 2 Results for noninterest income for global sample (1990–2022)

Dependent	NIIAA	NIR
C	5.83*** (7.7)	34.8*** (5.4)
Lagged dependent (− 1)	0.551*** (17.7)	0.394*** (22.9)
Bank size (− 1)	− 0.25*** (7.2)	− 0.96*** (3.2)
Capital ratio (− 1)	0.62* (1.9)	
Credit risk (− 1)	− 0.0221* (1.9)	0.303*** (4.3)
Cost/income (− 1)		0.0674*** (5.6)
ROAA (− 1)	− 0.052*** (3.8)	0.316** (2.5)
Net interest margin (− 1)	0.0403*** (3.3)	− 0.5*** (4.1)
Loan-asset ratio (− 1)	− 0.232** (2.4)	− 6.395*** (5.3)
Lerner index (− 1)	− 0.614*** (4.2)	
Banking crisis	− 0.0818* (1.8)	
Inflation	0.0084* (1.9)	0.0419** (2.0)
Growth		
R^2	0.65	0.57
SE	1.57	13.5
Periods	31	32
OBS	73,637	82,598
Banks	5862	6211

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. For variable definitions see Table 1. Coefficient values are reported and the t-statistics are reported in parenthesis. ***Significant at 1%, **significant at 5%, *significant at 10%

[10] An updated version of the Alam et al. [54] working paper is now published in a journal [55]. Since we use a lag for macroprudential effects, the ending of the IMaPP data used in 2021 does not prevent estimates going up to 2022.

Our baseline estimation results for the global sample, with dependent variables noninterest income/average assets

(NIIAA) and noninterest income/total income (NIR), are shown in Table 2 below, after elimination of insignificant variables.

In each equation, the lagged dependent variable is sizeable, suggesting a high degree of persistence both in the contribution of noninterest income to profitability and its share of income. This may reflect the effect of strategic business models in line with Goddard et al. [4] and Saunders et al. [8].

Large banks are seen to be less dependent on noninterest income than smaller ones, as also found by Molyneux et al. [22]. However, this is contrary to the result found in the much earlier sample used by Hahm [2]. This suggests a relative shift to noninterest income by smaller banks in more recent years. Higher loan/asset ratios tend to reduce noninterest income relative both to assets and income as in Hahm [2], suggesting that noninterest income and loan issue are substitutes rather than complements.

A higher net interest margin relates to a higher ratio of noninterest income to assets, suggesting that banks can exploit scope economies. On the other hand, the ratio of noninterest income to total income is negatively related to the margin as in Hahm [2] and Haubrich and Young [6] post the Global Financial Crisis. This is consistent with the suggestion that pressure on margins leads banks to seek a greater share of noninterest income. Greater market power (a higher Lerner index) tends to reduce the importance of noninterest income in profitability, its growth is thus related to more intense competition. This variable is, as noted, not included in the studies we have cited, but its significance suggests considerable importance, not least as many studies show a link between bank competition and risk-taking.[11]

The other bank-specific determinants show that noninterest income rises as a proportion of assets in line with the capital ratio (as in Ammer (2008) and Meng et al. [19]), while it falls in line with credit risk and the return on average assets. Meanwhile, in line with studies such as Molyneux et al. [22], the share of noninterest income in total income rises with the scope of credit risk (more risk relates to higher relative reliance on noninterest income) and the cost to income ratio (suggesting such income generation is costly in terms of staff). It also rises with the return on average assets (more profitable banks are more reliant on noninterest income).

As regards effects of macroeconomic variables, the noninterest ratio to average assets and to income rises with inflation as in Hahm [2], while the ratio to average assets falls during banking crises. Growth of GDP does not affect either measure of noninterest income in the global sample, suggesting our results are driven more by endogenous bank decisions.

In line with papers such as Borio et al. [21] and Molyneux et al. [22] cited above, we tested the central bank interest rate as an additional variable in these equations. Note that with a global sample we could not include the yield curve as for most Emerging Market and Developing Economy (EMDE) countries there is no long-term bond market. In fact, our finding was that in the global equations set out here, the central bank rate was not significant, either for the noninterest/income ratio or the noninterest income/assets equation. This is also the case for the subperiod 2007–2022 which is the focus of work on the effect of low interest rates on noninterest income. Our result is in line with Altavilla et al. [23] who also found no relationship between the level of interest rates and noninterest income.[12]

Table 3 Results for summary macroprudential instruments for global sample (1990–2022)

Dependent	NIIAA	NIR
MAPP-INDEX (-1)	0.0098*** (3.7)	0.0531 (1.1)
LOAN-TARGETED (-1)	0.021*** (3.0)	0.0628 (0.6)
DEMAND (-1)	0.024** (2.3)	-0.0781 (0.5)
SUPPLY-ALL (-1)	0.0099*** (3.0)	0.0702 (0.2)
SUPPLY-LOANS (-1)	0.0342*** (3.1)	0.239 (1.4)
SUPPLY-GENERAL (-1)	0.0056 (0.7)	0.0844 (0.8)
SUPPLY-CAPITAL (-1)	0.0214** (2.7)	0.09 (0.9)

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table 2, with cumulated summary macroprudential variables added one at a time. MAPP INDEX is the sum of dummies for all of 17 categories shown in Appendix Table 16. The LOAN TARGETED group consists of the "Demand" and the "Supply-loans" instruments. DEMAND comprises loan-to-value and debt-service-to-interest limits. SUPPLY-LOANS is loan growth limits, provision measures, loan measures, limits to the loan to deposit ratio, and limits to foreign currency loans. SUPPLY-GENERAL is reserve requirements, liquidity requirements, and limits to FX positions. SUPPLY-CAPITAL is leverage, countercyclical buffers, conservation buffers, and capital requirements. See Appendix Table 17 for more details on summary variables

Summary macroprudential variables in the global sample

Analysing the results when we add the summary macroprudential measures one-by-one to the global baseline equations, we find in Table 3 that there are significant positive effects in the global sample of macroprudential policies on noninterest income as a ratio of average assets, in line with Hypothesis 1. This is the case for the measure of all macroprudential policies (MAPP-INDEX), the loan-targeted

[11] This result is also found in our own estimates for log Z score determination discussed in "Bank performance and noninterest income" section and shown in Appendix Table 21

[12] Results are available from the authors on request.

measure, all supply policies and their subcomponents, supply-loans and supply-capital. This is as predicted, whereby the positive effects of capital requirements may be a result of banks shifting from lending activities to noninterest income to avoid "penalties" from capital requirements which penalise loan assets. Loan limits have a direct effect on the scope to generate net interest income from lending and thus stimulate noninterest activity.[13]

On the other hand, there are no significant effects on the share of noninterest income in gross income from macroprudential policies, contrary to Hypothesis 1. This may suggest, on average, that the overall business approach of banks is not greatly affected by macroprudential policy (in terms of their chosen level of diversification) but it is affected according to levels of profitability generated by noninterest income.

Table 4 Results for individual macroprudential instruments for global sample (1990–2022)

Dependent	NIIAA	NIR
Countercyclical buffer (− 1)	0.035 (1.5)	0.179 (0.7)
Conservation buffer (− 1)	0.044** (2.6)	0.727*** (3.9)
Capital requirements (− 1)	0.017* (1.9)	− 0.152 (1.1)
Leverage requirements (− 1)	0.02 (0.7)	0.178 (0.3)
Provisioning requirements (− 1)	0.0464* (1.7)	0.325 (1.1)
Credit growth limits (− 1)	0.109 (1.2)	− 0.3 (0.3)
loan restrictions (− 1)	0.055*** (3.9)	0.419* (1.7)
Limits on foreign currency loans (− 1)	0.0187 (1.2)	0.477 (1.4)
Loan to value limits (− 1)	0.0254** (2.1)	− 0.054 (0.2)
Debt to income limits (− 1)	0.057 (1.5)	− 0.267 (1.1)
Levy/tax on financial institution (− 1)	0.0106 (0.8)	− 0.174 (0.7)
Liquidity measures (− 1)	0.0203 (1.6)	0.36** (2.2)
Loan to deposit limits (− 1)	− 0.144*** (3.3)	− 2.81*** (4.6)
Limits on fx operations (− 1)	− 0.044 (0.9)	− 0.661 (1.5)
Reserve requirements (− 1)	0.004 (0.4)	0.051 (0.4)
Sifi surcharges (− 1)	0.042* (2.2)	0.539** (2.2)
Other macroprudential measures (− 1)	0.03* (1.8)	0.32 (1.4)

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table 2, with cumulated macroprudential variables added one at a time. See Appendix Table 16 for more details on individual variables

[13] This is a contrast with the effects found for the overall return on average assets for a similar sample in Davis et al. [26], who found only a negative effect from supply-capital macroprudential policies. This suggests there are offsetting effects of macroprudential policy on other components of profitability (the net interest margin, noninterest costs and provisions).

Individual macroprudential variables in the global sample

Underlying these aggregate results for the global sample, Table 4 shows that capital measures such as the conservation buffer, capital requirements and SIFI surcharges, and loan-related measures such as loan restrictions and loan-to-value limits, together with provisioning requirements and other macroprudential measures all have positive effects on noninterest income to average assets. On the other hand, limits to the loan-deposit ratio have a negative effect. Liquidity restrictions such as lower loan-deposit ratios may directly curtail banks' ability to generate fee revenue from lending.

There are also some significant effects on the noninterest to income ratio, in contrast to the results for summary measures. Capital measures on systemic institutions, the conservation buffer, loan restrictions and liquidity measures all raise noninterest income as a share of income. We again find a negative effect on the noninterest ratio for the loan-deposit ratio.

These patterns may again reflect banks seeking to economise on capital in response to tighter capital requirements (as noted by [1]). We note that in line with the suggestion in "Potential effects of macroprudential polices on noninterest income" section, the effects arise from risk-adjusted capital measures and not the leverage ratio, which may have a lesser effect on risk in the loan book. Loan restrictions can be seen as limiting banks' profits from the banking book and leading to a greater focus on fees, dividends and trading as substitutes, in line with the long-term shift to non-interest income when opportunities for lending diminished as firms switched to securities markets [2]. Also, they seek to shift income sources to noninterest income when constrained to hold lower-yielding assets by liquidity requirements.

Disaggregation by type of noninterest income

As noted above, noninterest income can be divided into fee income and the remainder, which comprises capital gains, dividends and other income. These can in turn be measured relative to average assets and total income. We consider this of particular interest, as this breakdown is not often considered in the literature (exceptions include DeYoung and Torna [18], Chen et al. [7], Molyneux et al. [22] and Saklain and Williams [9]). And as shown in "Bank performance and noninterest income" section, there are major contrasting effects of the noninterest subcomponents on bank performance measures, namely risk and overall profitability.

The results of estimation of the baseline equations are shown in Table 5. These are largely in line with the results for total noninterest income shown in Table 4, as discussed above. For example, each series has a significant lagged

Table 5 Results for disaggregated noninterest income on global sample (1990–2022)

Type of income	Fee income		Non-fee noninterest income	
Dependent	NIFEEAA	NIFEER	NIINON-FEEAA	NINON-FEER
C	2.69*** (6.6)	33.42*** (9.6)	2.588*** (6.8)	9.628*** (4.7)
Lagged dependent (− 1)	0.665*** (29.8)	0.564*** (27.7)	0.416*** (19.0)	0.342*** (18.3)
Bank size (− 1)	− 0.119*** (6.4)	− 1.144*** (6.7)	− 0.101*** (5.8)	
Capital ratio (− 1)	0.256* (1.8)		0.649* (2.2)	
Credit risk (− 1)				0.257*** (3.9)
Cost/income (− 1)	0.00081*** (3.3)	− 0.0647*** (7.2)		0.0653*** (7.2)
ROAA (− 1)				0.204** (2.1)
Net interest margin (− 1)		− 0.186*** (3.3)		− 0.27** (2.3)
Loan-asset ratio (− 1)			− 0.192** (2.6)	− 6.513*** (6.2)
Lerner index (− 1)		− 4.506*** (4.1)	− 0.547*** (4.8)	
Deposits/liabilities (− 1)		1.777*** (2.8)		− 2.33*** (3.6)
Banking crisis			− 0.0911* (1.9)	
Inflation	0.002* (2.0)		0.00716** (2.1)	0.0487** (2.2)
Growth	0.00821* (1.8)	0.137*** (4.5)	− 0.015*** (2.7)	− 0.194*** (3.2)
R^2	0.822	0.697	0.487	0.4
SE	0.682	8.407	1.026	10.51
Periods	31	32	31	32
OBS	85,521	73,658	68,265	74,409
Banks	6274	5732	5477	5681

NIFEEAA is fee income as a proportion of average assets and NIFEER is fee income as a proportion of total income NINON-FEEAA is non-fee noninterest income as a proportion of average assets and NINON-FEER is non-fee noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. For variable definitions see Table 1. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%

dependent variable, and all show a negative relation to bank size except for the income share for non-fee income which is insignificant (as in [9]). Both fee and non-fee income are higher as a ratio to average assets for banks with higher capital ratios, while a higher net interest margin is related to lower shares of both fee and non-fee income in total income. Both the income share of fee income and the ratio of non-fee income to average assets rise when competition increases and market power declines.

