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Risk-Taking Channel and Its Non-Linearities: The Case of an Emerging Market Economy*

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Abstract

We test whether the risk-taking channel of monetary policy transmission mechanism is active in Poland, an emerging market economy. Based on confidential bank-level data we construct novel measures of risk taken by banks, and exploit asymmetries in bank lending with respect to the level of the interest rate and across bank types in order to identify the risk-taking channel. Our results provide some evidence of the risk-taking behavior of Polish banks. However, only in the segment of large loans to non-financial corporations we are able to conclude that increased risk of new loans after lowering short-term interest rates represents supply-side phenomenon. We show that the loosening of monetary policy has different effects depending on the initial level of interest rates and this effect is different across banks, depending on their size, liquidity and funding structure. Our results contribute to the ongoing discussion on consequences of conducting monetary policy in the low interest rate environment as currently observed in many advanced and emerging economies.

1. Introduction

Loosening of monetary policy typically makes banks grant more loans, as a result of the operation of the traditional interest rate and credit channels. As far as conventional view on the monetary transmission focuses on the quantity of loans, growing literature suggests that the risk profile of loans and the so-called risk-taking channel can be another significant dimension of the effects of monetary policy. The importance of this channel seems particularly large in the current environment of low interest rates, supplemented and supported in a number of economies with unconventional monetary policy measures. When banks perceive nominal interest rates on risk-free instruments, such as government bonds, as low and expect them to remain low for an extended period, they can be willing

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to search for yield (Rajan, 2006) and accept more risk for contractual or institutional reasons (Gambacorta, 2009; Borio and Zhu, 2012), increasing supply of loans more than it would result from the operation of conventional credit channel (Paligorova and Santos, 2017). Expectations that interest rates will remain low for a prolonged period—as signalled nowadays in communication by many central banks—constitute a crucial element activating the risk-taking channel. In such circumstances banks may not only offer an excessive amount of higher-risk loans, but also under-price these loans, not reflecting the real cost of risk (Paligorova and Santos, 2017).

From the policy perspective, risk-taking behavior is also a natural concern for macroprudential policy, due to its financial stability implications. More bank lending might help an economy expand again at the rate closer to its potential (as a low interest rate environment is usually a symptom of subdued economic conditions). The concern might be that the rebound in credit growth, fuelled with low interest rates, might result in excessive risk taking, leading to financial stability concerns at later stages of the business cycle. Therefore, the empirical assessment of the risk-taking channel could also be relevant for the research on interactions between monetary policy and financial stability.

Considerable amount of empirical evidence confirms that the risk-taking channel is active, especially in large advanced economies like US and the euro area/euro area economies (e.g. Altunbas et al., 2014; Delis and Kouretas, 2011; Delis et al., 2017; Gambacorta, 2009; de Bondt et al., 2010). Several studies investigate also selected aspects of risk-taking behavior in emerging economies (e.g. Chen et al., 2017; Özşuca and Akbostancı, 2016; Drakos et al., 2016). For example, Jiménez et al. (2014) show that in the low interest rate environment banks are more willing to grant loans to firms with higher default probability, these loans have higher volume and are more likely to be uncollateralized. Other authors stress that not only the level of interest rates matter for the risk-taking behavior but also the duration of period of low interest rates (Dell'Ariccia et al., 2017; Maddaloni and Peydró, 2011). Literature suggests also that some banks are more vulnerable to risk-taking behavior than others (Altunbas et al., 2014; Buch et al., 2014; Dell'Ariccia et al., 2017).

The aim of our study is to test whether the risk-taking channel operates in the Polish economy. We propose the measures of the new risk at the bank level, using the highest possible level of disaggregation of bank loan portfolio and risk weights of different types of loans being to a large extent forward-looking, and use them to assess the impact of monetary policy decisions concerning short-term interest rates on the risk profile of new loans. As the risk-taking channel of monetary policy works through loan supply, we identify it by assessing if banks with different characteristics adjust differently the risk of new loans to changes in the level of short-term interest rates. The analytical method applied captures potential non-linear effects, i.e. allows identifying different impact of monetary policy on the new risk taken by banks for different levels of the interest rates.

Poland seems a promising laboratory for testing the existence of the risk-taking channel for a number of reasons. Two of them seem the most important. First, the headline short-term interest rate of Narodowy Bank Polski (NBP)—the Polish central bank—has remained at the historically lowest, albeit positive, level (1.5%) for a very long time, i.e. since early 2015, and stayed there beyond the end of our sample. Second, since the beginning of its transition from centrally-planned to a market economy (1989) Polish banking sector has developed considerably. During the period under consideration, i.e.

2008-2018, the credit-to-GDP ratio was substantially larger than in the previous years, mainly due to an increase in housing loans granted to households.[1] It is likely that the process of financial deepening, involving extension of loan activity towards new borrowers, was driven not only by demand factors, but with a strong role of supply-side factors. Such environment seems to facilitate the identification of the risk-taking channel.

We contribute to the literature offering two principal novelties. Firstly, in terms of the analytical set-up we propose a novel empirical specification for assessing the existence of the risk-taking channel, i.e. we explicitly test whether the bank reaction depends on the level of interest rates by introducing terms that are nonlinear with respect to the interest rate. Secondly, we introduce bank-level measures of risk taking, which seem more precise than the measures used so far in the literature covering risk-taking channel of monetary policy in emerging market economies. More specifically, the construction of our proxies for risk taken by banks relies on confidential data from supervisory reporting that contains inter alia information on so-called "large exposures". In general, the proxies of risk take into account volumes of new loans granted to different NACE sections or business lines and precisely define ex-ante risks of those exposures.

On the top of that, to our best knowledge our study constitutes the first attempt to analyze in detail the operation of the risk-taking channel in the Polish economy. Our paper is to certain degree related to Wróbel (2018) and Górajski et al. (2019). The former study investigates the response of lending standards set by Polish banks to monetary policy shocks. The finding that lower monetary policy rate contributes to softening of lending standards is in line with operation of the risk-taking channel. The latter study employs the same data on "large exposures" as we do in the present paper to construct conditional expected time to default, a credit risk measure intended to inform about time of default of corporate loans under stress conditions. Based on this new measure the authors find that credit risk in the Polish banking sector is positively related to GDP growth.

In general, we find some evidence of the risk-taking behavior of Polish banks. In all cases considered—for the whole portfolio of loans to the non-financial sector and for portfolio of large loans to the non-financial firms—there is a negative non-linear relationship between new risk taken by banks and the interest rate level. However, only in the segment of large loans to the non-financial firms we are able to conclude that increased risk of new loans represents supply-side phenomenon. Our robust evidence on the risk-taking channel in segment of loans to non-financial firms corroborate findings for other economies. We show that the loosening of monetary policy has different effects depending on the initial level of interest rates—the lower the interest rate is, the larger the increase in risk that is generated by the lowering of interest rate. This response is also different across banks, with stronger reaction displayed by banks that are large, with low liquidity and low share of deposits.

The paper is structured in the following way. Section 2 describes our motivation and a way of thinking about the risk-taking channel. In section 3 we present an approach to identify this mechanism in the banking sector with a particular focus on the construction of the measures of risks taken by banks. This section also includes a description of a model

[1] In these years the share of households with housing loans has been gradually growing—from 7% in 2006 and 9.6% in 2008 to 15.7% in 2018. In the same period, the ratio of housing loans to GDP increased from 7.6% in 2006 and 15.4% in 2008 to 20.4% in 2018.

specification and data applied in the study. In section 4 we discuss the main results, while the final section concludes.

