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## Bank stress testing under different balance sheet assumptions

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# Non-technical summary


### Research Question

Changes in the interest rates have two direct effects on banks: First, concerning new business, yields on loans and customer deposits change (price effect) and, second, banks adjust their balance sheet composition (quantity effect) because demand and supply for their various products differently react to an interest rate shock. From financial statement data, one can often only infer the total effect. In our analysis, we decompose the total effect into the price and quantity effects.

### Contribution

To decompose the total effect, we use data that was collected by the banking supervisor in summer 2015 in a survey among all the small and medium-sized banks in Germany. In this survey, banks were requested to determine their interest income and other P&L components in various scenarios. In our analysis, we concentrate on three of these scenarios which are especially suitable for decomposing the total effect.

### Results

We find that in the short run (one year) the price effect is nearly eight times as large as the quantity effect. By contrast, in the medium term (after five years), the price effect is only twice as important as the quantity effect. We find that large banks adjust their balance sheets more strongly than small banks, but large banks are more impacted by the price effect. In addition, it turns out that the current balance sheet composition explains the price effect more weakly the longer the horizon is. With the quantity effect, it is the other way around: the longer the horizon, the higher the explanatory power of the current balance sheet composition. This can be explained by the presumption that banks only gradually adjust the composition of their balance sheet.

# Nichttechnische Zusammenfassung

## Fragestellung

Zinsänderungen machen sich bei Banken zunächst auf zweierlei Weisen bemerkbar: Erstens ändert sich im Neugeschäft die Verzinsung von Krediten und Kundeneinlagen (Preiseffekt) und zweitens ändern die Banken ihre Bilanzzusammensetzung (Mengeneffekt), weil Angebot und Nachfrage für verschiedene Produkte unterschiedlich auf einen Zinsschock reagieren. Aus Jahresabschlussdaten kann meist nur der Gesamteffekt ermittelt werden. In unserer Analyse spalten wir den Gesamteffekt in den Preis- und Mengeneffekt auf.

## Beitrag

Zur Aufspaltung des Gesamteffekts verwenden wir Daten, die die Bankenaufsicht im Sommer 2015 in einer Umfrage unter allen kleinen und mittelgroßen Banken in Deutschland erhoben hat. In dieser Umfrage wurden die Banken aufgefordert, ihr Zinsergebnis und andere Positionen ihrer Gewinn- und Verlustrechnung für verschiedene Szenarien zu ermitteln. In unserer Analyse konzentrieren wir uns auf drei dieser Szenarien, die besonders geeignet sind, den Gesamteffekt aufzuspalten.

## Ergebnisse

Wir finden, dass auf kurze Sicht (ein Jahr) der Preiseffekt fast achtmal so groß ist wie der Mengeneffekt. Mittelfristig (nach fünf Jahren) dagegen ist der Preiseffekt nur noch doppelt so groß. Auch zeigt sich, dass große Banken ihre Bilanz stärker anpassen als kleine Banken, dass aber große Banken von dem Preiseffekt stärker getroffen sind. Wir finden außerdem, dass die gegenwärtige Bilanzzusammensetzung einer Bank den Preiseffekt mit zunehmendem Horizont schlechter erklärt; bei dem Mengeneffekt ist es umgekehrt: Je länger der Horizont, desto höher ist die Erklärungskraft der gegenwärtigen Bilanzzusammensetzung. Dies kann dadurch erklärt werden, dass die Banken die Zusammensetzung ihrer Bilanz nur schrittweise anpassen.

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# Bank stress testing under different balance sheet assumptions*

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**Abstract**

Using unique supervisory survey data on the impact of a hypothetical interest rate shock on German banks, we analyse price and quantity effects on banks' net interest margin components under different balance sheet assumptions. In the first year, the cross-sectional variation of banks' simulated price effect is nearly eight times as large as the one of the simulated quantity effect. After five years, however, the importance of both effects converges. Large banks adjust their balance sheets more strongly than small banks, but they are impacted more strongly by the price effect. The quantity effects are explained better by a bank's current balance sheet composition, the longer the forecast horizon. The opposite holds for banks' price effect.