For fee income, the cost-income ratio is positively related to the ratio of noninterest income to assets but negatively linked to the income share (in contrast to [22]). The income share of fee income is higher for banks with lower liquidity risk (a higher deposit/liability ratio). Non-fee income as a ratio to assets is lower during a banking crisis when trading is likely to be at a low ebb and regulation may impose additional limits. The loan/asset ratio is negatively related to both measures of non-fee income but has no relation to fee income (despite some fees being linked to loan issuance). Besides the return on average assets, the non-fee income ratio is also positively related to credit risk and liquidity risk (as also in [9]), suggesting grounds for caution by regulators, because high profitability and high risk are consistent with boom periods that may precede banking crises.

There is a contrasting cyclical pattern, whereby in periods of economic growth, fee income rises as a ratio to average assets and as a proportion of total income (as also in [3]). On the other hand, when there is recession, the banks become more reliant on non-fee income, both as a ratio to assets and a share of income. As discussed below, this implies a need for vigilance by regulators given the particular link of non-fee income to risk that we find in "Bank performance and noninterest income" section. Inflation on the other hand, increases all the measures except the income share of fees for which the effect is zero.

Macroprudential policy effects on types of noninterest income

Concerning the effects of macroprudential policy, the significant summary measures of macroprudential policy for the fee and non-fee income are all positive. As for the global sample, the overall tightness of policy (MAPP-INDEX) leads to higher fee/assets and non-fee income/assets, as does supply-all and supply-loans. Hence supply-side loan restrictions lead banks to raise both fee and non-fee income, despite the likely restriction they imply on loan—based fees.

Other measures affect only one type of income. For example, unlike non-fee income, fee income links positively to loan-targeted policies, demand and supply-general measures, with loan restrictions and liquidity measures reducing balance sheet activity. On the other hand, unlike fee income, non-fee also relates positively to supply-capital. This suggests that tighter capital requirements stimulate trading, possibly shifting rather than reducing the degree of bank risk.

Concerning effects on the fee and non-fee shares in income, there is no effect of macroprudential policies on the share of fee income but the share of non-fee is boosted by supply-loans policies; limits on loan growth thus also stimulate trading and other noninterest income as a share of income, while fee income only rises as a ratio to assets. The contrasting effects of policies on the subcomponents suggests there is scope to tailor policies to benefit particular types of noninterest income, if that is desired.

The results for individual macroprudential measures reflect these points. Again, the majority of effects on fee and non-fee income are positive. Capital measures, namely the countercyclical buffer, the conservation buffer and SIFI surcharges boost the income share of fee income while SIFI surcharges also raise the ratio of fee income to assets. Similarly, the ratio of non-fee income to assets is raised by tighter conservation buffers and overall capital requirements. Tighter capital requirements of different types hence lead banks to raise exposure to both types of fee income.

Loan measures (credit growth limits and loan restrictions) boost fee income/average assets while both measures of non fee income are also raised by loan restrictions. The income ratio of non-fee income is raised by limits on foreign currency loans, suggesting it is seen as an alternative source of diversification. There are negative effects on all four measures from loan to deposit limits.

Some measures have opposite effects on fee and non-fee income, suggesting again there is scope to vary macroprudential policy to stimulate fee or non-fee. For example, loan to value limits raise the ratio of fee income to assets while they reduce the non-fee/income ratio. Banks may raise fees on mortgages to compensate for lower interest rates on lower LTV mortgages. Tighter provisioning requirements reduce the income share of fees, possibly as they discourage loan growth, while they raise that of non-fees.

Some additional measures affect individual indicators, such as reserve requirements that boost fee income/average assets while limits on FX operations reduce the fee/income ratio. Other macroprudential measures raise the asset and income ratios of non-fee income but have no significant effect on fee income.

Three further breakdowns of the data—summary of main results

To investigate further, we examined three subdivisions of the global sample, with the dependent variable being total noninterest income/average assets and noninterest income/total income, as in "Baseline equation for the global sample"–"Individual macroprudential variables in the global sample" sections. The first subdivision is between advanced countries and emerging and developing economy banks, as classified by the IMF. Are differences in national economic development and income per head reflected in different behaviour of banks in respect of noninterest income and their response to macroprudential policy? These might be a consequence of aspects such as financial development and regulatory differences.

A further disaggregation is by bank size, where the sample is split at the median level of assets. Are determinants different for large and small banks' noninterest income and do they respond differently to macroprudential policies in this regard? Note that there may be a relation of large banks to advanced countries and small ones to EMDEs.

Finally, we can divide the sample at the start of the subprime crisis (1990–2007 and 2008–2022). Did the crisis engender a differing response of noninterest income to its determinants, as suggested by Haubrich and Young [6] for the US? That could be a consequence of the Dodd-Frank tightening of regulation in the US, and similar policies elsewhere, notably Basel III related capital measures, affecting noninterest income. Macroprudential policy itself was less widely used prior to the crisis (the exceptions are I in East Asia and Eastern Europe) which may affect the response which is detected.

Detailed results are provided in Appendix 3, Table 18 (baseline results),[14]. Table 19 (summary macroprudential policy effects) and Table 20 (individual macroprudential policy effects). For brevity, we provide a brief summary of key results here. A general point is that both the baseline and the macroprudential policy effects are largely in line with the global results in Tables 3, 4 and 5, which underlines the

[14] We tested the inclusion in the baseline equation for 2007–2022 of a dummy variable which is set to one for zero and lower interest rates and zero otherwise. In no case is it significant, suggesting that there was no significant additional effect.

robustness of the results, as is further confirmed by the three robustness checks shown in "Robustness checks" section.

The baseline results for the subsamples (Appendix Table 18) are almost wholly consistent with the global baseline shown in Table 3, in the sense that there are virtually no significant effects with opposite signs to Table 3, although in some cases effects that are significant in Table 3 become insignificant, and vice versa in the subsamples.

The main idiosyncratic results in the subsamples compared with the global baseline are where market power in advanced countries boosts the share of noninterest income (elsewhere it reduces it), and positive effects of banking crises on the share of noninterest income in Emerging and Developing Economies, for small banks and pre-crisis.

The significant results for summary macroprudential policies (Appendix Table 19) are all positive, as in Table 4. The main difference is between the pre-crisis period (1990–2007) and the other five subsamples, since in that period there are no significant summary variables. In the pre-crisis period, fewer countries operated active macroprudential policies (mainly East Asia and Eastern Europe) which may help explain this result. This does however contrast with Davis et al. [26] who found a significant negative effect of supply-capital measures on total profitability before as well as after the crisis. All the other subsamples show positive effects of policy on the noninterest share of assets. As regards the ratio to income, entailing banks' strategic decisions, in contrast with the global sample (Table 3) it is positively affected by some of the summary measures in Emerging and Developing Countries, for small banks and post crisis (2007–2022).

The most common result for summary measures is a positive effect of the overall stance of macroprudential policies (MAPP-INDEX) and of supply-loans policies. Concerning the balance between capital-based and loan-based summary variables, both tend to be significant for large banks, Emerging and Developing Economies and in the post-crisis period. Capital effects are not significant in the Advanced Countries and for small banks. Demand-based policies (loan-to-value and debt-service-to-interest limits) are significant for Advanced Countries and for small banks. Where the policy effects are significant, the effects appear to be larger for EMDEs than advanced countries, and for small banks relative to large banks. The latter result was also found for the effects of macroprudential policy on measures of total profitability in Davis et al. [26].

Concerning individual measures, we find some individual capital and supply-loan effects with a positive and significant effect in all the subsamples except pre-crisis (Appendix Table 20). There are some negative effects of individual policies, which as noted do not emerge when the policies are aggregated into the summary measures. Consistently negative effects are found, for example, for loan-to-deposit limits and limits on FX operations.

Contrary to the results for the summary measures, some individual measures are significant pre-crisis over 1990–2007, with generally positive effects on the ratio of noninterest income to average assets, but with some negative effects on the income share (notably capital requirements, credit growth limits and limits on FX operations). This may relate to specific aspects of the Asian crisis (see Tables 6 and 7).

Table 6 Results for summary macroprudential instruments for disaggregated noninterest income on global sample (1990–2022)

Type of income	Fee income		Non-fee noninterest income	
Dependent	NIFEEAA	NIFEER	NINON-FEEAA	NINON-FEER
MAPP-INDEX (− 1)	0.00477*** (2.7)	0.0203 (0.6)	0.0039* (2.0)	0.0167 (0.9)
LOAN-TARGETED (− 1)	0.00829* (1.9)	0.0175 (0.2)	0.008 (1.6)	0.047 (0.9)
DEMAND (− 1)	0.0103* (1.8)	0.0472 (0.4)	0.0025 (0.3)	-0.118 (1.3)
SUPPLY-ALL (− 1)	0.00546** (2.2)	0.02 (0.5)	0.0046* (1.7)	0.169 (0.8)
SUPPLY-LOANS (− 1)	0.013* (1.7)	0.0027 (0.1)	0.0191** (2.6)	0.224** (2.6)
SUPPLY-GENERAL (− 1)	0.00884** (2.2)	0.037 (0.5)	-0.00003 (0.1)	-0.0334 (0.7)
SUPPLY-CAPITAL (− 1)	0.0059 (1.3)	0.037 (0.7)	0.0129** (2.5)	0.0345 (0.5)

NIFEEAA is fee income as a proportion of average assets and NIFEER is fee income as a proportion of total income NINON-FEEAA is non-fee noninterest income as a proportion of average assets and NINON-FEER is non-fee noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table 5, with cumulated summary macroprudential variables added one at a time. MAPP INDEX is the sum of dummies for all of 17 categories shown in Appendix Table 16. The LOAN TARGETED group consists of the "Demand" and the "Supply-loans" instruments. DEMAND comprises loan-to-value and debt-service-to-interest limits. SUPPLY-LOANS is loan growth limits, provision measures, loan measures, limits to the loan to deposit ratio, and limits to foreign currency loans. SUPPLY-GENERAL is reserve requirements, liquidity requirements, and limits to FX positions. SUPPLY-CAPITAL is leverage, countercyclical buffers, conservation buffers, and capital requirements. See Appendix Table 17 for more details on summary variables

Table 7 Results for individual macroprudential instruments for disaggregated noninterest income on global sample (1990–2022)

Type of income	FEE INCOME		NON-FEE NONINTEREST INCOME	
Dependent	NIFEEAA	NIFEER	NINON-FEEAA	NINON-FEER
Countercyclical buffer (− 1)	0.02 (1.4)	0.34** (2.0)	0.0078 (0.5)	− 0.222 (0.1)
Conservation buffer (− 1)	0.017 (1.7)	0.297** (2.5)	0.0219* (1.9)	0.236 (1.5)
Capital requirements (− 1)	0.000268 (0.1)	− 0.066 (0.8)	0.0137** (2.1)	− 0.0018 (0.1)
Leverage requirements (− 1)	0.0183 (0.6)	− 0.098 (0.4)	0.0171 (1.0)	0.079 (0.3)
Provisioning requirements (− 1)	0.00672 (0.5)	− 0.345** (2.3)	0.0344 (1.6)	0.627** (2.6)
Credit growth limits (− 1)	0.0682* (1.8)	0.0363 (0.1)	0.031 (0.8)	− 0.469 (1.1)
Loan restrictions (− 1)	0.024** (2.4)	0.153 (0.9)	0.0249*** (2.7)	0.169* (1.7)
Limits on foreign currency loans (− 1)	− 0.00078 (0.1)	0.131 (0.8)	0.0161 (1.3)	0.442** (2.3)
Loan to value limits (− 1)	0.0184** (2.0)	0.141 (0.7)	− 0.0054 (0.7)	− 0.263*** (2.9)
Debt to income limits (− 1)	0.0029 (0.3)	− 0.124 (0.6)	0.0262 (0.8)	0.119 (0.4)
Levy/tax on financial institution (− 1)	0.0063 (0.8)	− 0.038 (0.2)8	− 0.002 (0.2)	0.0191 (0.1)
Liquidity measures (− 1)	0.0103 (0.5)	0.214 (1.3)	0.0053 (0.5)	0.0331 (0.3)
Loan to deposit limits (− 1)	− 0.0527** (2.3)	− 0.679** (2.1)	− 0.0581** (2.4)	− 0.862* (1.8)
Limits on fx operations (− 1)	− 0.0114 (0.5)	− 0.215** (2.6)	− 0.0188 (0.7)	− 0.489 (1.6)
Reserve requirements (− 1)	0.00952** (2.0)	0.034 (0.4)	− 0.0006 (0.1)	− 0.032 (0.7)
Sifi surcharges (− 1)	0.0215** (2.2)	0.37** (2.1)	0.016 (1.3)	0.167 (1.2)
Other macroprudential measures (− 1)	0.0113 (1.1)	− 0.096 (0.8)	0.0193* (1.7)	0.445*** (3.7)

Notes: NIFEEAA is fee income as a proportion of average assets and NIFEER is fee income as a proportion of total income NINON-FEEAA is non-fee noninterest income as a proportion of average assets and NINON-FEER is non-fee noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table 5, with cumulated macroprudential variables added one at a time. See Appendix Table 16 for more details on individual variables

Robustness checks

We ran three robustness checks on the global sample to validate the results. First, we added summary measures for activity restrictions, capital requirement stringency and supervisory power from the series of World Bank regulation and supervision surveys [58] updated using the latest survey for 2016 [59].[15] Second, we ran the baseline using bank-clustered instead of country-clustered standard errors as in Anginer et al. [61]. Third, we ran the estimates using a dynamic panel approach of Two-Step Difference GMM, which should allow for issues of endogeneity at a cost of a somewhat smaller sample.