2. Stylised View on the Risk-Taking Channel

The risk-taking channel implies that banks have incentives to increase the riskiness of their operations in response to prevailing low interest rate environment. The literature so far has offered neither a convincing theoretical model explaining this channel of monetary transmission, nor consensus about the economic processes behind it. Two of them seem, however, the most important (Gambacorta, 2009). First, shareholders of banks and other financial institutions usually require managers of these entities to attain pre-set nominal rates of return, which tend to be relatively stable over time. Declining policy interest rates trigger a decrease in the rates of return on risk-free assets, therefore to attain the intended profits, agents seek riskier assets, ones that would generate higher yields. Second, a reduction of interest rates boosts the value of assets and collateral, resulting in lower assessment of default likelihood of potential borrowers and a fall of risk perceived by banks.

Our preferred economic story behind the risk-taking channel stresses the importance of incentives faced by bank senior executives (Fahlenbrach and Stulz, 2011). In particular, performance-based bonuses are a widespread phenomenon in the banking industry. However, inherent uncertainty related to future outcome of bank business activities implies that the "performance" is to a large extend a realization from some stochastic process (therefore it is not fully a signal about an effort or competence). Therefore, given such randomness, a bank executive making some business decisions can only influence parameters of the process behind the random outcome. This randomness, however, is quite often neglected in contracts between shareholders and hired bank executives, resulting sometimes in adverse incentives for the latter.

Anecdotal evidence suggests that contracts between shareholders and bank managers quite often stipulate that a lump sum bonus payment is triggered if certain targets—set in terms of return on equity—are met (Cai et al., 2010). Such a framework incentivises the managers to achieve some profitability level within the constraints of bank equity (as the scope for risk-taking is limited by bank equity). Due to risk-return trade-off, a higher profitability target implies the necessity to increase the risk of bank operations. However, higher risk of bank operations implies higher volatility of bank profits (DeYoung and Roland, 2001), affecting the probability of bank executives receiving a bonus payment. On the other hand, a low realization of bank profits might imply reputational losses for the bank managers and a deterioration in prospects for future income. Therefore, the bank executive decision problem is to construct the bank risk profile in such a way that expected bonus payments are maximized.

The net interest margin (NIM) constitutes an important part of banks' profit. In the low interest rate environment the NIM might be squeezed due to the zero lower bound for bank financing sources (Claessens et al., 2018)—i.e. with market interest rates going low, banks cannot further decrease interest rate costs for some instruments (e.g. nonfinancial sector deposits with interest rates already very close to 0), while the interest income (e.g.

for loans) is still decreasing.[2] Bank business lines might have quite different NIM elasticities with respect to changes in the level of interest rates. Since safer business lines (e.g. mortgage lending) tend to be associated with lower interest rate spreads (due to lower inherent credit risk) than more risky types of bank activity (e.g. consumer loans), the former ones are more vulnerable to profitability deterioration in the low interest rate environment. For a bank with relatively large importance of low-risk business lines, this could imply a lower probability of bank executives receiving bonus payments. To restore the previous level of expected bonus payments, the bank management might be forced to allocate more resources to higher-risk higher-return business lines, resulting in the type of behavior summarized as the bank risk-taking channel.

Operating in a low interest rate environment is a challenge common for all banks active in a given economy. Therefore, all the banks face challenges related to lower profitability of their business and incentives to improve profits by gravitating towards a more risky business profile. The question is whether there are any factors that could prevent a bank from taking more risk in order to shift the distribution of potential profits to the right.

Having capital buffers, i.e. bank equity above the level implied by capital requirements, is a necessary condition for increasing risk exposure by a bank.[3] Banks with low capital buffers might be restricted in their capacity to take more risk. On the other hand, lower interest rate levels might result in lower credit risk for existing borrowers (as they have to use smaller fractions of their cash flows to service debt), therefore releasing some economic capital for new risk-taking. Even if the net effect is ambiguous, it seems important to control for capital buffers in empirical specification. Another important factor might be the bank size. First, big banks might enjoy implicit "too big to fail" subsidy, making it easier for them to move to more risky activities (Davies and Tracey, 2014). Second, large banks are more likely to finance large infrastructure projects for which financing might be not viable when interest rates are high. Therefore, larger banks might be more likely to have a change in customer structure when interest rates go low. On the other hand, big banks might have access to a wider spectrum of potential funding sources, allowing them to have better control over interest costs, so decreasing the incentive to increase risk-taking to restore profitability.

The source of funding, including the importance of deposit funding, might be another variable influencing bank reaction to low market interest rates. On the one hand, banks with large share of non-financial sector deposits might encounter problems with further lowering of interest costs when deposit interest rates are already close to zero (Eggertsson et al., 2019). On the other hand, banks with dominating market-based funding sources might have initially lower net interest margins, so might be more susceptible to any negative profitability shocks. The net effect of a given amount of deposit funding on the potential occurrence of the bank risk-taking channel is therefore ambiguous.

Bank liquidity is often a factor considered among determinants of bank reaction to different shocks, including monetary policy shocks. A larger share of liquid instruments

[2] Using a large sample of banks from 47 countries Claessens et al. (2018) find that a one percentage point interest rate drop implies an 8 basis points lower net interest margin, with this effect significantly larger (20 basis points) at low rates.

[3] This statement needs to be qualified, though. For banks using standardized approach to calculating capital requirements for credit risk it is possible to increase risk taken by substituting lower-risk borrowers with high-risk borrowers within the same risk weight class.

in bank assets might be a signal of high risk aversion of the bank management (as liquid assets can be used as a cushion in case of adverse shocks hitting a bank), even if it worsens bank ability to generate profits. If it is the case, risk averse bank executives would be less willing to take additional risk to improve profitability. Moreover, valuation of fixed coupon financial instruments (like e.g. liquid government bonds) will increase with interest rates going down, hence improving profits and mitigating incentives to beef up profits by taking more credit risk.

Empirical studies suggest that the above characteristics have, indeed, an impact on banks' risk-taking. Capital buffers, smaller deposit ratios and smaller liquidity are usually found to decrease risk taken by banks (e.g. Acharya and Naqvi, 2012; Khan et al., 2017; Laeven et al., 2016), while in the case of bank size the evidence is mixed (e.g. Boyd and Runkle, 1993; de Haan and Poghosyan, 2012; Laeven et al., 2016).

3. Methods and Data

3.1 Identification of Risk-Taking Channel and Defining Risk Measures

Identification of the risk-taking behavior of banks poses an empirical challenge, especially given constrains in data availability. The main reason is that even if an increase in bank risk-taking in a low interest rate environment is visible in the data, it is not straightforward to conclude that such a phenomenon has been driven by bank behavior. An alternative explanation might be that the lower level of interest rates affects the structure of loan demand—i.e. some more risky non-financial sector agents decide to apply for loans only in a low interest rate environment. An empirical approach to determine whether changes in bank risk-taking are supply-side or demand-side driven depends on data available to a researcher. One possibility is to fully control for developments on the demand side of the credit market. This is possible e.g. if information on loan applications is available (e.g. Jiménez et al., 2014). If the structure of loan applicants population is similar in low interest rate and high interest rate periods, the conclusion could be that any resulting changes in the bank risk-taking is due to bank active decision to change the structure of loan applicants accepted. However, having an access to full information on loan applications is a quite rare situation. Another approach is to use bank-level data and to test whether there is any systematic relationship between bank characteristics and bank risk-taking behavior at different levels of interest rates. Given data limitations, it is the approach we use in this paper.