**Keywords:** Stress testing, low-interest-rate environment; net interest margin; static balance sheet, dynamic balance sheet; price effect; quantity effect

**JEL classification:** G11, G21

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# 1 Introduction

An interest rate shock has two direct effects on banks' net interest margin: a price effect and a quantity effect. The price effect results from the change in interest rates assuming the balance sheet structure and size to be constant. By contrast, the quantity effect on the balance sheet structure and size is due to banks' and depositors' behavioral adjustments as a consequence of the interest rate change. In empirical data, we usually observe only the combined effect, i.e. the addition of the price and the quantity effects. Using unique supervisory survey data on German small and medium-size banks, we are able to disentangle the simulated price and quantity effects of net interest margin components following a hypothetical 100 basis points downward shift in the yield curve. The data set contains simulated data on net interest margin components for a forecast horizon of one year, two, three, four and five years, which also allows us to analyse the time dimension of these effects.

We believe that distinguishing between the two effects is an important issue for three reasons: first, the time profiles of the two effects are expected to be different. Price effects are likely to have an immediate impact whereas quantity effects can be assumed to gradually materialize due to behavioural and financial frictions. For instance, depositors exhibit behavioural rigidities and banks' portfolio decisions are subject to various regulatory constraints. When setting behavioural assumptions on the balance sheet structure and size in microprudential or macroprudential stress tests, the time profile of both effects plays a key role.

Second, from a financial stability perspective, it is crucial to know how banks react to shocks and adjust their balance sheets because this reaction can have considerable impact on other financial intermediaries and on the real economy. From the microprudential perspective of a single bank, the balance sheet adjustments may be perfectly rational. However, if all banks react in the same way, then this behaviour may have unintended negative externalities. For instance, as a consequence of considerable losses due to an interest rate shock, a significant number of banks may shrink their balance sheets thereby reducing the credit supply to the real economy.

Third, the impact of price changes on banks' income statements are often dealt with in a symmetric manner: the effect of a price increase is assumed to equal – in absolute terms – the effect of a decrease in prices. This may be a good approximation if only the price effect is considered, but the quantity effect due to balance sheet adjustments is expected to work in the majority of cases in favour of the bank which leads to an asymmetry.

Our contribution is threefold. First, our study is among the first that focuses on the question, under which setting a static or dynamic balance sheet assumption seems to be justified in micro- and macroprudential stress testing exercises. Second, our study is among the few that deals with the separation of the price and quantity effects in the wake of a macroeconomic shock. This separation makes it possible to quantify the relative importance of the price and quantity effects. Third, we are the first to have a time dimension at our disposal. Our results can help in gaining a general understanding of balance sheet reactions which are mostly at the core of macroprudential stress testing exercises.

Our supervisory survey data include forecasted net interest margin for the five years following the base year 2014 under different scenarios. In addition, we have data concerning the balance sheet composition of these banks in the base year 2014. Our results show that, in the first year, the cross-sectional variation of the simulated price effect is nearly eight times as large as the one of simulated quantity effect. After five years, however, the magnitudes of these two effects are converging as the simulated price effect is just twice as large as the simulated quantity effect. We conclude that in interest rate stress tests with a short forecast horizon a static balance sheet assumption might be justified, but not for the medium term. In addition, it is theoretically motivated and empirically shown that the simulated quantity effects are explained better by a bank's current balance sheet composition, the longer the forecast horizon. The opposite holds for banks' price effect.

The paper is structured as follows. In Section 2, we give a short overview of the related literature. In Section 3, we introduce empirical modeling. Section 4 elaborates on the data we use and in Section 5, we give the empirical results. Section 6 concludes.

## 2 Literature

The contribution of our study to the existing literature is twofold: first, to the literature on stress testing and second, to the literature on interest margins.