As can be seen from Table 8, the robustness regressions are in line with the main estimate from Table 3. In the equations with the World Bank variables, it is capital stringency which is significant and negative for the ratio of noninterest income to average assets, and the activity restrictions with a negative sign for the share of income. The implication is that capital requirements have a greater effect on the profitability generated by noninterest income while leaving the strategy (choice of markets to serve as shown by the noninterest/income ratio) unchanged. Meanwhile, the strategy is affected more powerfully by activity restrictions, which may restrict the bank from entering sectors such as insurance and investment banking which generate noninterest income. The further implication is that the easing of such regulations will boost the share of noninterest income. For the income share equation, the significant variables are the same as the baseline, whereas for the ratio to average assets, the capital ratio, credit risk and inflation become insignificant, although there is now a negative effect of GDP growth.

With bank-clustered standard errors, coefficients are virtually identical to country-clusters in the baseline, as would be expected, but we now have a significant negative effect of growth on noninterest income. The GMM equations have satisfactory diagnostics in terms of the AR(2) and Hansen statistic, and the sample size (as expected) is over 10,000 observations smaller. The equation for the ratio of average assets has similar significant variables and signs to Table 3, except the capital ratio and the loan/asset ratio are not

[15] These data were also used in papers such as Karolyi and Tabaoda [60], Gaganis et al. [52] and Davis et al. [26]. We note that the studies themselves are dated 1999, 2003, 2007, 2011 and 2016. To cover the sample, we have interpolated between the values given in the samples and fixed the values of 1999 for 1990–8 and 2016 for 2017–22. Karolyi and Tabaoda [60] similarly fixed their values for 2012–2015 at the 2011 level.

Table 8 Robustness checks—baseline results for noninterest income using global sample (1990–2022)

Estimation method	With world bank regulation variables		With bank clustered standard errors		With difference GMM	
Dependent	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR
C	8.27*** (8.6)	33.9*** (5.0)	5.93*** (12.3)	35.8*** (8.1)		
Lagged dependent (− 1)	0.551*** (17.8)	0.385*** (21.1)	0.551*** (29.2)	0.394*** (33.7)	0.822*** (13.9)	0.454*** (17.1)
Lagged dependent (− 2)						0.101*** (6.5)
Bank size (− 1)	− 0.349*** (8.2)	− 0.872*** (3.2)	− 0.253*** (11.2)	− 0.997*** (5.1)	− 0.372*** (2.8)	− 0.651** (2.4)
Capital ratio (− 1)			0.624** (2.0)			
Credit risk (− 1)		0.323*** (4.0)	− 0.023** (2.4)	0.296*** (4.7)	− 0.216*** (7.0)	0.116* (1.9)
Cost/income (− 1)		0.0754*** (6.7)		0.0675*** (8.4)		0.053*** (5.2)
ROAA (− 1)	− 0.202* (1.8)	0.421*** (3.2)	− 0.0519*** ((3.6)	0.322*** (3.5)	− 0.396*** (9.1)	
Net interest margin (− 1)		0.466*** (3.8)	0.04*** (4.1)	− 0.522*** (7.1)	0.295*** (10.8)	
Loan-asset ratio (− 1)	− 0.251** (2.6)	− 6.495*** (5.4)	− 0.238** (2.4)	− 6.393*** (7.5)		− 6.35*** (4.4)
Lerner index (− 1)	− 0.692*** (6.4)		− 0.614*** (5.2)		− 1.215*** (2.9)	
Banking crisis	− 0.134** (2.2)		− 0.106*** (3.1)		− 0.219** (2.0)	
Inflation		0.045* (1.8)		0.353*** (3.1)	0.022** (2.1)	0.0176* (1.7)
Growth	− 0.0176** (2.0)		− 0.0091*** (2.4)	− 0.68** (2.1)		
Activity restrictions	− 0.0063 (0.7)	− 0.276* (1.7)				
Capital stringency	− 0.0209* (1.8)	− 0.215 (1.3)				
Supervisory power	0.0051 (0.6)	0.141 (0.8)				
R^2	0.649	0.577	0.648	0.569		
SE	1.77	13.3	1.57	13.5		
Periods	31	32	31	32	30	30
OBS	71,883	75,104	73,570	82,415	64,563	65,664
Banks	5937	5980	5862	6211	5557	5376

For variable definitions see Table 1. ACTIVITY RESTRICTIONS is the World Bank's summary variable for activity restrictions, CAPITAL STRINGENCY is the summary variable for stringency of capital requirements and SUPERVISORY POWER is the summary variable for supervisory power, source Barth et al. [58], Anginer et al. [59] and authors' calculations. The World Bank Regulation Variables equations are estimated by panel OLS with bank and time dummies and country-clustered standard errors. The Bank Clustered Standard Errors equations are estimated by panel OLS with bank clustered standard errors and time and bank dummies. The Difference GMM equations are estimated with two-step Difference GMM with time dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. The NIIAA GMM equation has AR(2) p value of 0.27 and Hansen test p-value of 0.15. The NIR GMM equation has AR(2) p value of 0.333 and Hansen test p-value of 0.208

Table 9 Robustness checks—results for summary macroprudential instruments (1990–2022)

Estimation method	With world bank regulation variables		With bank clustered standard errors		With difference GMM	
Dependent	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR
MAPP-INDEX (− 1)	0.004 (1.1)	0.315 (0.7)	0.0095*** (5.2)	0.0529*** (3.3)	0.0058*** (2.7)	0.0726* (1.8)
LOAN-TARGETED (− 1)	0.0173*** (4.1)	0.054 (0.7)	0.0207*** (5.6)	0.0627* (1.7)	0.0126*** (2.8)	0.112 (1.2)
DEMAND (− 1)	0.0192** (2.4)	− 0.0853 (0.8)	0.0245*** (4.4)	− 0.076 (1.3)	0.0159** (2.2)	0.0131 (0.1)
SUPPLY-ALL (− 1)	0.0031 (0.6)	0.046 (0.9)	0.00944*** (3.8)	0.0696*** (3.3)	0.0059* (1.9)	0.0872 (1.6)
SUPPLY-LOANS (− 1)	0.028*** (3.3)	0.229 (1.6)	0.0335*** (4.9)	0.238*** (3.8)	0.02*** (2.7)	0.284* (2.0)
SUPPLY-GENERAL (− 1)	− 0.0082 (0.6)	0.246 (0.3)	0.0049 (1.2)	0.0829*** (2.4)	0.0023 (0.3)	0.108 (1.1)
SUPPLY-CAPITAL (− 1)	0.0121* (1.7)	0.0585 (0.6)	0.0206*** (3.6)	0.089* (1.8)	0.0146*** (2.8)	0.104 (1.2)

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. The World Bank Regulation Variables equations are estimated by panel OLS with bank and time dummies and country-clustered standard errors. The Bank Clustered Standard Errors equations are estimated by panel OLS with bank clustered standard errors and time and bank dummies. The Difference GMM equations are estimated with two-step Difference GMM with time dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table 7, with cumulated summary macroprudential variables added one at a time. MAPP INDEX is the sum of dummies for all of 17 categories. The LOAN TARGETED group consists of the "Demand" and the "Supply-loans" instruments. DEMAND comprises loan-to-value and debt-service-to-interest limits. SUPPLY-LOANS is loan growth limits, provision measures, loan measures, limits to the loan to deposit ratio, and limits to foreign currency loans. SUPPLY-GENERAL is reserve requirements, liquidity requirements, and limits to FX positions. SUPPLY-CAPITAL is leverage, countercyclical buffers, conservation buffers, and capital requirements. See Appendix Table 17 for more details on summary variables

Table 10 Robustness checks-results for individual macroprudential instruments (1990–2022)

Estimation method	With world bank regulation variables		With bank clustered standard errors		With difference GMM	
Dependent	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR
Countercyclical buffer (− 1)	0.033 (1.3)	0.044 (0.2)	0.0352** (2.5)	0.179 (1.2)	0.0121 (0.6)	0.25 (0.9)
Conservation buffer (− 1)	0.0352* (1.9)	0.635*** (3.7)	0.0437*** (4.7)	0.719*** (7.8)	0.0157 (1.1)	0.525*** (2.8)
Capital requirements (− 1)	0.0059 (0.7)	− 0.151 (1.2)	0.0158* (1.8)	− 0.149** (2.0)	0.0147** (2.0)	− 0.076 (0.6)
Leverage requirements (− 1)	− 0.00457 (0.1)	0.139 (0.3)	0.0251 (1.4)	0.154 (0.9)	0.051 (1.3)	0.362 (0.7)
Provisioning requirements (− 1)	0.0408* (1.9)	0.269 (1.0)	0.0439*** (3.2)	0.324** (2.5)	0.0336* (1.8)	0.237 (0.8)
Credit growth limits (− 1)	0.0638 (1.0)	0.0067 (0.1)	0.109* (1.7)	− 0.2 (0.5)	0.0126 (0.2)	0.162 (0.2)
Loan restrictions (− 1)	0.052*** (3.8)	0.377* (1.7)	0.0542*** (6.3)	0.412*** (4.6)	0.0389*** (3.4)	0.47** (2.4)
Limits on foreign currency loans (− 1)	− 0.00596 (0.2)	0.4 (1.1)	0.0176 (0.9)	0.465*** (2.6)	0.0031 (0.2)	0.403 (1.5)
Loan to value limits (− 1)	0.0231* (2.0)	− 0.107 (0.5)	0.0235*** (3.8)	− 0.054 (0.7)	0.0146 (1.3)	0.055 (0.3)
Debt to income limits (− 1)	0.0396 (1.5)	− 0.162 (0.7)	0.0584*** (3.5)	− 0.256** (2.0)	0.0449** (2.2)	− 0.079 (0.3)
Levy/tax on financial institution (− 1)	− 0.0028 (0.1)	− 0.406 (1.6)	0.00971 (1.0)	− 0.184 (1.4)	0.008 (0.7)	− 0.045 (0.2)
Liquidity measures (− 1)	− 0.016 (0.8)	0.315* (1.9)	0.0202*** (3.1)	0.353*** (5.0)	0.0037 (0.3)	0.224 (1.4)
Loan to deposit limits (− 1)	− 0.0978** (2.3)	− 2.31*** (5.9)	− 0.138*** (6.1)	− 2.77*** (8.5)	− 0.105*** (2.8)	− 1.825*** (4.0)
Limits on FX operations (− 1)	− 0.0832 (1.3)	− 0.789** (2.0)	− 0.464* (1.9)	− 0.675*** (3.7)	− 0.0146 (0.3)	− 0.478 (1.2)
Reserve requirements (− 1)	0.001 (0.1)	− 0.0289 (0.2)	0.0032 (0.6)	0.051 (1.2)	0.0027 (0.2)	0.107 (0.9)
SIFI surcharges (− 1)	0.0336 (1.6)	0.357 (1.5)	0.043*** (3.8)	0.545*** (5.3)	0.024 (1.3)	0.541** (2.0)
Other macroprudential measures (− 1)	0.001 (0.1)	0.289 (1.5)	0.0306*** (3.7)	0.328*** (3.4)	0.0168 (1.2)	0.3 (1.6)

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. The World Bank Regulation Variables equations are estimated by panel OLS with bank and time dummies and country-clustered standard errors. The Bank Clustered Standard Errors equations are estimated by panel OLS with bank clustered standard errors and time and bank dummies. The Difference GMM equations are estimated with two-step difference GMM with time dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table 7, with cumulated macroprudential variables added one at a time. See Appendix Table 16 for more details on individual variables

significant. For the income share equation, a second lagged dependent was needed to obtain the appropriate AR(2). In this case it is the return on average assets and the net interest margin that are not significant.

Examining macroprudential policy effects, the World Bank robustness check has similar summary variables (Table 9) to the baseline (Table 3), except that the overall measure of macroprudential policies and the supply-all variables are no longer significant for the noninterest/average asset ratio. The bank-clustered standard errors make many more of the summary variables significant both for the ratio to average assets and income, always again with a positive sign. And equally, estimating by GMM, we have all the same measures significant with a positive sign for the average assets ratio as in the baseline, suggesting endogeneity issues are not serious. In this case, we also have the sum of all measures and supply-loans significant for the income share.

Looking at the individual measures (Table 10), in all three robustness checks, the earlier patterns are repeated with capital measures, loan restrictions and liquidity measures tending to boost noninterest income while loan-to-deposit measures and (in some estimates) limits on FX operations have a negative effect.

On balance, we contend that the robustness checks underpin the baseline results. The general conclusion remains in line with Hypothesis 1 that macroprudential policy tightening boosts noninterest income, albeit having a greater effect on noninterest income/average assets than on noninterest income/total income.

Bank performance and noninterest income

Given the strong results that we have found regarding the positive effect of macroprudential policy tightening on noninterest income, we considered it relevant to assess using our extensive global dataset whether noninterest income growth that might be boosted by macroprudential policy is related to bank risk-taking and also bank profitability. As

shown in "Literature" section, an adverse effect on risk is widely suggested in the literature, albeit typically using a much more restricted sample in terms of time-period and country coverage. This gives an important motivation for regulatory concerns about possible unintended and potentially counterproductive side effects of the positive impact of macroprudential policy on noninterest income that we have discovered.