Another difficulty refers to finding a good proxy for risk. Many authors refer to survey data based on loan officer surveys (cf. Maddaloni and Peydró, 2011). A loosening of lending standards is interpreted as indicative of improved access to credit for low-quality borrowers. However, this assumption is dubious. As pointed out by Dell'Ariccia et al. (2017), typical lending surveys (e.g. the ECB's Bank Lending Survey, BLS or the Federal Reserve's SLOOS) provide information only about whether lending standards have changed relative to the recent past, not about the absolute level of strictness of lending criteria. Moreover, a decline in lending standards may reflect an improvement in the quality of the borrowers, not the increased willingness of banks to take more risk. Other studies testing the existence of the risk-taking channel use ex-post risk measures, such as nonperforming loans, NPLs (Delis and Kouretas, 2011). The measures of this kind seem problematic due to the fact that they reflect ex-post realized risk, not the ex-ante risk taken by banks that is a key element in the risk-taking channel considerations. On the

other hand, market-based risk measures (e.g. Expected Default Frequency, EDF – Gambacorta, 2009; Altunbas et al., 2014), although potentially forward-looking, reflect changes in total riskiness of banks (i.e. due to new lending and the change in risk of the pre-existing portfolio), making it cumbersome to isolate the effect of the current interest rate environment on the current risk-taking decisions of bank managers. Moreover, market-based measures assume validity of the efficient market hypothesis. If this assumption is not met, market-based measures might be biased due to waves of excessive optimism or pessimism in the financial markets.

Finally, it is important to distinguish between the new risk taken by the bank (as a result of the current business decisions) and changes in the risk stemming from the legacy loan portfolio (being a result of past decisions[4]). To construct a measure of new risk taken by banks some studies make use of confidential internal credit ratings of each loan (Ioannidou et al., 2015; Dell'Ariccia et al., 2017), credit spreads of individual loans (Delis et al., 2017) or, mentioned above, other data based on credit registers, containing comprehensive bank-borrower level data on loan applications and outcomes (Jiménez et al., 2014). Such approaches, although potentially quite efficient, impose significant data requirements and therefore might not be feasible in some countries, including Poland, due to data constraints.

Given the desired features of risk measures outlined above and data constraints we measure the risk at the bank level, using the highest possible level of disaggregation of bank loan portfolio. Our approach makes use of obligatory confidential reporting by commercial banks for bank supervision purposes. We classify bank loans into number of categories (according to loan type or type of borrower's activity), characterized by broadly similar credit risk. For each category of loans we assign well-defined proxies for risk. New risk taken by a bank in a given period is a combination of new loans of different types (approximated by change in the volume of loans) and associated risk weights, relative to the total volume of loans. In the light of this measure, increasing riskiness of bank's activity is associated with extending more loans and/or allocating new loans into more risky segments of the market.

We compute three versions of such a measure ($\Delta R^{(I)}$, $\Delta R^{(II)}$, $\Delta R^{(III)}$) differing from each other in terms of coverage of the total loan portfolio, classification of loans into categories with similar risk, and risk weights:

$$\Delta R_{i,t}^{(I)} = \frac{\sum_j llr_{j,t-1}\Delta L_{j,i,t}}{\sum_j L_{j,i,t-1}} \tag{1}$$

$$\Delta R_{i,t}^{(II)} = \frac{\sum_k llr_{k,i,t-1}\Delta L_{k,i,t}}{\sum_k L_{k,i,t-1}} \tag{2}$$

$$\Delta R_{i,t}^{(III)} = \frac{\sum_k eloss_{k,i,t-1}\Delta L_{k,i,t}}{\sum_k L_{k,i,t-1}} \tag{3}$$

[4] In general, the risk of the pre-existing loan portfolio might be modified using securitization or credit derivatives, but this concern can be addressed by treating such transactions as negative new lending.

The first risk measure (1) refers only to large loans granted to non-financial firms (so called "large exposures" defined for banking supervisory purposes). These loans might be categorized according to sections of NACE: $\Delta L_{j,i,t}$ denotes a change in the volume of loans granted to firms classified to the *j-th* NACE section; *i* refers to an individual bank and *t* to time. To each section of economic activity we attribute a risk weight, equal to loan loss reserve ratio of loans in given section ($llr_{j,t-1}$). This risk weight is time-varying, but not bank-specific as we pool loans from all banks while calculating the loan loss reserve ratio.[5] In the denominator there is a total volume of large loans to non-financial firms. The major advantage of measuring risk as specified in (1) is that it allows considerable disaggregation of the individual bank portfolio. Disaggregating bank loans into many categories, for which a similar risk profile might be assigned, constitutes an important advantage, even at cost of covering only part of total bank loans to the non-financial sector. For the remaining components of the bank loan portfolio our data allows less detailed disaggregation.

The second (2) and third (3) measures of risk cover all loans to the non-financial sector, which we categorize into six business lines: investment loans to non-financial corporations, other loans to non-financial corporations, loans to sole enterprises, housing loans to individuals, consumption loans to individuals, other loans to households.[6] Accordingly, $\Delta L_{k,i,t}$ denotes change in loan volume in the *k-th* business line in the *i-th* bank at time *t*. Loans within a business line are assumed to be characterized by broadly similar risk levels. The difference between these two measures lies in risk weights applied to business lines. In (2) the risk of a given loan category is approximated by the ratio of loan loss reserves to total loans, similarly as in the first measure. Loan loss reserve ratios for each business line are calculated at bank-level, so they are bank specific ($llr_{k,i,t}$).

The loan loss reserve ratio might be criticized on the ground that it is a backward-looking measure of default risk. The accounting rules binding banks within our sample (that covers the period before introduction of the new IFRS 9 standard) imposed restrictions on forward-looking credit risk cost recognition (BCBS, 2015). Moreover, majority of banks under investigation were using the standardized approach for capital adequacy purposes, so the credit risk capital charge was not based on internal models. Unfortunately, our data does not include internal bank credit assessment at loan origination. Therefore, we face the problem common to many researchers analyzing various aspects of bank risk taking that available accounting information reflects mostly past developments in realized credit risk. For this reason, the third risk measure, given by the formula (3), uses risk weights which have more ex-ante character. The starting point for their calculation is a standard assumption that a more risky business line should bring more profit. Therefore, for each business line in a single bank we compute implied expected loss ($eloss_{k,i,t}$), which is equal to the net interest margin minus the minimum required return—proxied by bank's ROA—and apply it as a risk weight. Such a measure should be positively related to expected future losses. The positive link between the net interest margin and credit risk on bank loans is indicated by theoretical models as well as

[5] In some banks the number of loans in individual NACE sections is quite small and bank-specific loan loss ratios by NACE sections might not plausibly proxy risk of a given category of loans, as lenders' idiosyncratic factors might dominate. Pooling data for all banks helps to overcome this problem and to better reflect risk associated with granting a loan to firm from a given section.

[6] Business line definitions are imposed by the supervisory reporting framework.

confirmed in empirical studies (e.g. Angbazo, 1997; Drakos, 2002; Wong, 1997). Along the same lines Delis et al. (2017) employ the loan spread as an indicator of ex-ante measure of individual corporate loan risk.