When it comes to stress testing, our study can help to assess whether a static balance sheet assumption might be justified or a dynamic balance sheet assumption might be necessary. The methodologies of the supervisory stress tests performed by the Bank of England, the European Banking Authority, the US Federal Reserve and the Bundesbank/BaFin treat the balance sheet composition and size differently.

The Bank of England's annual stress test[1] allows banks to account for changes in the composition and size of their balance sheets (bottom-up stress test). Banks should explicitly incorporate corporate plans of costs and business changes. In order to ensure comparability of those changes, the methodology restricts these changes, for instance, by demanding that lending should not exceed the current market share (see Bank of England (2016)).

In the European Union, the European Banking Authority (EBA) ST 2016 is run under the static balance sheet assumption in terms that maturing assets and liabilities are replaced with similar financial instruments (bottom-up stress test). The methodology does not allow for mitigating management actions, such as changes in the composition and size of the balance sheet. Instead, the impact of this assumption is considered in the evaluation and application of the stress test results (see European Banking Authority (2016)).

The US Federal Reserve applies a dynamic balance sheet approach (top-down and bottom-up) for the US Comprehensive Capital Analysis and review (CCAR) ST 2016 mirroring the expected balance sheet development through the forecast horizon in line with banks' corporate plans (see Federal Reserve System (2016)).

The Bundesbank/BaFin ST 2015 accounts for a static and dynamic balance sheet (bottom-up) under the negative interest rate scenario, respectively. The static balance sheet is used to ensure comparable results and to illustrate the counterfactual outcome without active management actions. The dynamic scenario is meant to account for ex-

[1]The stress test aims to support both the macroprudential-related Financial Policy Committee (FPC) and microprudential-related Prudential Regulation Authority (PRA) in meeting their statutory objectives

ogenously and endogenously driven changes in the volume, resulting in changes in the composition and size of the balance sheet (see Bundesbank (2016)).

Concerning the literature on banks' interest margins, we contribute to three strands; namely, the composition of the interest rate pass-through, the time profile of the interest rate pass-through as well as the the level of interest rate margins against the backdrop of the balance sheet composition

First, our paper contributes to the literature on how banks react to a macroeconomic shock. Memmel and Schertler (2013) perform a separation of changes in the net interest margin of German banks into a price effect and a quantity effect, where the quantity effect is due to balance sheet adjustments and can be seen as a measure of banks' behaviour. Concerning this aspect of their research, their study is closest to ours. Unlike them, we do not use realized data from banks' financial statements, but rather banks' simulated data on interest margins under different scenarios, where the distinction between price and quantity effects can be directly inferred. In addition, we have a time dimension of up to five years of the forecast horizon.

Market interest rates are an important macroeconomic factor, especially for banks, and many studies on banks' interest margins include the interest rate level as an explanatory variable (see, for instance, Bolt, de Haan, Hoeberichts, Oordt, and Swank (2012)). Albertazzi and Gambacorta (2009) show that increasing long term market rates affect interest income positively, while the opposite holds true for non-interest income. Busch and Memmel (2015) make the impact of the interest rate level a central question of their paper. Using a long time series of the German banking system, they show that a downward shift in the term structure is at first beneficial for the banks' net interest margin, but that this downward shift reduces the net interest margin in the medium and long term. Using the time dimension of our survey data, we can see whether the short-term effect is qualitatively different from the medium and long-term effects. Furthermore, we are able to disentangle the influence of the balance sheet adjustment.

Second, our paper contributes to the empirical literature that examines the pass-through from market rates to bank rates (See, for instance, Kleimeier and Sander (2006), Schlueter, Busch, Hartmann-Wendels, and Sievers (2016) and Pangopoulos and Spiliotis (2015)). This pass-through is most often found to be incomplete, with differences regarding various product categories (see, for instance, De Graeve, De Jonghe, and Vennet (2007)). In such studies, the bank rates are often assumed to be a linear combination of their own past values and of past and present market rates. By contrast, in our survey data, we can determine the pass-through directly and for different time horizons (up to five years).