Bank risk and noninterest income

Measures of risk we use are twofold, the log of the Z-score (return on average assets plus the capital ratio divided by the standard deviation of the return on average assets) and the nonperforming loan/gross loans ratio. The former is an indicator of risk across the whole bank, while the second focuses on risk in the loan book. The Z-score is widely used in the literature such as Antao and Karnik [14] and Saklain and Williams [9] in the context of bank non-interest income and risk, and Altunbas et al. [25] and Chan et al. [29] for testing macroprudential policy and bank risk. Mehmood and DeLuca [62] assess the relation of noninterest income to nonperforming loans for Asian banks over 2009–2021.

We note that the nonperforming loans ratio is only a partial indicator of risk, showing that certain loans that are considered to be at default. This is effectively a discretionary accounting measure; a bank has a lot of discretion is disclosing the level of nonperforming loans in the financial reports, and there is substantial variation in the laws across countries to determine when a loan is at default. We suggest that Z-score is more reliable because it is an aggregate measure as well as a cleaner measure of risk-taking, especially as the return on assets uses gross income before tax, amortization and extraordinary items. As noted by Liu et al. [63], it is appropriate to log the Z-score as it is highly skewed. Accordingly, we use log Z-score as the dependent variable.

Table 11 Results for effects of noninterest income measures on risk (log Z-score and nonperforming loans/loans)

Measure of noninterest income	NIIAA (− 1)	NIR (− 1)	NIFEEAA (− 1)	NIFEER (− 1)	NINON-FEEAA (− 1)	NINON-FEER (− 1)
Risk measure (dependent)—LOG Z-score						
Global sample	− 0.016*** (4.4)	− 0.0015*** (3.7)	− 0.0051 (0.8)	0.0014** (2.1)	− 0.0338*** (5.2)	− 0.0024*** (5.2)
Large banks	− 0.00878 (1.6)	− 0.00127** (2.0)	0.0163 (1.3)	0.00189 (1.6)	− 0.0282*** (3.4)	− 0.00242*** (4.3)
Small banks	− 0.0191*** (4.3)	− 0.00159*** (2.9)	− 0.0137 (1.7)	0.00053 (0.8)	− 0.0359*** (5.8)	− 0.00214*** (3.5)
Advanced countries	− 0.0223*** (4.2)	− 0.00231*** (4.5)	− 0.0228** (2.5)	0.001 (1.2)	− 0.0494*** (5.5)	− 0.00302*** (7.1)
Emerging market and developing countries	− 0.0145*** (3.4)	− 0.00131** (2.5)	0.00254 (0.4)	0.00235*** (3.1)	− 0.0288*** (4.3)	− 0.00252*** (4.2)
1990–2007	− 0.0228*** (4.3)	− 0.00156*** (3.2)	0.01 (0.9)	0.0024*** (2.8)	− 0.0411*** (5.9)	− 0.00284*** (4.8)
2008–2022	− 0.0182*** (3.6)	− 0.00154** (2.4)	− 0.011 (1.3)	0.00143* (1.9)	− 0.0321*** (3.8)	− 0.00219*** (3.1)
Risk measure (dependent)—nonperforming loans/gross loans						
Global sample	0.0384 (1.2)	0.00264 (0.8)	− 0.0746 (1.3)	− 0.0035 (0.6)	0.0981* (1.7)	0.006 (1.4)
Large banks	0.145* (2.0)	0.00783 (0.9)	− 0.195 (1.1)	− 0.00242 (0.2)	0.252*** (2.7)	0.119* (1.9)
Small banks	0.0394 (1.1)	0.00834 (1.6)	− 0.0763 (1.3)	0.00173 (0.2)	0.12 (1.5)	0.0136* (2.0)
Advanced countries	0.0417 (0.2)	− 0.0021 (0.6)	− 0.0404 (0.4)	− 0.001 (0.1)	0.0653 (0.9)	− 0.0002 (0.1)
Emerging market and developing countries	0.0345 (0.8)	0.00363 (0.8)	− 0.111 (1.3)	− 0.0128 (1.3)	0.0975 (1.3)	0.00882 (1.5)
1990–2007	− 0.0524 (1.1)	0.00478 (0.9)	0.0458 (0.4)	0.00664 (0.6)	− 0.109 (1.4)	0.00592 (0.8)
2008–2022	0.032 (0.6)	0.00491 (1.4)	− 0.157** (2.5)	− 0.174*** (3.0)	0.108 (1.6)	0.00283 (0.6)

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. NIFEEAA is fee income as a proportion of average assets and NIFEER is fee income as a proportion of total income NINON-FEEAA is non-fee noninterest income as a proportion of average assets and NINON-FEER is non-fee noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes the control variables shown in Table A3.4, restricted for each subsample to significant variables. The global estimates are shown in Appendix Table 21, other results are available from the authors on request

Using the same variables as in Table 2, we estimated baseline equations for the global sample, and separately for the subsamples large banks, small banks, Advanced Countries, Emerging Market and Developing Economies, as well as pre-crisis (1990–2007) and post-crisis (2008–2022). In each case, the equations were restricted to significant variables.

The results of the baseline for the global sample are shown in Appendix Table 21, other results are available from the authors on request. Bear in mind that the Z-score is inversely related to risk while the NPL/loans ratio is positively related. We can see that for each measure, risk is positively influenced by both credit risk (provisions/loans) and liquidity risk (which rises when deposits/liabilities falls). Risk by both measures also increases in the context of banking crises and in recessions. Meanwhile, larger banks have higher Z scores (lower risk) but also higher NPL/loan ratios (higher risk). Risk according to the Z-score is greater when banks have more competitive conditions and high cost-income ratios. Chan et al. [29] with a sample of Asian banks similarly found competition, crisis and credit risk were positively related to bank risk as shown by the Z-score. Gaganis et al. [52] found recession and a high cost/income ratio to be indicators of risk.

We then added (to each equation in turn) lags of each of the noninterest income measures shown in the text. These are noninterest income as a proportion of average assets (NIIAA), noninterest income as a proportion of total income (NIR), fee income as a proportion of average assets (NIFEEAA), fee income as a proportion of total income (NIFEER), non-fee noninterest income as a proportion of average assets (NINON-FEEAA) and non-fee noninterest income as a proportion of total income (NINON-FEER).

As shown in Table 11, for the log Z-score, there are consistent results of a positive relation to risk for the two measures of total noninterest income across the global sample and virtually all[16] the subsamples, as in Stiroh and Rumble [5] and Antao and Karnik [14]. This is in line with Hypothesis 2. Effects are also found for the two measures of noninterest non-fee income (as in [7]) for the global sample and all the subsamples. The negative sign indicates a positive relation to risk since a lower Z-score relates to higher risk. On the other hand, there is generally either no relation or a positive relation of noninterest fee income to risk (the sole exception is for fees/average assets for advanced countries).

This result for fee income, contrary to Hypothesis 2, is in contrast with Chen et al. [7] who found fee income boosts risk for US banks. However, is it in line with DeYoung and Torna [18], who found fee income as from insurance sales and brokerage reduces failure for distressed US banks, while non-fee income such as venture capital, asset securitisation and investment banking boosts it.

When we extend to the risk measure, nonperforming loans/gross loans, using the same procedure for baseline equations and for noninterest income measures, the results are somewhat different, and generally contrary to Hypothesis 2. For total noninterest income, the results show a zero relation to risk except for a weak positive effect for large banks, as in Mehmood and DeLuca [62]. The fee income results are generally also insignificant with the exception that for the 2008–2022 both measures are negatively related to risk as shown by NPLs. Non-fee income does raise risk in some limited cases, notably for large banks and with a weaker effect for the global and small-bank samples, but other effects are zero.

The overall implication is that when banks raise fee income, the effect on risk in the loan book is generally zero or it is risk-reducing. The positive effect on risk found for total noninterest income is shown to derive from non-fee income, which includes net capital gains, dividends and other income. The effect of non-fee income is, however, less linked to the loan book since the relation to nonperforming loans is zero in most subsamples, although we do find some positive effects, particularly for large banks.

Effects on the Z-score show that the impact of non-fee income is linked to the full range of bank activities. Further investigation suggested that the non-fee/asset ratio has a negative effect on all three components of the Z-score; income level and the capital ratio are affected negatively while also there is a positive effect on income volatility. The same is the case for the non-fee/income ratio, except there is no significant effect on the capital ratio.[17]

We suggest that besides their implications for the side-effects of macroprudential policy that we have found, and the differing results of subcategories of noninterest income, our results for risk effects of noninterest income are of considerable interest in themselves given the global scale, large number of banks and long period coverage of our dataset.

[16] The exception is the effect of the noninterest/asset ratio on the Z-score for advanced countries.

[17] Results are available from the authors on request.

Table 12 Results for effects of noninterest income measures on profitability (return on average assets)

Measure of noninterest income	NIIAA (− 1)	NIR (− 1)	NIFEEAA (− 1)	NIFEER (− 1)	NINON-FEEAA (− 1)	NINON-FEER (− 1)
Global sample	0.0207** (2.0)	0.00067 (0.7)	0.1*** (4.3)	0.0073*** (4.4)	− 0.0378*** (3.2)	− 0.003*** (3.1)
Large banks	0.028* (1.9)	0.0015 (1.2)	0.118*** (4.0)	0.00572*** (3.1)	− 0.0266 (1.3)	− 0.00115 (1.0)
Small banks	0.013 (1.0)	− 0.00062 (0.4)	0.102*** (3.6)	0.0093*** (4.8)	− 0.039* (1.9)	− 0.00483*** (2.8)
Advanced countries	0.0409** (2.3)	0.00037 (0.4)	0.112*** (3.7)	0.00554*** (3.1)	− 0.0264 (1.1)	− 0.00254** (2.3)
Emerging market and developing countries	0.0112 (1.0)	0.00224 (1.6)	0.114*** (4.0)	0.0117*** (5.6)	− 0.0356** (2.4)	− 0.00282** (2.1)
1990–2007	− 0.0104 (0.6)	− 0.00151 (1.0)	0.106** (2.2)	0.00641*** (2.8)	− 0.0873*** (3.5)	− 0.00467** (2.5)
2008–2022	0.017 (1.2)	0.00019 (0.1)	0.12*** (4.0)	0.00606*** (2.8)	− 0.03* (1.7)	− 0.00242* (1.7)

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. NIFEEAA is fee income as a proportion of average assets and NIFEER is fee income as a proportion of total income NINON-FEEAA is non-fee noninterest income as a proportion of average assets and NINON-FEER is non-fee noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes the control variables shown in Table A3.4, restricted for each subsample to significant variables. The global estimates are shown in Appendix Table 21, other results are available from the authors on request

Table 13 Direction of significant effects of macroprudential policy on risk via noninterest income for global sample

Effects on risk (Z-SCORE)						
Noninterest measure	NIIAA	NIR	NIFEEAA	NIFEER	NINON-FEEAA	NINON-FEER
MAPP-INDEX	Increase				Increase	
LOAN-TARGETED	Increase					
DEMAND	Increase					
SUPPLY-ALL	Increase				Increase	Increase
SUPPLY-LOANS	Increase				Increase	
SUPPLY-GENERAL						
SUPPLY-CAPITAL	Increase				Increase	

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. NIFEEAA is fee income as a proportion of average assets and NIFEER is fee income as a proportion of total income NINON-FEEAA is non-fee noninterest income as a proportion of average assets and NINON-FEER is non-fee noninterest income as a proportion of total income. Results are derived from the significant effects of macroprudential policy on noninterest income (Table 3) and its components (Table 15), and significant effects of noninterest income and its components on risk (Table 10) where both variables are significant. Blanks are cases where one or both effects are insignificant

Bank profitability and noninterest income

To complement the above investigation of the impact on risk, we also sought to briefly assess the impact of noninterest income on overall bank profitability. As noted in the introduction, much of the literature, such as Goddard et al. [4], Saunders et al. [8] and Saklain and Williams (2014) find a positive effect, although results of Saona [12] suggested a negative impact.

As for risk, we estimated an equation for the determination of the pre-tax return on average assets, which is a common measure of bank profitability used in the literature (Appendix Table 21). Concerning bank-specific effects, we find evidence for the global sample of diseconomies of scale (a negative effect of bank size) and of the cost/income ratio. On the other hand, the net interest margin and the deposit/liabilities ratio have a positive impact. At a macro level, GDP growth and inflation both boost profitability, while banking crises are understandably adverse. These results are in line with those found by Davis et al. [26] with a similar dataset and Xu et al. [64] with an advanced country sample over 2004–2017.