3.2 Empirical Specification

As mentioned above, our strategy to identify active risk-taking channel relies on finding two non-linearities: (1) a stronger reaction of risk to interest rate changes when the interest rate level is lower, and (2) systematic differences in behavior of banks. Therefore, we estimate the following model:

$$\Delta R_{i,t} = \alpha_i + \beta i_{t-1} + \sum_{j=1}^{4} \beta_j^* B_{i,t-1}^j i_{t-1} + \eta i_{t-1}^2 + \sum_{j=1}^{4} \eta_j^* B_{i,t-1}^j i_{t-1}^2 + \sum_{j=1}^{4} \delta_j B_{i,t-1}^j + \sum_{j=1}^{4} \gamma_j M_{t-1}^j + \lambda \Delta R_{i,t-1} + \sum_{j=1}^{3} \mu_j Q_t^j + \varepsilon_{i,t} \quad (4)$$

in which risk taken by a bank ($\Delta R_{i,t}$) is regressed on its lagged value, a nominal interest rate (i), the squared nominal interest rate, interactions between bank characteristics and the interest rate as well as the squared interest rate, the set of control variables and quarterly dummy variables (Q_t^j). The set of control variables consists of both macroeconomic variables (M_{t-1}^j) and individual bank characteristics ($B_{i,t-1}^j$). The former include the output gap (obtained with the Hodrick-Prescott filter), core inflation excluding foodstuffs and energy, the quarterly change in the nominal effective exchange rate (an increase means appreciation) and default probability of corporations. The latter group of control variables consists of the total assets (in log), the liquidity ratio (liquid assets[7] relative to total assets), the capital buffer (the ratio of excess bank capital over regulatory requirement to assets) and the total deposits to total liabilities ratio. All control variables are introduced with a one-period lag to avoid potential endogeneity problems. The bank level characteristics are normalized with respect to median in a given quarter (assets and capital buffer) or median in the whole sample (other variables).[8]

We measure monetary policy with the nominal interest rate. We use a four-quarter moving average of the 3-month money market rate (WIBOR 3M) in order to account for sluggishness of processing loan applications. In order to capture a non-linear character of the risk-taking phenomenon the specification includes also the squared interest rate. The interest rate and the squared interest rate are interacted with the bank characteristics. The interaction variables are crucial for our strategy to identify the risk-taking channel. It is due to the fact that we are going to identify supply-side factors affecting risk-taking by banks rather than demand factors, reflected, at least to some extent, in the estimated coefficients on the interest rate and the squared interest rate. In this approach, we follow a well-established identification strategy used i.a. in the bank lending channel literature

[7] To liquid assets belong: cash, operations with the central bank except reserve requirements, current accounts and overnight deposits from financial institutions, debt securities issued by central banks and central government institutions.

[8] Normalization with respect to the median in a given quarter is intended to remove trend in assets and capital buffer.

(Kashyap and Stein, 2000). This strategy relies on the assumption that customers of different banks are relatively homogeneous and operate in the same macroeconomic environment. Therefore, the demand-side reactions on the credit market to macroeconomic shocks are independent of individual bank's characteristics. However, if parameters estimated for the interaction terms turn out to be statistically significant, it can be concluded that reactions of individual banks are systematically linked to characteristics of these banks. Therefore, the effects captured by the interaction terms might be interpreted as resulting from supply-side developments. Additionally, because we augment our specification with quadratic terms, we are able to distill both demand and supply-side effects that depend on the short-term interest rate level.

We consider four bank-specific indicators: bank size, liquidity, capital position and deposit ratio. The first three indicators are the main characteristics important from the monetary transmission mechanism perspective and are standard in the bank lending channel literature (e.g. Altunbas et al., 2009; Ehrmann et al., 2001; Kishan and Opiela, 2000; Matousek and Sarantis, 2009; Kashyap and Stein, 2000). The last one, deposits ratio, reflects financing conditions of a bank which affect, among others, its effective funding costs.[9] Asymmetric reaction of banks to low interest rates is confirmed also in the risk-taking literature. As described in section 2, all these individual characteristics potentially affect reaction of banks to low interest rates.

Finally, the model includes the set of standard macro control variables. The output gap and inflation control for cyclical changes in the demand for loans. The importance of the exchange rate stems from various reasons. Firstly, calculating risk measures we considered loans in all currencies, therefore changes in the exchange rate affect directly the volume loans expressed in the local currency. Secondly, as enterprises are exposed to the exchange rate risk, fluctuations in the exchange rate affect their future financial condition, which is most clearly visible in the case of importers and exporters. Moreover, when firms mismanage their FX hedging activities, this can result in changes in their liabilities towards banks being counterparties for FX derivative transactions. Such a problem occurred in Poland after a rapid exchange rate depreciation in 2008 (for details, see e.g. Box 2 in NBP, 2009). Lastly, changes in the exchange rate affect also default probability of households (mostly due to FX mortgage loans) and this, via portfolio effects, might also influence bank lending decisions in general. The intention of including default probability of corporations is mainly to capture the effect of the global financial crisis.

In order to address the problem of potentially omitted macro variables that could result in biased estimates, we additionally estimate a model in which macro variables are substituted with time dummies capturing the impact of all period-specific factors:

$$\Delta R_{i,t} = \alpha_i + \sum_{j=1}^{4} \beta_j^* B_{i,t-1}^j i_{t-1} + \sum_{j=1}^{4} \eta_j^* B_{i,t-1}^j i_{t-1}^2 + \sum_{j=1}^{4} \delta_j B_{i,t-1}^j + \lambda \Delta R_{i,t-1} + \varepsilon_{i,t} \qquad (5)$$

[9] As a part of robustness checks we tested a wider set of macroeconomic and bank-specific variables (the slope of the yield curve, index of property prices, share price index, share of mortgages in total loans, share of foreign currency mortgages in total loans), but the estimates turned out non-statistically significant or the results were unintuitive.

Such a specification is preferred when it comes to assessing differences among banks, however, it does not allow to infer about the impact of the interest rate on banks' risk, the variable crucial for our analysis. Large differences in estimates from both specifications could signal that some of the macro factors affecting risk taken by banks are omitted in the benchmark model.

3.3 Data

We investigate the risk-taking channel on a panel of commercial banks operating in Poland. Our sample includes all banks with assets equal to at least 1% of the total sector assets and covers about 84% of the sector in terms of assets.[10] The period under consideration extends from 2008q3 to 2018q1. During this time span the ownership structure of the banking sector underwent some changes resulting from mergers and takeovers.[11] We take a twofold approach to account for these events. In the case of a merger of two banks of roughly similar size, both of them disappear from the sample at the merger date, and a new entity emerges next period. Such a treatment is the most neutral one, but shortens the length of series used in estimation. Therefore, in the remaining cases, i.e. when much larger bank absorbed a smaller one, we ignore the merger: the smaller bank disappears from the sample at the merger date, while the series for the larger one is continued. Our intervention is limited to adjusting the dynamics of loans at the merger quarter by backward aggregation. An implicit assumption of this treatment is that acquiring a relatively small bank does not affect the risk-taking behavior of the absorbing bank.[12] Our final effective sample consists of 26 banks and 39 periods (quarters). The panel is unbalanced.