Our interest then is to find the pattern of effects within such an equation for the lagged measures of noninterest income including both subcomponents and the various subsamples, as for risk in Table 11. The corresponding results

Table 14 Direction of significant effects of macroprudential policy on profitability via noninterest income for global sample

Effects on profitability (return on average assets)						
Noninterest measure	NIIAA	NIR	NIFEEAA	NIFEER	NINON-FEEAA	NINON-FEER
MAPP-INDEX	Increase		Increase		Reduce	
LOAN-TARGETED	Increase		Increase			
DEMAND	Increase		Increase			
SUPPLY-ALL	Increase		Increase		Reduce	Reduce
SUPPLY-LOANS	Increase		Increase		Reduce	
SUPPLY-GENERAL			Increase			
SUPPLY-CAPITAL	Increase				Reduce	

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. NIFEEAA is fee income as a proportion of average assets and NIFEER is fee income as a proportion of total income NINON-FEEAA is non-fee noninterest income as a proportion of average assets and NINON-FEER is non-fee noninterest income as a proportion of total income. Results are derived from the significant effects of macroprudential policy on noninterest income (Table 3) and its components (Table 15), and significant effects of noninterest income and its components on profitability (Table 11) where both variables are significant. Blanks are cases where one or both effects are insignificant

for profitability are shown in Table 12. Results for the aggregate measures noninterest income/assets and as a share of income are mostly not significant, contrary to Hypothesis 3. The exceptions are positive effects of the ratio to assets in the global sample, for large banks and in advanced countries.

There are much more consistent results for the subcomponents fee and non-fee noninterest income. For fee income we find that for both the ratio to assets and to income, and for all the subsamples, there is a significant positive effect on profitability, as in Mamun et al. [65] and Saklain and Williams [9]. A rise in fee income raises overall profitability, consistent with Hypothesis 3. Entirely the opposite result is found for non-fee income. In most cases we find a significant negative effect on profitability, contrary to Hypothesis 3. The only exception is for large banks by both measures and for advanced countries by the ratio to assets, where the effect is not significant.

Effects of macroprudential policy on risk and profitability via noninterest income

The main results of the paper are that macroprudential policies boost noninterest income in line with Hypothesis 1, albeit to a greater extent relative to average assets than relative to income. We have shown in "Bank risk and noninterest income" section that noninterest income boosts risk consistent with Hypothesis 2, driven by its non-fee component and affecting bank-wide risk rather than nonperforming loans. "Bank profitability and noninterest income" section has shown that noninterest income boosts profitability via its fee component but reduces it via non-fee income and hence is only partly consistent with Hypothesis 3.

Drawing together these significant results, we obtain the effects shown in Table 13, for the specific example of the summary measures and the global sample (results for the subsamples and individual measures will differ). The table shows cases where the effect of macroprudential policy on noninterest income and also the effect of noninterest income on risk and profitability are both significant. The broad result is that tighter macroprudential policies tend to raise risk both via total noninterest income and non-fee noninterest income but not via fee income, where combined effects are insignificant.

As regards profitability (Table 14), macroprudential policies boost it via total noninterest income and fee income while non-fee income tends to reduce it. For both risk and profitability, effects arise via the ratio to average assets and not the ratio to income in virtually all cases—the exception is the effect of supply-all measures via the ratio of non-fee income to total income which raises risk and reduces profitability.

We note that macroprudential policy may affect risk and profitability by other channels which may enhance or offset these effects (see for example Altunbas et al. [25] and Davis et al. [26] for estimates of direct effects). We nonetheless contend that they are of considerable interest in the context of our current research.

Further exploratory results

Before concluding, we outline three additional exploratory results which further explore the relationship between macroprudential policy and noninterest income, and further asses the causal effect of macroprudential policy on

noninterest income. These are to consider the potential interaction of competition and regulation in the context of noninterest income, the scope for nonlinear responses of noninterest income to macroprudential policy and an investigation of the "shock" from the introduction of Basel III buffers on noninterest income.

Accordingly, the first test (shown in Appendix Tables 22 and 23) is to assess the interaction between competition and macroprudential policy by including in the equations shown in Tables 2, 3 and 4 an interaction term between the stance of macroprudential policy and the Lerner Index of market power for individual banks. To summarise, we find a number of cases where the interaction term is significant and has a positive sign. Amongst the summary macroprudential variables, this is the case for both noninterest income as a ratio of average assets and for the proportion of income via supply-capital, which includes leverage, countercyclical buffers, conservation buffers, and capital requirements. This result alone has important policy implications. It means that when authorities impose tighter capital requirements it is the banks with more market power in a less competitive situation that shift more into noninterest income and thus face risks as set out in "Bank performance and noninterest income" section above, This is less so for banks with less market power and in a more competitive situation.

As regards the individual measures, we find there are more positive effects from macroprudential policy according to both noninterest income as a proportion of average assets and as a ratio to gross income for banks with more market power in the case of the conservation buffer, a tax or levy on financial institutions and liquidity requirements. Additional interaction terms are significant for noninterest income as a proportion of average assets in the cases of leverage requirements, provisioning requirements and SIFI surcharges. Again, these raise important policy issues as these specific policies are shown to have an asymmetric effect across banks with more or less market power.

The second test, shown in Appendix Tables 24 and 25 is to investigation possible nonlinearities between macroprudential policy and noninterest income. Inclusion of a squared term allows for the possibility than an increasingly tighter stance of macroprudential policy can have a disproportionate effect on banks' noninterest income.

We find that this is indeed the case for many of the summary variables; for noninterest income as proportion of average assets we find a significant positive squared term for the MAPP-index of all policies, supply-all, supply-loans and supply general. We also find a number of nonlinear effects for the ratio of noninterest income to gross income. In this case there are positive squared terms for all of the measures except supply-capital. In the case of demand measures the initial response is shown to be negative but it becomes positive when the stance of policy reaches an index value of 10. This suggests only with a tight stance of such measures is the positive effect sufficient to boost the share of such income. It may show that a decline in mortgage lending as often targeted by demand measures reduces fee income directly, and only when such losses of revenue are considerable with further tightening do banks shift proactively into greater non-interest income generation.

Concerning the individual measures, we find again that that for noninterest income as a proportion of average assets there is a positive squared term for loan to value limits and in the case of noninterest income as a proportion of gross income there are positive squared terms for leverage requirements, loan restrictions, limits on foreign currency loans, loan to value limits and reserve requirements. In all these cases, a tighter policy stance leads to a greater shift by banks into noninterest income. There are also some negative squared terms meaning a tighter stance leads banks to increasingly shift out of noninterest income. For noninterest income as a share of average assets this is the case for credit growth limits and SIFI surcharges, while for noninterest income as a ratio to gross income a negative squared term is found for credit growth limits and a levy/tax on financial institutions.

For noninterest income as a proportion of average assets, there are two cases where an initial positive effect on noninterest income becomes negative when the stance tightens further. This is the case for credit growth limits and SIFI surcharges. For credit growth limits a stance of 1 has a positive effect but at 2 and beyond it is negative. Meanwhile, for SIFI surcharges a stance of up to 6 raises noninterest income, beyond which it becomes negative. The implication is that beyond a certain level of tightness the bank either shifts policy or is simply unable to generate further noninterest income (e.g. due to lack of lending under credit restrictions).

As a memo item we also show the squared coefficients only for the subcategories of fee and non-fee income. The overall pattern is that positive nonlinear effects are largely confined to fee income. For nonfee income the equations are thus linear. Tightening of policy thus shifts the composition of noninterest income towards fee income, other things

being equal. On exception though is that leverage requirements boost non-fee income both as a ratio of average assets and income.

Again, there are important policy implications from these findings of nonlinear relationships between macroprudential policy and noninterest income. It is important for the authorities to make their own assessment of the degree of such nonlinearity and not assume the relationship is linear.

The third exploratory set of results is for a basic difference-in-difference specification for the introduction of Basel III. Whereas buffers were not introduced by most countries till 2016, or later, we suggest that the announcement of the policy and the intention of the authorities to implement it would have been signalled in advance to banks. This in turn would lead to a difference in banks' behaviour across countries that by or during the year in question, or eventually introduced the countercyclical buffers and those that did not, and similarly for conservation buffers We include respective "treatment groups" where the value of one is given to a treatment dummy for the year in question and subsequent years, while a value of zero is given for the previous years in these countries and for all other countries at all times.

The results show that the treatment of either the anticipation or the actual introduction of the buffers has a significant positive effect for all of the years 2013, 2014 and 2015 onwards (with one exception). Bearing in mind that the equations also include all of the additional control variables shown in Table 2, for both measures we find a significant difference between the treatment group of countries which were to introduce Basel III buffers and those which would desist. We argue that these estimates capturing the effect of large scale macroprudential shocks from the introduction of Basel III underline the positive causal effect of macroprudential policy on noninterest income found in the fixed effects and GMM estimates with appropriate lags found elsewhere in this article.

We suggest that all three of these additional exploratory sets of results are relevant not only for the specific outcomes we find for banks' noninterest income but as an additional set of tests that can usefully be used in research for other targets of macroprudential policy, including bank risk and other aspects of performance.

Conclusion

We have found that a range of macroprudential policies have a significant positive effect on banks' noninterest income, particularly those focused on loan supply/demand restrictions and capital measures. Similar results are found for a range of disaggregated samples by type of noninterest income, country development, bank size and pre and post the Global Financial Crisis, and in three robustness checks. These positive effects can be attributed to an impact of macroprudential policy akin to that of financial change that originally generated the shift to noninterest income, notably the decline in loan demand and tightening of capital requirements on loans. It can also be seen as parallel with other responses to macroprudential policies detected in the empirical literature such as raising corporate lending and securities holdings [30], shifting financial activities to non-bank credit outside regulatory parameters [31] and increasing borrowing from foreign branches [32] and cross-border [33]. This overall result of a boost to noninterest income is consistent with our Hypothesis 1, although the effect is more marked for noninterest income as a ratio to average assets than for noninterest income/total income.

A boost to noninterest income, and particularly its non-fee component, is found to affect bank risk adversely, as highlighted widely in the literature and also with our dataset, consistent with our Hypothesis 2. On the other hand, fee income, and to a lesser extent total noninterest income, feed through positively to total profitability. But non-fee income is found to be adverse for total profitability. These results for risk, in line with Hypothesis 2, give grounds for caution in respect of unintended side effects of macroprudential policy on risk. The results for profitability, only partly consistent with Hypothesis 3, do not fully allay concerns that macroprudential policy may inhibit scope to raise capital via retentions.

Summarising in more detail the main results for 100 countries over 1990–2022, we have found noninterest income is persistent over time and negatively related to bank size and the loan/asset ratio. The ratio of noninterest income to average assets links positively to the capital ratio and the net interest margin, and negatively to credit risk, the return on average assets, market power, bank crises and inflation. The ratio of noninterest income to total income links positively to credit risk, the cost/income ratio, the return on average assets and inflation, and negatively to the net interest margin.

A number of measures of macroprudential policy influence noninterest income, and the significant effects are positive. From the summary measure results, the effects appear to be stronger for the measure noninterest income/average assets than for noninterest income's share in total income—indeed, the latter are generally zero in the global sample. This suggests a greater effect on profitability from noninterest income than from bank strategy in terms of its division with net interest income. In terms of individual measures, loan-targeted policies have a positive effect across global banks, while capital measures also boost noninterest income in a number of cases. Only tighter loan/deposit ratios have a consistently negative effect.

The results for determinants of noninterest income are also largely apparent for samples disaggregated by type of noninterest income, region, bank size and pre and post the Global Financial Crisis, and also in three robustness checks. One interesting contrast, however, is that fee income is boosted by economic growth whereas non-fee income rises in recession. Especially for the summary measures, macroprudential policy effects are also similar and positive across subsamples. Unlike the global sample, there are a number of positive effects of macroprudential policy categories on the share of noninterest income, notably for EMDE banks, non-fee income and small banks. Only pre-crisis were positive effects of macroprudential policy on noninterest income relatively absent.

These results are of considerable relevance to regulators. Notably, the results for the ratio of noninterest income to average assets suggest that negative effects of macroprudential policies on net interest margins [27], are at least partly offset by such diversification. This reduces concern that banks may be less able to accumulate capital when macroprudential policy is tightened.

On the other hand, there may be grounds for caution since a rise in dependence on noninterest income, and particularly its non-fee component, due to macroprudential policy increases bank risk, as has been found widely in the literature and in our own dataset. Furthermore we find some negative effects of the non-fee component of noninterest income on profitability. We also note that banks facing higher credit and liquidity risks seek higher noninterest income. Digging deeper, we have found that non-fee noninterest income boosts risk consistently at a bank level (as measured by the log Z score) and in some cases also in the loan book (NPL/loan ratio). Non-fee income also reduces profitability, from which capital to enhance reliance against risk could be accumulated. Higher fee income on the other hand tends to lower risk or have a zero effect, albeit not in advanced countries where it raises risk. It also tends to boost profitability.

This raises further regulatory issues relating to whether it is desirable to encourage fee as opposed to non-fee income generation, both when macroprudential policy is tightened and in general terms, and how that could be accomplished. Given the inverse relation of non-fee income to economic growth, recessions would need particular vigilance for this reason also. Choice of macroprudential policy is also relevant in this context, since we find both types of noninterest income are boosted by macroprudential policy tightening, although fee income is raised by both demand and supply measures while non-fee is largely affected by supply measures. Among individual measures, provisioning requirements and loan-to-value limits have opposite effects on fee and non-fee income.

Insights from our additional exploratory regressions are that there are potential interactions of competition and macroprudential policy affecting the response of noninterest income, with less competitive banks responding more; there are some detectable nonlinearities in the response of noninterest income to policy, generally a tighter policy leads to a greater response; and an effect of the overall introduction of Basel III can be detected before individual countries implemented buffers, underlining the positive causal effect of policy on noninterest income. All these additional results are of clear interest to regulators.

Further research could investigate the effects of macroprudential policies on other components of overall bank profitability (such as noninterest costs and provisions). Assessment of impacts of macroprudential policies by regions and for individual country banks could also be fruitful. A more granular breakdown of fee and non-fee income, where suitable data are available, could provide further insights. Further work on risk and noninterest income could focus on the positive estimated effects of fee income on bank risk in advanced countries.

Appendix 1

Sample details

See Table 15.

Table 15 List of countries and number of banks

Country	IMF Category	Region	Number of banks in IMF category ADV	Number of banks in IMF category EMDE
Algeria	EMDE	Africa		16
Angola	EMDE	Africa		26
Argentina	EMDE	South America		157
Australia	ADV	Oceania	172	
Austria	ADV	Europe	162	
Bahamas	EMDE	Caribbean		55
Bahrain	EMDE	Middle East		26
Bangladesh	EMDE	Asia		52
Barbados	EMDE	Caribbean		8
Belgium	ADV	Europe	130	
Belize	EMDE	Caribbean		5
Bolivia	EMDE	South America		24
Brazil	EMDE	South America		161
Bulgaria	EMDE	Europe		36
Canada	ADV	North America	137	
Chile	EMDE	South America		50
China	EMDE	Asia		145
Colombia	EMDE	South America		88
Costa Rica	EMDE	Central America		90
Cote D'Ivoire	EMDE	Africa		23
Croatia	EMDE	Europe		82
Cyprus	ADV	Europe	37	
Czech Republic	ADV	Europe	62	
Denmark	ADV	Europe	117	
Ecuador	EMDE	South America		64
Egypt	EMDE	Africa		36
El Salvador	EMDE	Central America		34
Estonia	ADV	Europe	19	
Ethiopia	EMDE	Africa		24
Finland	ADV	Europe	94	
France	ADV	Europe	163	
Germany	ADV	Europe	158	
Ghana	EMDE	Africa		49
Greece	ADV	Europe	39	
Guatemala	EMDE	Central America		49
Guyana	EMDE	Caribbean		7
Honduras	EMDE	Central America		35
Hong Kong	ADV	Asia	128	
Hungary	EMDE	Europe		123
Iceland	ADV	Europe	47	
India	EMDE	Asia		129
Indonesia	EMDE	Asia		130
Ireland	ADV	Europe	89	
Israel	ADV	Europe	23	
Italy	ADV	Europe	184	
Jamaica	EMDE	Caribbean		18
Japan	ADV	Asia	151	
Jordan	EMDE	Middle East		17
Kenya	EMDE	Africa		72
Korea	ADV	Asia	123	
Kuwait	EMDE	Middle East		18
Latvia	ADV	Europe	34	
Lithuania	ADV	Europe	20	
Luxembourg	ADV	Europe	164	
Malaysia	EMDE	Asia		79

Table 15 (continued)

Country	IMF Category	Region	Number of banks in IMF category ADV	Number of banks in IMF category EMDE
Malta	ADV	Europe	26	
Mexico	EMDE	Central America		115
Mongolia	EMDE	Asia		13
Morocco	EMDE	Africa		33
Mozambique	EMDE	Africa		19
Netherlands	ADV	Europe	107	
New Zealand	ADV	Oceania	45	
Nicaragua	EMDE	Central America		21
Nigeria	EMDE	Africa		103
Norway	ADV	Europe	148	
Oman	EMDE	Middle East		14
Pakistan	EMDE	Asia		51
Panama	EMDE	Asia		105
Paraguay	EMDE	South America		48
Peru	EMDE	South America		46
Philippines	EMDE	Asia		96
Poland	EMDE	Europe		138
Portugal	ADV	Europe	135	
Qatar	EMDE	Middle East		8
Romania	EMDE	Europe		51
Russia	EMDE	Europe		166
Saudi Arabia	EMDE	Middle East		15
Senegal	EMDE	Africa		16
Serbia	EMDE	Europe		56
Singapore	ADV	Asia	55	
Slovak Republic	ADV	Europe	37	
Slovenia	ADV	Europe	40	
South Africa	EMDE	Africa		66
Spain	ADV	Europe	202	
Sri Lanka	EMDE	Asia		36
Suriname	EMDE	Caribbean		4
Sweden	ADV	Europe	85	
Switzerland	ADV	Europe	173	
Tanzania	EMDE	Africa		50
Thailand	EMDE	Asia		50
Trinidad and Tobago	EMDE	Caribbean		21
Turkey	EMDE	Europe		106
Uganda	EMDE	Africa		40
UK	ADV	Europe	169	
Ukraine	EMDE	Europe		134
United Arab Emirates	EMDE	Middle East		31
Uruguay	EMDE	South America		60
USA	ADV	North America	186	
Vietnam	EMDE	Asia		62
Zambia	EMDE	Africa		32
Total			3661	3734

Data sources: Fitch-Connect and IMF. *ADV* advanced countries, *EMDE* emerging market and developing economies

Appendix 2

Macroprudential variables

See Tables 16 and 17.

Table 16 Instruments in the IMF iMaPP integrated macroprudential policy database

Individual macroprudential instruments	Abbreviation	Definition
Countercyclical buffer	CCB	A requirement for banks to maintain a countercyclical capital buffer. Implementations at 0% are not considered as a tightening in dummy-type indicators
Conservation buffer	CONSERVATION	Requirements for banks to maintain a capital conservation buffer, including the one established under Basel III
Capital requirements	CAPITAL	Capital requirements for banks, which include risk weights, systemic risk buffers, and minimum capital requirements. Countercyclical capital buffers and capital conservation buffers are captured in the above measures respectively and thus not included here
Leverage requirements	LVR	A limit on leverage of banks, calculated by dividing a measure of capital by the bank's non-risk-weighted exposures (e.g., Basel III leverage ratio)
Provisioning requirements	LLP	Loan-loss provision requirements for macroprudential purposes, which include dynamic provisioning and sectoral provisions (e.g., housing loans)
Credit growth limits	LCG	Limits on growth or the volume of aggregate credit, the household-sector credit, or the corporate-sector credit by banks, and penalties for high credit growth
Loan restrictions	LOANR	Loan restrictions, that are more tailored than those captured in "LCG". They include loan limits and prohibitions, which may be conditioned on loan characteristics (e.g., the maturity, the size, the LTV ratio and the type of interest rate of loans), bank characteristics (e.g., mortgage banks), and other factors
Limits on Foreign Currency Loans	LFC	Limits on foreign currency (FC) lending, and rules or recommendations on FC loans
Loan-to-value limits	LTV	Limits to the loan-to-value ratios, including those mostly targeted at housing loans, but also includes those targeted at automobile loans, and commercial real estate loans
Debt-to-income limits	DSTI	Limits to the debt-service-to-income ratio and the loan-to-income ratio, which restrict the size of debt services or debt relative to income. They include those targeted at housing loans, consumer loans, and commercial real estate loans
Levy/Tax on Financial Institutions	TAX	Taxes and levies applied to specified transactions, assets, or liabilities, which include stamp duties, and capital gain taxes
Liquidity measures	LIQUIDITY	Measures taken to mitigate systemic liquidity and funding risks, including minimum requirements for liquidity coverage ratios, liquid asset ratios, net stable funding ratios, core funding ratios and external debt restrictions that do not distinguish currencies
Loan to deposit limits	LTD	Limits to the loan-to-deposit (LTD) ratio and penalties for high LTD ratios
Limits on FX operations	LFX	Limits on net or gross open foreign exchange (FX) positions, limits on FX exposures and FX funding, and currency mismatch regulations
Reserve requirements	RR	Reserve requirements (domestic or foreign currency) for macroprudential purposes. This category may currently include those for monetary policy as distinguishing those for macroprudential or monetary policy purposes is often not clear-cut
SIFI surcharges	SIFI	Measures taken to mitigate risks from global and domestic systemically important financial institutions (SIFIs), which includes capital and liquidity surcharges
Other macroprudential measures	Other	Macroprudential measures not captured in the above categories—e.g., stress testing, restrictions on profit distribution, and structural measures (e.g., limits on exposures between financial institutions)

Source: Alam et al. [54], IMF [53]. The database covers a sample from 1990 to 2021, with monthly data which we have cumulated over time and annualised

Table 17 Summary instruments derived from the IMF iMaPP integrated Macroprudential Policy Database

Summary macroprudential instruments	Abbreviation	Definition
All measures	MAPP-INDEX	Sum-total of the instruments listed in Table 2
Loan-targeted measures	LOAN-TARGETED	Sum of the "Demand" and the "Supply-loans" instruments
Demand-targeted measures	DEMAND	Sum of loan-to-value limits and debt-to-income limits
Supply-targeted measures	SUPPLY-ALL	Sum of all the instruments listed in Table 2 except loan-to-value limits and debt-to-income limits
Loan-supply targeted measures	SUPPLY-LOANS	Sum of provisioning requirements, credit growth limits, loan restrictions, limits to the loan to deposit ratio, and limits to foreign currency loans
General supply targeted measures	SUPPLY-GENERAL	Sum of reserve requirements, liquidity requirements, and limits to FX positions
Capital-related supply measures	SUPPLY-CAPITAL	Sum of leverage, countercyclical buffers, conservation buffers, and capital requirements

Source: Alam et al. [54], IMF [53]. The database covers a sample from 1990 to 2021 with monthly data, which we have cumulated over time and annualised. Note that the summary measures supply-capital and supply-general omit SIFI surcharges as they include both capital and liquidity elements [54]

Appendix 3

Further regressions

(1) Results for three further breakdowns of the data
- Advanced countries and emerging market and developing countries
- Large and small banks
- Pre and post Global Financial Crisis (1990–2007 and 2008–2022)

(2) Results for risk and profitability for the global sample
(3) Results for interaction of macroprudential policy and the Lerner Index
(4) Results for nonlinear effects of macroprudential policy
(5) Results for a difference in difference framework for the introduction of Basel III buffers

See Tables 18, 19, 20, 21, 22, 23, 24, 25, 26.

Table 18 Results for noninterest income (1990–2022), subdivided by country-development, bank size and pre and post Global Financial Crisis

Sample	Advanced countries		Emerging and developing economies		Large banks		Small banks		1990–2007		2008–2022	
Dependent	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR
C	4.898*** (7.0)	31.8*** (8.0)	7.575*** (5.6)	53.3*** (5.3)	5.07*** (5.7)	13.36*** (4.4)	8.668*** (7.1)	41.04*** (4.7)	12.36*** (8.5)	54.07*** (5.9)	9.58*** (8.1)	66.67*** (5.7)
Lagged dependent (− 1)	0.696*** (21.0)	0.421*** (17.3)	0.439*** (24.5)	0.342*** (15.1)	0.558*** (11.6)	0.409*** (19.6)	0.486*** (20.7)	0.308*** (16.4)	0.323*** (9.7)	0.271*** (10.3)	0.489*** (16.6)	0.321*** (15.1)
Bank size (− 1)	− 0.21*** (6.7)	− 1.11*** (3.4)	− 0.32*** (4.9)	− 1.089** (2.4)	− 0.2*** (5.2)		− 0.427*** (6.6)	− 1.063** (2.4)	− 0.54*** (7.9)	− 1.31*** (3.1)	− 0.39*** (7.0)	− 2.034*** (4.0)
Capital ratio (− 1)										− 9.27*** (3.0)		
Credit risk (− 1)	− 0.5*** (3.8)	0.327** (2.1)		0.228*** (3.9)		0.568*** (4.1)	− 0.0292** (2.1)	0.123* (1.8)				− 0.357*** (3.0)
Cost/income (− 1)		0.139*** (7.1)				0.0903*** (5.2)		0.0409*** (3.9)				0.0872*** (5.4)
ROAA (− 1)	− 0.08*** (2.7)	0.73*** (3.3)				0.713*** (2.9)	− 0.05*** (2.7)					0.4*** (3.3)
Net interest margin (− 1)	0.0468** (2,5)	− 1.12*** (5.6)	0.039*** (3.0)	− 0.56*** (3.0)		− 1.09*** (4.5)	0.452*** (2.7)	− 0.348*** (3.6)				− 1.035*** (4.2)
Loan-asset ratio (− 1)		− 5.6*** (3.6)		− 9.7*** (4.4)	− 0.188* (1.8)	− 5.828*** (3.9)		− 7.77*** (4.9)		− 9.27*** (5.0)	− 0.45*** (3.4)	− 9.64*** (6.2)
Lerner index (− 1)	− 0.56*** (4.3)	6.426*** (3.0)	− 1.17*** (4.8)	− 4.88*** (3.6)	− 0.66*** (4.1)		− 0.628*** (3.1)		− 0.662** (2.5)	− 8.21*** (4.6)	− 0.79*** (4.6)	5.403*** (2.7)
Banking crisis				2.659** (2.7)	− 0.11*** (2.8)			1.904** (2.2)		2.932* (2.6)		− 1.926** (2.4)
Inflation			0.0083* (1.8)				0.0183*** (5.1)	0.0862*** (3.4)	0.0073* (1.7)		0.0126** (2.2)	
R^2	0.775	0.63	0.57	0.46	0.712	0.623	0.631	0.514	0.442	0.459	0.619	0.478
SE	0.953	12.7	2.397	14.5	1.11	12.12	2.081	17.13	2.371	17.3	1.815	14.42
Periods	30	31	30	31	31	32	31	32	15	16	16	16
OBS	41,554	42,170	31,017	30,604	45,792	47,656	31,181	35,496	31,232	35,548	48,779	46,784
Banks	3051	3055	2877	2890	3402	3480	3972	4325	4143	4574	4719	4671