The most important source of data is a financial reporting by banks passed on to NBP on regular basis within the supervisory reporting framework. This includes, inter alia, confidential data on bank loans granted to individual firms, obligatorily reported if the exposures exceed 500 thousand PLN (ca. 125 thousand EUR, so-called "large exposures"). We exploit the fact that reports on large exposures include information about loan loss reserves which might serve as a proxy for quality of loans. Another important feature of the reports is the fact that in the case of firms they contain the activity type code of a debtor.[13] It allows us to assess riskiness of providing credit to a given sector of the

[10] The choice to omit the smallest banks stems from the fact that they have negligible impact on the aggregate behavior of the sector. If they were included, they would affect estimates in the same degree as the bigger banks. As the final goal of our analysis is to draw macroeconomic and policy-relevant conclusions, we attempt to limit this effect. A decision to limit our analysis to larger banks does not affect our main findings, as proved in additional analyses. As a robustness check we included in the estimation all commercial banks except highly specialized ones (car banks, mortgage banks, banks specializing in consumer credit and servicing credit cards). The results, available on request, have remained broadly unchanged with respect to benchmark results reported in our study.

[11] We identify 16 mergers out of which 9 we treat as establishing a new bank and 7 as continuation of the larger bank.

[12] Another strategy to deal with mergers would involve summing balance sheet items of both banks for all periods in the sample (Kishan and Opiela, 2000; Ehrmann et al., 2001). Such backward aggregation assumes that merging banks are characterized by similar lending policy, which we consider too restrictive. Applying this approach would lead also to smaller number of banks in the sample. The bank lending literature suggests that choice of the treatment of mergers does not affect the results significantly (Ehrmann et al., 2001; Worms, 2001).

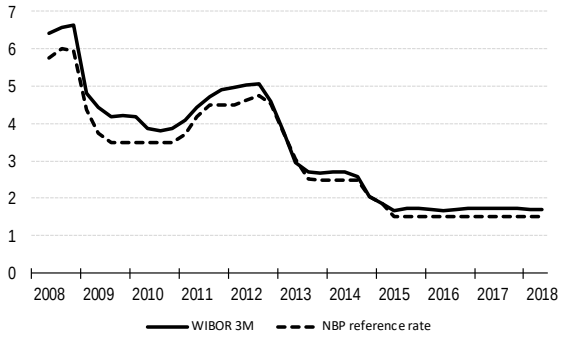
[13] A classification code according to the Polish Classification of Activity PKD, harmonized with NACE. We use the highest level of this classification, denoted with alphabetical code. Out of 21 sections of activity

economy, an important part of our $\Delta R^{(I)}$ measure of risk taken by a bank. Apart from "large exposures", the financial reporting provides rich information about banks' balance sheets (including types of loans) and profit and loss accounts, which allows us calculate the remaining risk measures as described in section 3.1 and individual bank characteristics employed in regressions. In order to avoid problems caused by extreme observations, the risk measures for individual banks were winsorized prior to employing them in the model.[14]

Additionally, we employ a set of macroeconomic indicators from Statistics Poland (GUS) and an indicator of default probability of corporations (excluding banks) provided by Bloomberg.

When it comes to the choice of the estimation method of equations (4) and (5), after careful consideration we decided to employ a bias-corrected fixed effect estimator (Everaert and Pozzi, 2007; Vos et al., 2015). In dynamic panel models the fixed effect estimator suffers from bias due to the violation of the weak exogeneity assumption, with the size of this bias diminishing as T grows large (Nickell, 1981). The bias-corrected fixed effect (BCFE) estimator corrects for this bias and allows to avoid some problems related to use of alternative GMM estimators in applications when T is relatively large compared to N as in our case ($T = 39$, $N = 26$). Nevertheless, as a robustness check, we applied also Arellano-Bond estimator and got very similar results (available on request).

Figure 1 Interest Rates in Poland



Source: NBP data.

Figure 1 shows policy rate (NBP reference rate) and market rate (WIBOR 3M) in Poland, while Figures 2a, 2b and 2c depict the evolution of new risk measures ($\Delta R^{(I)}$, $\Delta R^{(II)}$, $\Delta R^{(III)}$) for a median bank over the whole sample.[15] The NBP reference rate went down from about 6% in 2008 to 1.5% in the first quarter 2015 and has stayed at this historically low level since then. The short-term interbank market rate, which we employ in the model, closely follows the central bank policy rate and is crucial for determining

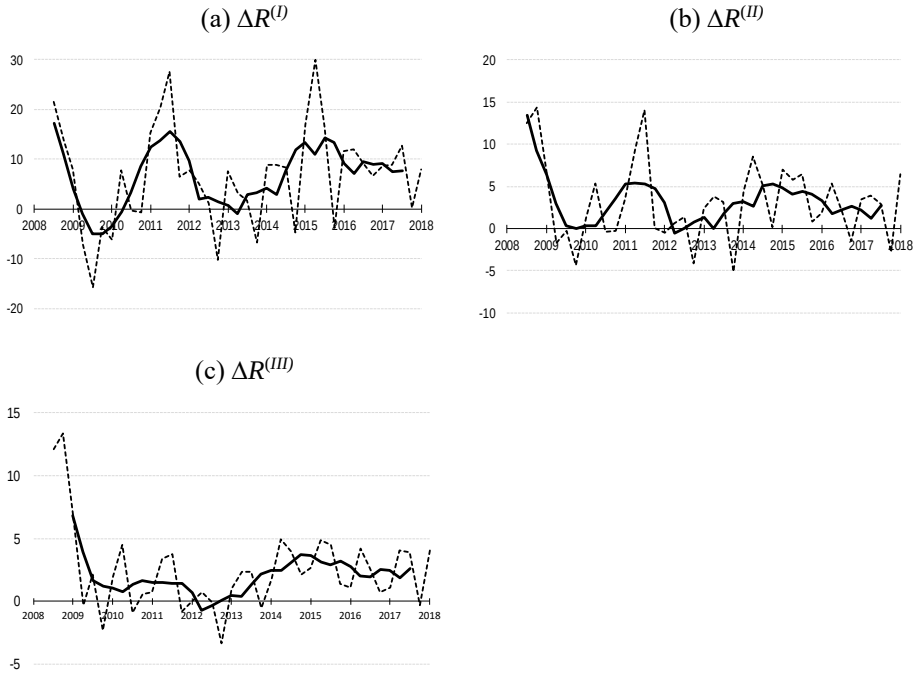
distinguished in NACE Rev. 2, no loans were attributed only to 2 of them: T (Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use) and U (Activities of extraterritorial organizations and bodies).

[14] Winsorizing affected no more than 7% of observations.

[15] The seasonality of risk measures is driven by seasonality of loan growth (quarter-to-quarter) which is a component of all three versions of risk measures.

the banks' interest income. The important feature of the Polish credit market is that the dominating majority of the loan portfolio consists of floating rate loans with the interest rate on these loans indexed to a short-term interbank interest rate. The deposits are dominated by short-term household deposits. Therefore, although there is clear maturity transformation in the Polish banking sector, the net interest margin is not in any meaningful way affected by the slope of the yield curve. In other words, because long-term loans are floating-rate loans, with interest rates closely following short-term market rates, the long end of the yield curve does not matter much for the interest income of banks.

Figure 2 Measures of Risk



Notes: Median across banks in the sample. Dotted line denotes risk measure, while solid line denotes its moving average.
Source: Own calculations based on NBP data.