Notes: For variable definitions see Table 1. NIIAA is noninterest income as a proportion of average assets, NIR is noninterest income as a proportion of total income,. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. GDP growth was not significant in these regressions

Table 19 Results for summary macroprudential instruments (1990–2022), subdivided by country-development, bank size and pre and post Global Financial Crisis

Subsample	Advanced countries		Emerging and developing economies		Large banks		Small banks		1990–2007		2008–2022	
Dependent	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR
MAPP-index (− 1)	0.0042* (1.9)	− 0.018 (0.3)	0.0117** (2.4)	0.105* (1.8)	0.00555* (1.8)	0.0243 (0.4)	0.0104* (1.8)	0.0944 (1.5)	0.0151 (1.1)	− 0.0569 (0.2)	0.0128*** (4.1)	0.0948** (2.4)
Loan-targeted (− 1)	0.0109*** (2.9)	0.0366 (0.4)	0.0241 (1.4)	0.135 (0.8)	0.00982* (1.7)	− 0.009 (0.1)	0.031** (2.3)	0.265* (1.7)	0.0451 (1.4)	− 0.295 (0.5)	0.0186** (2.5)	0.162* (1.9)
Demand (− 1)	0.0184*** (3.0)	− 0.014 (0.1)	0.008 (0.2)	− 0.1 (0.3)	0.00526 (0.7)	− 0.2 (1.1)	0.0515** (2.3)	0.297 (1.2)	0.0729 (1.2)	− 0.411 (0.4)	0.0141 (1.0)	0.028 (0.2)
Supply-all (− 1)	0.003 (0.8)	− 0.001 (0.1)	0.0131** (2.4)	0.123* (1.7)	0.00683* (1.7)	0.046 (0.7)	0.0055 (0.8)	0.0793 (1.0)	0.0108 (0.7)	− 0.0647 (0.4)	0.0148*** (4.4)	0.123** (2.4)
Supply-loans (− 1)	0.012* (1.7)	0.162 (0.8)	0.045** (2.1)	0.329 (1.4)	0.0213** (2.0)	0.142 (0.7)	0.0333 (1.5)	0.431** (2.0)	0.045 (1.0)	− 0.331 (0.5)	0.0378*** (3.4)	0.431*** (3.0)
Supply-general (− 1)	− 0.00149 (0.1)	− 0.152 (0.5)	0.0098 (0.8)	0.136 (1.0)	0.0056 (0.7)	0.0671 (0.6)	− 0.0062 (0.5)	0.0409 (0.3)	0.0073 (0.5)	− 0.0281 (0.1)	0.0166* (1.8)	0.083 (0.7)
Supply-capital (− 1)	0.004 (0.7)	0.142 (0.1)	0.0349** (2.0)	0.274** (2.3)	0.0161** (2.2)	0.0621 (0.5)	0.0121 (0.9)	0.0329 (0.2)	0.0223 (0.3)	− 0.781 (0.8)	0.0255*** (3.2)	0.216** (2.1)

Notes: NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table A3.1, with cumulated summary macroprudential variables added one at a time. MAPP INDEX is the sum of dummies for all of 17 categories shown in Appendix Table A2.1. The LOAN TARGETED group consists of the "Demand" and the "Supply-loans" instruments. DEMAND comprises loan-to-value and debt-service-to-interest limits. SUPPLY-LOANS is loan growth limits, provision measures, loan measures, limits to the loan to deposit ratio, and limits to foreign currency loans. SUPPLY-GENERAL is reserve requirements, liquidity requirements, and limits to FX positions. SUPPLY-CAPITAL is leverage, countercyclical buffers, conservation buffers, and capital requirements. See Appendix Table A2.2 for more details on summary variables

Table 20 Results for individual macroprudential instruments (1990–2022), subdivided by country-development, bank size and pre and post Global Financial Crisis

Subsample	Advanced countries		Emerging and developing economies		Large banks		Small banks		1990–2007		2008–2022	
Dependent	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR	NIIAA	NIR
Countercyclical buffer (− 1)	0.0094 (0.4)	0.078 (0.3)	0.0015 (0.1)	0.0837 (0.2)	0.0015 (0.1)	0.0837 (0.2)	0.0616* (1.7)	0.372 (1.1)	Na	Na	0.0188 (0.8)	0.196 (0.9)
Conservation buffer (− 1)	0.0059 (0.4)	0.54* (1.9)	0.0455*** (3.1)	0.683*** (4.2)	0.0455*** (3.1)	0.683*** (4.2)	0.05 (1.4)	0.698* (1.8)	Na	Na	0.0394** (2.3)	0.671*** (3.5)
Capital requirements (− 1)	0.005 (0.6)	− 0.159 (0.8)	0.0077 (0.6)	− 0.182 (1.2)	0.0077 (0.6)	− 0.182 (1.2)	− 0.0007 (0.1)	− 0.209 (0.9)	− 0.0628 (1.1)	− 0.95 (0.8)	0.0242** (2.6)	0.0598 (0.5)
Leverage requirements (− 1)	− 0.106 (0.4)	− 0.355 (0.6)	0.0252 (0.7)	0.0793 (0.1)	0.0252 (0.7)	0.0793 (0.1)	− 0.0095 (0.1)	− 0.373 (0.5)	0.346** (2.1)	0.0709 (0.1)	− 0.0106 (0.4)	0.402 (0.7)
Provisioning requirements (− 1)	0.0332 (1.4)	0.442 (0.9)	0.027 (1.2)	0.0327 (0.1)	0.027 (1.2)	0.0327 (0.1)	0.018 (0.4)	0.654 (1.6)	− 0.019 (0.5)	− 0.59 (0.7)	0.0728* (1.8)	0.937*** (3.0)
Credit growth limits (− 1)	− 0.076 (0.4)	− 0.361 (0.1)	0.119* (1.8)	0.398 (0.3)	0.119* (1.8)	0.398 (0.3)	0.0077 (0.1)	− 1.463 (1.2)	− 0.0462 (0.3)	− 3.445* (1.8)	− 0.0759 (0.4)	0.253 (0.3)
Loan restrictions (− 1)	0.0206 (1.2)	0.071 (0.2)	0.0344** (2.4)	0.253 (1.0)	0.0344** (2.4)	0.253 (1.0)	0.091*** (3.2)	0.715 (1.5)	0.135 (0.3)	1.127 (0.7)	0.0592*** (4.5)	0.602*** (2.7)
Limits on foreign currency loans (− 1)	0.004 (0.5)	0.273 (1.2)	0.0016 (0.1)	0.283 (0.6)	0.0016 (0.1)	0.283 (0.6)	− 0.0137 (0.4)	0.892** (2.5)	0.256** (2.4)	0.006 (0.0)	− 0.018 (0.6)	0.495 (1.1)
Loan to value limits (− 1)	0.0313*** (2.8)	0.09 (0.3)	0.0118 (1.1)	− 0.163 (0.6)	0.0118 (1.1)	− 0.163 (0.6)	0.037 (1.3)	0.287 (0.7)	0.0671 (1.0)	− 0.16 (0.1)	0.00619 (0.5)	− 0.013 (0.1)
debt to income limits (− 1)	0.0189 (1.3)	− 0.316 (0.9)	− 0.00531 (0.3)	− 0.651*** (2.7)	− 0.00531 (0.3)	− 0.65*** (2.7)	0.155** (2.4)	0.741 (1.6)	0.151 (1.0)	− 2.201 (1.3)	0.0582 (1.1)	0.181 (0.5)
Levy/tax on financial institution (− 1)	0.01 (0.8)	− 0.488 (1.5)	0.0075 (0.6)	− 0.275 (1.0)	0.0075 (0.6)	− 0.275 (1.0)	0.0121 (0.5)	− 0.316 (0.8)	0.0747 (1.4)	5.931*** (10.2)	0.0041 (0.3)	− 0.388 (1.6)
Liquidity measures (− 1)	0.0127 (0.8)	0.507 (1.3)	− 0.0058 (0.5)	0.172 (1.5)	− 0.0058 (0.5)	0.172 (1.5)	0.0362 (1.5)	0.637** (2.4)	0.0178 (0.3)	− 0.752 (0.7)	0.00653 (0.4)	0.203 (1.1)
Loan to deposit limits (− 1)	− 0.127** (2.6)	− 2.8*** (3.4)	− 0.927** (2.5)	− 1.668*** (3.6)	− 0.927** (2.5)	− 1.67*** (3.6)	− 0.0928* (1.7)	− 2.6*** (2.8)	− 0.135 (0.3)	0.305 (0.1)	− 0.146*** (3.2)	− 2.02*** (3.8)
Limits on FX operations (− 1)	− 0.154*** (9.2)	− 2.1*** (8.9)	− 0.0597** (2.3)	− 0.886*** (3.0)	− 0.0597** (2.3)	− 0.8*** (3.90)	0.009 (0.1)	− 0.55 (0.9)	− 0.141* (2.0)	− 4.75*** (2.6)	− 0.02 (0.4)	− 0.762 (1.4)
Reserve requirements (− 1)	− 0.0073 (0.6)	− 0.54** (2.1)	0.0117 (1.5)	0.0818 (0.7)	0.0117 (1.5)	0.0818 (0.7)	− 0.0286* (1.8)	− 0.219 (1.1)	0.0094 (0.6)	0.078 (0.4)	0.0237** (2.3)	0.108 (0.8)
SIFI surcharges (− 1)	0.006 (0.3)	0.128 (0.3)	0.0176 (1.1)	0.244 (1.0)	0.0176 (1.1)	0.244 (1.0)	0.0637** (2.1)	0.938** (2.3)	Na	Na	0.0449*** (2.5)	0.466** (2.2)
Other macroprudential measures (− 1)	− 0.007 (0.4)	− 0.18 (0.5)	0.0111 (0.7)	0.238 (1.4)	0.0111 (0.7)	0.238 (1.4)	0.0532 (1.2)	0.248 (0.5)	0.322 (1.4)	0.606 (0.3)	0.0446** (2.5)	0.378* (1.9)

Notes: NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table A3.1, with cumulated macroprudential variables added one at a time. See Appendix Table A2.1 for more details on individual variables

Table 21 Results for risk (Z-score and NPL ratio) and profitability (ROAA) for the global sample (1990–2022)

Dependent	Log Z Score	NPL/loan ratio	Return on average assets
C	0.453 (1.2)	− 5.42*** (2.7)	3.867*** (4.5)
Lagged dependent (− 1)	0.451*** (68.4)	0.68*** (31.9)	0.379*** (17.7)
Bank size (− 1)	0.0478*** (2.8)	0.349*** (3.4)	− 0.178*** (4.7)
Credit risk (− 1)	− 0.0373*** (9.1)	0.158*** (3.4)	
Cost/income (− 1)	− 0.0016*** (3.5)		− 0.00404*** (4.4)
ROAA (− 1)		− 0.142*** (4.0)	NA
Net interest margin (− 1)			0.0569*** (4.7)
Loan-asset ratio (− 1)		4.536*** (6.6)	
Liquidity risk (− 1)	0.197*** (4.2)	− 1.534*** (3.3)	0.24* (1.9)
Lerner index (− 1)	0.131* (1.9)		
Banking crisis	− 0.23*** (4.6)	0.558** (2.3)	− 0.318*** (3.2)
Inflation		0.0184* (1.7)	0.00846** (2.8)
Growth	0.021*** (5.4)	− 0.222*** (6.4)	0.0792*** (5.4)
R^2	0.489	0.712	0.392
SE	0.823	4.055	1.559
Periods	31	32	32
OBS	66,238	50,772	82,622
BANKS	5572	4506	6178

Estimated by panel OLS with time and bank dummies and country-clustered standard errors. For variable definitions see Table 1. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Capital ratios were not significant in these equations

Table 22 Results for summary macroprudential instruments for global sample, with macroprudential policy leveraged by Lerner Index (1990–2022)

Dependent	NIIAA		NIR	
	MP (− 1)	MP (− 1)* LERNER (− 1)	MP (− 1)	MP (− 1)* LERNER (− 1)
MAPP-INDEX (− 1)	0.0074 (1.5)	0.0084 (0.7)	0.039 (0.8)	0.078 (0.9)0
LOAN-TARGETED (− 1)	0.02 (1.6)	0.0026 (0.1)	0.046 (0.4)	0.1 (0.5)
DEMAND (− 1)	0.035 (1.3)	− 0.036 (0.5)	− 0.003 (0.1)	− 0.096 (0.2)
SUPPLY-ALL (− 1)	0.0074 (1.4)	0.0095 (0.7)	0.045 (0.7)	0.11 (1.0)
SUPPLY-LOANS (− 1)	0.021 (1.6)	− 0.049 (1.2)	0.119 (0.7)	0.452 (1.2)
SUPPLY-GENERAL (− 1)	0.012 (1.2)	0.025 (0.7)	0.097 (0.8)	0.074 (0.3)
SUPPLY-CAPITAL (− 1)	0.0019 (0.2)	0.0703** (2.7)	− 0.018 (0.2)	0.454** (2.2)

Notes: NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table 2, with cumulated summary macroprudential variables added one at a time. MAPP INDEX is the sum of dummies for all of 17 categories shown in Appendix Table A2.1. The LOAN TARGETED group consists of the "Demand" and the "Supply-loans" instruments. DEMAND comprises loan-to-value and debt-service-to-interest limits. SUPPLY-LOANS is loan growth limits, provision measures, loan measures, limits to the loan to deposit ratio, and limits to foreign currency loans. SUPPLY-GENERAL is reserve requirements, liquidity requirements, and limits to FX positions. SUPPLY-CAPITAL is leverage, countercyclical buffers, conservation buffers, and capital requirements. LERNER is the Lerner Index for each bank. See Appendix Table A2.2 for more details on summary variables

Table 23 Results for individual macroprudential instruments for global sample, with macroprudential policy leveraged by Lerner Index (1990–2022)

Dependent	NIIAA		NIR	
	MP (− 1)	MP (− 1)* LERNER (− 1)	MP (− 1)	MP (− 1)* LERNER (− 1)
Countercyclical buffer (− 1)	− 0.01 (0.2)	0.136 (1.4)	− 0.096 (0.3)	1.347 (1.6)
Conservation buffer (− 1)	− 0.003 (0.2)	0.171*** (3.2)	0.357 (1.6)	1.166** (2.4)
Capital requirements (− 1)	0.005 (0.3)	0.473 (0.9)	− 0.194 (1.1)	0.381 (0.9)
Leverage requirements (− 1)	− 0.088 (1.6)	0.399*** (2.0)	− 0.173 (0.3)	0.744 (0.5)
Provisioning requirements (− 1)	0.0049 (0.2)	0.16* (2.0)	0.051 (0.2)	0.971 (1.2)
Credit growth limits (− 1)	0.249 (1.5)	− 0.602 (1.5)	0.075 (0.1)	− 1.82 (0.4)
Loan restrictions (− 1)	0.023 (1.1)	0.106 (1.4)	0.157 (0.5)	1.03 (1.5)
Limits on foreign currency loans (− 1)	0.009 (0.4)	0.039 (0.4)	0.485 (1.5)	− 0.1 (0.2)
Loan to value limits (− 1)	0.033 (1.3)	− 0.025 (0.4)	0.032 (0.1)	− 0.144 (0.2)
Debt to income limits (− 1)	0.089 (1.0)	− 0.108 (0.6)	− 0.083 (0.2)	− 0.178 (0.2)
Levy/tax on financial institution (− 1)	− 0.07* (1.9)	0.286** (2.5)	− 0.592 (1.6)	1.851*** (3.5)
Liquidity measures (− 1)	− 0.018 (0.9)	0.14* (1.8)	0.047 (0.3)	1.064** (2.5)
Loan to deposit limits (− 1)	− 0.061 (0.6)	− 0.269 (1.1)	− 3.375*** (3.1)	2.327 (0.8)
Limits on fx operations (− 1)	0.0198 (0.3)	− 0.244 (1.5)	− 0.379 (0.6)	− 0.716 (0.6)
Reserve requirements (− 1)	0.239 (1.6)	− 0.076 (1.2)	0.169 (1.2)	− 0.508 (1.6)
Sifi surcharges (− 1)	0.0052 (0.3)	0.136*** (2.9)	0.345 (1.4)	0.622 (1.4)
Other macroprudential measures (− 1)	0.0192 (0.5)	0.039 (0.3)	0.2 (0.7)	0.381 (0.6)

Notes: NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors Coefficient values are reported and the t-statistics are reported in parenthesis. ***Significant at 1%, **significant at 5%, *significant at 10%. Each equation includes all the control variables shown in Table 2, with cumulated macroprudential variables added one at a time. LERNER is the Lerner Index for each bank. See Appendix Table A2.1 for more details on individual variables

Table 24 Results for summary macroprudential instruments for global sample, with macroprudential policy entered as a level and squared (1990–2022)

Dependent	Total non interest income				Fee income		Non-fee income	
	NIIAA		NIR		NIFEEAA	NIFEER	NINON-FEEAA	NINON-FEER
	MP (− 1)	MP (− 1) **2	MP (− 1)	MP (− 1)**2	MP (− 1)**2	MP (− 1) **”	MP (− 1)**2	MP (− 1) **2
Mapp-index (− 1)	0.0065 (1.6)	0.0007* (1.7)	− 0.042 (0.8)	0.00183*** (3.5)	0.00078*** (2.9)	0.00048 (1.0)	− .000104 (0.3)	0.00061 (1.2)
Loan-targeted (− 1)	0.0157 (1.3)	0.0003 (0.9)	− 0.171 (1.2)	0.0137** (2.4)	0.00069*** (3.1)	0.009** (2.1)	− 0.00023 (0.7)	− 0.00376 (1.0)
Demand (− 1)	0.0095 (0.5)	0.0018 (1.6)	− 0.462** (2.0)	0.047** (2.8)	0.0018** (2.2)	0.0244 (1.6)	0.00069 (0.7)	0.0036 (0.3)
Supply-all (− 1)	0.0048 (1.0)	0.00015** (2.2)	− 0.044 (0.7)	0.003*** (3.6)	0.00012*** (3.1)	0.00081 (1.1)	0.000014 (0.2)	0.00132* (1.8)
Supply-loans (− 1)	0.0173 (1.2)	0.002** (2.5)	− 0.13 (0.7)	0.0402*** (3.3)	0.002*** (4.7)	0.0203** (2.0)	0.000005 (0.1)	− 0.0055 (0.6)
Supply-general (− 1)	− 0.0011 (0.2)	0.00053*** (2.9)	− 0.0601 (0.6)	0.0088*** (3.1)	0.00027 (1.5)	0.0029 (1.3)	0.000198 (1.1)	0.0032 (1.2)
Supply-capital (− 1)	0.0334* (1.8)	− 0.00095 (0.9)	0.13 (0.7)	− 0.0033 (0.3)	0.000273 (0.7)	− 0.00037 (0.1)	− 0.00136* (1.8)	0.00277 (0.3)

Notes: NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. NIFEEAA is fee income as a proportion of average assets and NIFEER is fee income as a proportion of total income NINON-FEEAA is non-fee noninterest income as a proportion of average assets and NINON-FEER is non-fee noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table 2, with cumulated summary macroprudential variables added one at a time. MAPP INDEX is the sum of dummies for all of 17 categories shown in Appendix Table A2.1. The LOAN TARGETED group consists of the “Demand” and the “Supply-loans” instruments. DEMAND comprises loan-to-value and debt-service-to-interest limits. SUPPLY-LOANS is loan growth limits, provision measures, loan measures, limits to the loan to deposit ratio, and limits to foreign currency loans. SUPPLY-GENERAL is reserve requirements, liquidity requirements, and limits to FX positions. SUPPLY-CAPITAL is leverage, countercyclical buffers, conservation buffers, and capital requirements. See Appendix Table A2.2 for more details on summary variables

Table 25 Results for individual macroprudential instruments for global sample, with macroprudential policy entered as a level and squared (1990–2022)

Dependent	Total non interest income				Fee income		Non-fee income	
	NIIAA		NIR		NIFEEAA	NIFEER	NINON-FEEAA	NINON-FEER
	MP (− 1)	MP (− 1) **2	MP (− 1)	MP (− 1) **2	MP (− 1)**2	MP (− 1) **2	MP (− 1) **2	MP (− 1) **2
Countercyclical buffer (− 1)	0.0147 (0.3)	0.007 (0.4)	1.012 (1.4)	− 0.291 (1.5)	− 0.0043 (0.3)	0.222 (1.6)	0.0053 (1.0)	0.0433 (0.6)
Conservation (− 1)	0.043 (1.5)	0.0003 (0.1)	1.013*** (3.1)	− 0.068 (1.2)	0.0067** (2.5)	− 0.0828* (1.8)	− 0.00255 (1.3)	0.00272 (0.1)
Capital requirements (− 1)	0.022 (1.2)	− 0.0007 (0.5)	− 0.302 (1.2)	0.0194 (1.1)	0.00057 (1.2)	0.0072 (0.7)	0.00181 (1.5)	0.00965 (0.6)
Leverage requirements (− 1)	0.0005 (0.1)	0.0132 (0.9)	− 0.99 (1.3)	0.577** (2.4)	0.00035 (0.1)	− 0.048 (0.3)	0.018** (2.5)	0.55*** (3.0)
Provisioning requirements (− 1)	0.045 (1.2)	0.0008 (0.1)	0.405 (1.2)	− − 0.035 (0.5)	0.0045 (1.6)	− 0.081 (1.5)	0.0031 (0.5)	0.0153 (0.2)
Credit growth limits (− 1)	0.331* (1.9)	− 0.168* (1.8)	1.676 (1.0)	− 1.543** (2.2)	− 0.038 (1.7)	− 0.651 (1.5)	− 0.137 (1.6)	− 1.034 (1.3)
Loan restrictions (− 1)	0.0357* (1.7)	0.0029 (1.6)	− 0.133 (0.4)	0.0741** (2.7)	0.0035*** (3.9)	0.034 (1.7)	− 0.00032 (0.3)	0.0036 (0.2)
Limits on foreign currency loans (− 1)	− 0.0105 (0.2)	0.0067 (0.6)	− 0.532 (0.7)	0.234** (2.4)	0.0062 (1.2)	0.00015 (0.1)	0.00229 (0.3)	0.149 (1.3)
Loan to value limits (− 1)	0.006 (0.4)	0.0041** (2.2)	− 0.482* (1.7)	0.083*** (3.6)	0.0038*** (4.1)	0.054*** (2.7)	0.00192 (1.2)	0.0043 (0.2)
Debt to income limits (− 1)	0.074 (0.7)	− 0.0045 (0.2)	− 0.692 (1.0)	0.111 (0.9)	0.0442 (1.2)	0.068 (1.1)	− 0.0102 (0.7)	− 0.0879 (0.8)
Levy/tax on financial institution (− 1)	0.0062 (0.3)	0.0012 (0.3)	0.367 (0.9)	− 0.146* (1.9)	0.00183 (0.7)	− 0.079* (2.0)	0.00232 (1.3)	− 0.0494 (1.1)
Liquidity measures (− 1)	0.0055 (0.3)	0.0024 (1.0)	0.345* (1.8)	0.0023 (0.1)	0.00155 (1.6)	0.011 (0.5)	− 0.00069 (0.4)	− 0.0265 (1.4)
Loan to deposit limits (− 1)	− 0.122*** (2.9)	0.0254 (1.2)	− 2.43*** (3.8)	0.441 (1.3)	− 0.0045 (0.9)	0.194 (0.9)	− 0.0149 (0.8)	0.0536 (0.2)
Limits on FX operations (− 1)	− 0.033 (0.6)	− 0.039 (1.6)	0.079 (0.1)	− 0.37 (1.2)	0.0056 (0.6)	− 0.22*** (2.9)	− 0.0157 (0.9)	0.154 (1.0)
Reserve requirements (− 1)	− 0.00028 (0.1)	0.00054 (1.2)	− 0.117 (0.8)	0.0137** (2.1)	0.0002 (0.6)	0.077** (2.0)	0.00022 (1.1)	0.00117 (0.3)
SIFI surcharges (− 1)	0.0851*** (3.1)	− 0.0127* (1.7)	0.959* (1.9)	− 01.24 (1.1)	− 0.0032 (0.8)	0.153 (0.3)	− 0.0088** (2.1)	− 0.074 (1.3)
Other macroprudential measures (− 1)	0.0113 (0.4)	0.0039 (0.9)	0.133 (0.3)	0.0373 (0.9)	0.0037 (1.2)	− 0.037 (1.2)	− 0.000137 (0.1)	0.0147 (0.5)

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. NIFEEAA is fee income as a proportion of average assets and NIFEER is fee income as a proportion of total income NINON-FEEAA is non-fee noninterest income as a proportion of average assets and NINON-FEER is non-fee noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors. Coefficient values are reported and the t-statistics are reported in parenthesis. ***Significant at 1%, **significant at 5%, *significant at 10%. Each equation includes all the control variables shown in Table 2, with cumulated macroprudential variables added one at a time. See Appendix Table A2.1 for more details on individual variables

Table 26 Results for difference in difference estimation for effects of Basel III measures in countries that implemented buffers, with Basel III introduction years set for treatment, for global sample, (1990–2022)

Dependent	NIIAA		NIR	
Basel III measure	Counter cyclical buffer	Conservation buffer	Counter cyclical buffer	Conservation buffer
Treatment year				
2013	0.137* (1.7)	0.139* (1.8)	1.989* (1.8)	3.599*** (3.2)
2014	0.127* (1.8)	0.112 (1.7)	1.977* (1.8)	3.244*** (3.0)
2015	0.114* (1.8)	0.126* (1.9)	2.019* (2.0)	3.146*** (3.0)

NIIAA is noninterest income as a proportion of average assets and NIR is noninterest income as a proportion of total income. Estimated by panel OLS with time and bank dummies and country-clustered standard errors.The treatment variables are "1" for banks in countries that actually introduced the respective buffers by or during the year, or subsequent to those shown and zero for all other observations. Coefficient values are reported and the t-statistics are reported in parenthesis. *** Significant at 1%, ** significant at 5%, * significant at 10%. Each equation includes all the control variables shown in Table 2

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