4. Main Findings

4.1 Risk-Taking Channel in Lending to Non-Financial Sector

Estimation results (Table 1) reveal that all the measures of risk taken by banks respond to changes in the short-term interest rate with the magnitude dependent on the initial level of interest rate. The non-linear character of the relationship between risk and the interest rate approximated by the quadratic function together with the negative sign of an estimated coefficient value for the interest rate and the positive sign for the squared interest rate, imply that interest rate reductions lead to higher risk of new loans and, as

expected, the size of this effect is larger when interest rates are low. On the contrary, interest rate increases discourage banks from taking more risk, but as the level of interest rate rises, the impact is weaker.[16] This observation, however, does not necessarily imply that in the environment of low interest rates banks change their policy and supply of credit towards riskier borrowers, because it can be also related to demand factors, i.e. to the fact that in such circumstances riskier borrowers increase their demand for credit.

A more direct confirmation of the operation of the risk-taking channel is provided by the model, in which the first measure of risk ($\Delta R^{(I)}$) is applied. In this case the response of risk of new loans to changes in the short-term interest rate is heterogeneous across banks with different size (in terms of total assets), different deposits-to-liabilities ratios and different degrees of liquidity. Estimation results of the model with time effects confirm that the above bank characteristics are indeed important in analyzing the risk-taking behavior (Table 2). It suggests that supply-side factors do play a role in the overall response of risk of large corporate exposures to changes in monetary policy. Interestingly, interactions of the above bank characteristics with both the interest rate and its squared value are statistically significant. In particular, a statistical significance of the squared interest rate is in line with the risk-taking channel literature indicating that this channel of monetary transmission is active in the environment of low nominal interest rates.

When it comes to the second measure of bank risk ($\Delta R^{(II)}$), we find that the reaction of risk to an interest rate change depends on bank's liquidity, but the estimates of related parameters are statistically significant only at 10% level. For the third risk measure ($\Delta R^{(III)}$) we find a homogeneous reaction of all banks, so we are not able to confirm that negative interdependence between risk and interest rates is supply driven. What these two risk measures have in common is that they comprise loans to the whole non-financial sector, contrary to the first risk measure which includes loans only to the non-financial firms. It suggests that it is not the whole credit activity that is affected by the risk-taking channel, but its effects are present mainly in the portfolio of large loans to nonfinancial firms. Another interpretation might be that developments related to the risk-taking channel are visible only for more granular data (i.e. borrower-level data).

Interpreting the above results one should keep in mind that the level of policy interest rates observed at the end of our sample (1.5%) does not seem to be low enough to significantly limit the interest margin of banks, and as a result, their profitability. This means that the bank management bodies do not feel under strong pressure to achieve a significant and rapid improvement in financial results, e.g. by increasing the risk incurred. This reading is in line with our selective evidence of risk taking in Poland, because the two largest components of loans to the non-financial sector, making up about 60% of the total loans portfolio, namely housing loans and consumer loans, have either the highest interest margins and/or yield high non-interest income. Moreover, banks adjust lending rates of these loan types to policy rates to lesser degree than lending rates of loans to corporations (Chmielewski et al., 2018), which might be related to lower price elasticity of household lending. Therefore banks enjoy more flexibility in setting lending rates in the case of housing and consumption loans as well as more room to protect their interest rate margins on these business lines, contrary to loans to firms for which we find robust evidence on risk-taking behavior.

[16] Theoretically, after reaching a certain high level of interest rate, the impact of interest rate increases on risk would become positive, as implied by the quadratic function.

Table 1 Estimation Output—Specification with Macro Controls

	$\Delta R^{(I)}$	$\Delta R^{(II)}$	$\Delta R^{(III)}$
nominal interest rate			
i	-10.97***	-4.35**	-2.54**
i^2	1.60***	0.69***	0.37**
interest rate interacted with bank characteristics			
i x assets	-8.10**	-3.03	-0.80
i x liquidity	0.63**	0.37*	-0.03
i x capital buffer	0.29	1.60	0.64
i x deposit ratio	0.52***	0.14	0.06
squared interest rate interacted with bank characteristics			
i^2 *x assets*	1.12**	0.46	0.11
i^2 *x liquidity*	-0.09**	-0.05*	0.00
i^2 *x capital buffer*	-0.11	-0.33	-0.12
i^2 *x deposit ratio*	-0.06**	-0.02	-0.01
bank characteristics			
assets	9.71	4.61	2.35
liquidity	-1.01*	-0.47	0.08
capital buffer	0.63	-0.95	-0.51
deposit ratio	-1.07***	-0.20	-0.10
control macro variables			
output gap	2.21***	0.89**	0.31
core inflation	13.34***	0.52	1.23
ΔNER	0.39*	0.67***	0.30***
default prob. of corporations	-82.85***	-19.26***	-9.92***
quarterly dummies			
*q*1	13.18***	8.09***	2.22***
*q*2	13.73***	8.19***	3.95***
*q*3	10.10***	5.39***	1.77***
lagged dependent variable			
ΔR_{t-1}	0.06	0.43***	0.61***
N	635	650	620

Notes: Boostrap-based bias corrected fixed effect estimator. Standard errors (bootstrapped, allowing for cross-sectional heteroscedasticity) in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculations.

Most of the empirical evidence in the literature on the risk-taking channel also refers to loans to non-financial firms (Buch et al., 2014; Dell'Ariccia et al., 2017; Ioannidou et al., 2015; Jiménez et al., 2014; Paligorova and Santos, 2017). The notable exceptions with this respect are Altunbas et al. (2014) and Maddaloni and Peydró (2011). The former study concerns the impact of policy rate on expected default frequency of a bank (EDF), which by construction is a proxy of risk of all bank activities, not only related

to extending loans to firms. The latter study shows that low interest rates soften lending standards for both, firms and households, but finds that the impact on lending standards for firms is stronger.

Table 2 Estimation Output—Specification with Time Effects

	$\Delta R^{(I)}$	$\Delta R^{(II)}$	$\Delta R^{(III)}$
interest rate interacted with bank characteristics			
i x assets	-7.50**	-0.53	0.63
i x liquidity	0.65*	0.35	-0.04
i x capital buffer	0.44	0.31	-0.17
i x deposit ratio	0.51***	0.00	-0.01
squared interest rate interacted with bank characteristics			
i^2 *x assets*	1.04**	0.12	-0.06
i^2 *x liquidity*	-0.09**	-0.05	0.01
i^2 *x capital buffer*	-0.12	-0.15	-0.01
i^2 *x deposit ratio*	-0.05**	0.00	0.00
bank characteristics			
assets	9.11	-2.87	-3.24
liquidity	-1.04*	-0.44	0.09
capital buffer	0.21	1.03	0.73
deposit ratio	-0.94***	0.06	0.02
lagged dependent variable			
ΔRt- 1	-0.01	0.37***	0.49***
N	635	650	620

Notes: Boostrap-based bias corrected fixed effect estimator. Standard errors (bootstrapped, allowing for cross-sectional heteroscedasticity) in parentheses. *** p <0.01, ** p<0.05, * p<0.1.
Source: Own calculations.

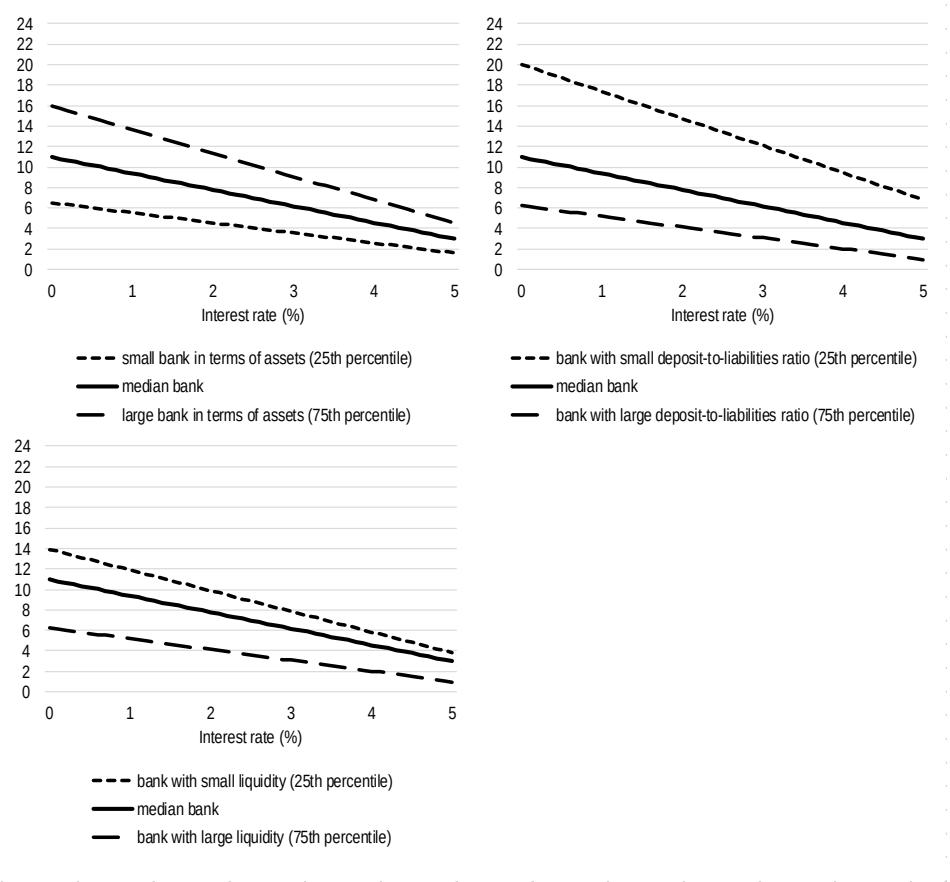
The other explanation is related to the degree of granularity of our data applied in constructing risk-measures. In the case of the first risk measure the level of disaggregation of loans—into 19 NACE sections—is much higher than in the case of the two remaining measures for which we are able to distinguish only six business lines. It might happen that such categorization is not detailed enough to capture the risk-taking in the total loan portfolio.

On the top of that, a relatively modest quantitative importance of the risk-taking channel may be related to the preferences of banks. The banking sector in Poland is well-supplied with capital. High capital buffers might reflect banks' prudence rather than be a symptom of taking on higher risk not included in the standard capital requirements. The fact that in periods of a deteriorating situation for enterprises, expressed in the increased

probability of their default, banks reduced the scale of risk that they took on (see Table 1) may also be evidence of banks' prudence.[17]

4.2 Discussion of Results on Risk-Taking in Lending to Firms

Figure 3 Change in the Risk Measure $\Delta R^{(l)}$ after the Reduction of the Interest Rate by 100 Bps for Different Levels of the Interest Rate



Source: Own calculations based on NBP data.

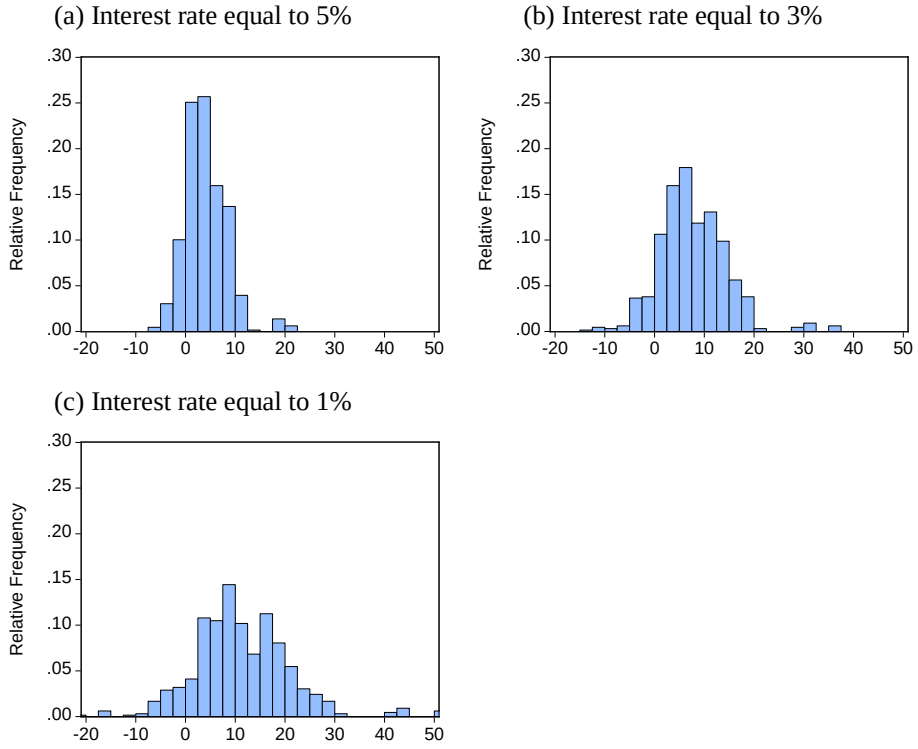
As the evidence on operation of the risk-taking channel is the most compelling for the corporate sector, in the remaining part of this section we discuss the results for the first measure of risk ($\Delta R^{(l)}$). Figure 3 illustrates differences in the response of risk of new loans across banks. It presents the impact of monetary policy loosening on risk taken by three types of banks—the median bank and the banks with analyzed characteristics

[17] It should be noted that the behavior of some smaller banks with weaker capital positions, could be different. However, the size of these institutions does not significantly impact at the level of the whole sector, and the development of the variables at this level is the most important from the point of view of conducting monetary policy.

corresponding to 25th or 75th percentiles of their distribution across all banks in the sample. It can be noticed that independently of the type of analysed banks, the smaller the short-term interest rate is the larger the increase of the risk taken by banks caused by loosening of monetary policy is.

Responding to expansionary monetary policy larger banks seem to take more risk relative to smaller banks. This finding is consistent with the fact that large banks are more active in financing large investment projects and display higher profitability than smaller banks as well and they might enjoy implicit "too big to fail" benefits. As far as the sources of funding are concerned, the increase of risk taken in response to a reduction of the nominal interest rate seems weaker in banks with a larger share of non-financial sector deposits than in banks with market financing. It reflects the fact that deposits are perceived as a more stable source of financing than short-term debt (Ivashina and Scharfstein, 2010). Finally, the risk-taking behavior is more pronounced in banks with low liquidity than in highly liquid banks. This result confirms a firmly established observation that more liquid banks are less affected by interest rate changes in supplying loans (Kashyap and Stein, 2000; Dell'Ariccia et al., 2017).

Figure 4 Distribution of Changes in the Risk Measure $\Delta R^{(l)}$ in Individual Banks after the Reduction of the Interest Rate by 100 Bps for Different Levels of the Interest Rate

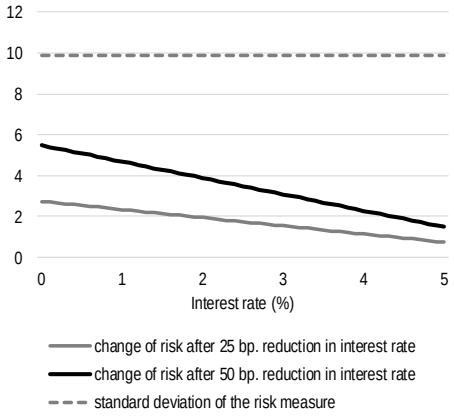


Source: Own calculations based on NBP data.

In the next step of our analysis we estimate the importance of the risk-taking channel in individual banks in our sample, considering their characteristics, especially size, liquidity and the dominant source of financing. We assess changes in the risk of new loans to lowering the short-term nominal interest rate from 5% to 4% (Figure 4a), from 3% to 2% (Figure 4b) and from 1% to 0% (Figure 4c). It can be observed that the distribution of implied changes in risk of new large exposures after a loosening of monetary policy moves clearly to larger values as the initial level of the interest rate gets lower. It means that the risk-taking channel has been active in Poland.

Finally, to assess quantitative relevance of this channel we analyze the impact of typical reductions of the NBP interest rates, i.e. by 25 or 50 bps, on the measure of risk taken by the median bank, comparing it with standard deviation of risk. In this way we address the question if changes in risk taken by banks generated by monetary policy can be treated as substantial source of variation of total risk. This comparison (Figure 5) indicates that even for very low interest rates the impact of typical interest rate reductions is significantly lower than usual variation of the measure of new risk taken by banks. However, the strength of the risk-taking channel is not negligible, especially in the low interest rate environment.

Figure 5 Quantitative Relevance of the Risk-Taking Channel



Notes: Change in the risk measure $\Delta R^{(i)}$ after the reduction of the interest rate by 25 and 50 bps for different levels of the interest rate.
Source: own calculations based on NBP data.

5. Conclusion

Low interest rates environment is challenging for both, monetary policy makers and financial sector institutions. One of its potential consequences is a limited ability of commercial banks to reach levels of profitability observed in regular market and macroeconomic conditions, which might lead to adjustments in banks business models and risk.

In this study we check whether the risk-taking channel is active in Poland, an emerging market economy experiencing recently a prolonged period of low interest rates, which however still remain significantly higher than in the euro zone. Doing so we

propose a new approach to measure the new risk taken by banks, capturing both changes in volumes of loans directed to different sectors of the economy and risks of those exposures. Moreover, we apply a novel non-linear specification of the estimated models, directly allowing for growing intensity of risk-taking behavior when interest rates are lower.

An important feature of this paper is its focus on a banking sector in a converging economy. In Poland, the real convergence process interacted with financial deepening. Therefore, banks have faced strategic choices whether (or to what extent) they should approach previously "unbanked" (and implicitly—riskier) customers. On the other hand, higher incomes and profits of existing borrowers (both households and firms) have increased their borrowing capacity. These two major factors increased—comparing to a situation in more developed economies—banks' flexibility in shaping the risk profile of their loan portfolios.

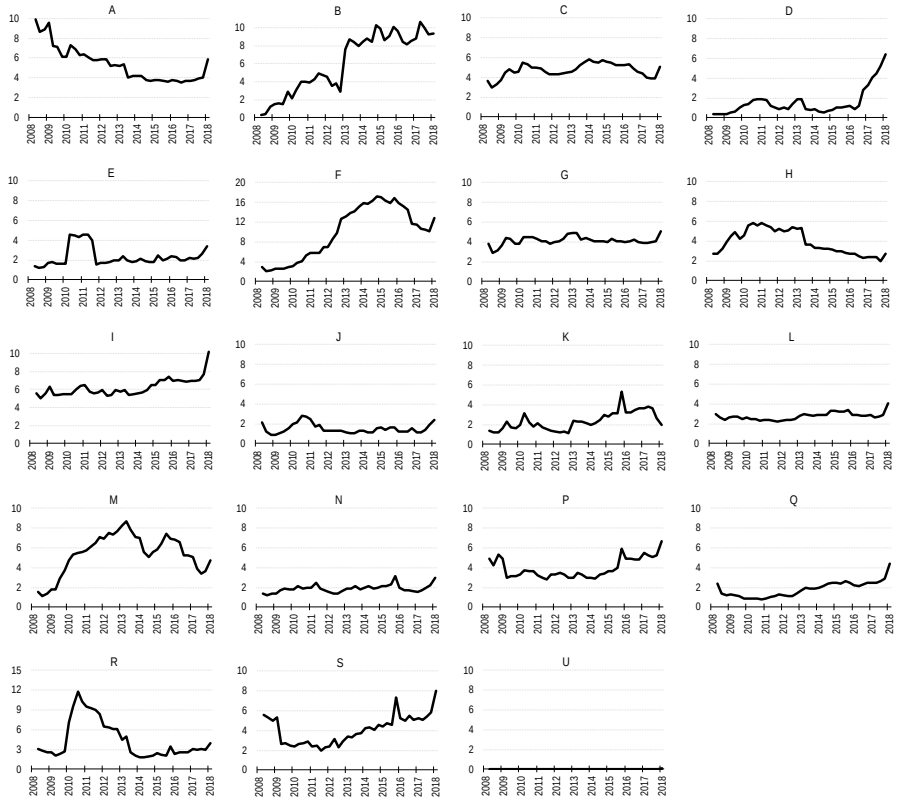
We find a robust evidence that the risk-taking channel operates in the segment of large corporate loans in Poland, even if its quantitative relevance is modest. Taking into consideration the whole portfolio of loans to the non-financial sector, we also find the negative relationship between the interest rate and risk taken by banks, however we are not able to unambiguously claim that this is a supply driven phenomenon. Another important conclusion concerns substantial asymmetrical features of the risk-taking channel with respect to the level of the short-term interest rate as well as heterogeneity of these effects across banks. Loosening of monetary policy has different effects depending on the initial level of interest rates—the lower the interest rate is, the larger increase of risk the lowering of interest rate generates. This response is also different across banks, with larger reaction displayed by large banks, banks with low liquidity and banks with low share of deposits in liabilities.

Finally, based on our sample, the observed behavior of banks due to the risk-taking channel seems not to be a concern from the financial stability perspective. The additional bank risk taking that might be attributed to low interest rate environment does not dominate the amount of risk taking resulting from other systematic factors, including the long-term trend of financial deepening. Therefore we conclude that in an emerging economy context the active risk-taking channel of the monetary policy transmission is unlikely to be detrimental to financial stability and should not complicate the conduct of macroprudential policy.

APPENDIX

Risk Weights of Loans

Figure A1 Risk Weights of Loans by NACE Sections (Ratio of Loan Loss Reserves to Total Loans, in %)



Notes: A - Agriculture, forestry and fishing; B - Mining and quarrying; C - Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply, sewerage, waste management and remediation activities; F - Construction; G - Wholesale and retail trade; repair of motor vehicles and motorcycles; H - Transportation and storage; I - Accommodation and food service activities; J - Information and communication; K - Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities; O - Public administration and defence; compulsory social security; P - Education; Q - Human health and social work activities; R - Arts, entertainment and recreation; S - Other service activities; U - Activities of extraterritorial organizations and bodies.

Source: Own calculations based on NBP data.

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