Third, we contribute to the literature that explains the level of interest margins using banks-specific variables (see, for instance, Ho and Saunders (1981), Angbazo (1997), Maudos and de Guevara (2004), and Busch and Memmel (2016)). These studies find that a bank's credit risk, its exposure to interest rate risk, its operating costs and its market power (among other things) determine the level of the interest margins. Some papers show how business models influence interest margins. For example, Lepetit, Nys, Rous, and Tarazi (2008) and Busch and Kick (2015) find a negative relationship between the interest rate margin and non-interest income and argue that banks react to decreasing interest margins by diversifying into new activities. Our approach differs from these studies: We investigate how far a bank's current balance sheet composition can explain future changes in the interest margins.

## 3 Empirical Modelling

In the literature, banks' net interest margins are often explained by bank-specific variables. In our paper, we do not explain the level of interest margins, but their changes due to an interest rate shock. As bank-specific variables, we use banks' balance sheet compositions in the base year (here: in the year 2014). That means that we aim to explain the bank's simulated price and quantity effects by its current balance sheet composition, using a stylized model.

We assume that the price effect $a_h$ , i.e. the effect on the net interest margin under the assumption of a constant balance sheet, can be modelled in a basic setting:

$$a_h = (w_0 + (1 - w_0) \cdot \phi_h)\, \Delta r + \varepsilon_h \tag{1}$$

where we assume that the asset-side of a bank consists of only two types of assets, namely overnight interbank loans (portion: $w_0$) and customer loans of longer maturity (portion: $1 - w_0$). $\phi_h$ gives the share of customer loans which have matured in the period from 0 to time $h$, $\Delta r$ is size of the interest shock and $\varepsilon_h$ is a noise term.

Equation (1) gives the business that is affected by the shift in the yield curve (multiplied by the shock size $\Delta r$): the interbank loans which have matured immediately in addition to those customer loans that have already matured (share: $\phi_h$).

**Proposition** 1: Given the model above, concerning the price effect $a_h$, the explanatory power of the current balance sheet composition (here: $w_0$) is falling with the length of the forecast horizon $h$.

Proof: From Equation (1), one can calculate the variance of the variable $a_h$ and its covariance to the weight $w_0$, where we assume that the stochastic comes from the weight $w_0$ (variance: $\sigma_w^2$) and the noise term $\varepsilon_h$ (variance: $\sigma_\varepsilon^2$), which we assume to be independent from the weight $w_0$:

$$var\,(a_h) = (\Delta r)^2\,(1 - \phi_h)^2 \sigma_w^2 + \sigma_\varepsilon^2 \tag{2}$$

and

$$cov\,(a_h, w_0) = \Delta r \cdot (1 - \phi_h) \cdot \sigma_w^2 \tag{3}$$

Defining the (positive) ratio $\eta_\varepsilon := \sigma_\varepsilon^2 / \left((\Delta r)^2\, \sigma_w^2\right)$, we obtain as the coefficient of determination $R^2_{a,h} := cov^2\,(a_h, w_0) \,/\, (var(a_h) \cdot \sigma_w^2)$ for the regression of the direct effect $a_h$ on the current weight $w_0$

$$R^2_{a,h} = \frac{(1 - \phi_h)^2}{(1 - \phi_h)^2 + \eta_\varepsilon}. \tag{4}$$

With the help of some conversions, one sees that the derivative of $R^2_{a,h}$ with respect to the horizon $h$ is negative, proving the statement in Proposition 1.

The economic intuition behind the declining coefficient of determination $R^2_{a,h}$ is that, in the short run, the banks differ in terms of the extent to which the price effect of the interest rate shock is passed-through, in the model above expressed by different weights $w_0$. In the long run, however, the price effect $a$ of the interest rate shock is similar across all banks because finally all positions are replaced by new business; in the model above, this corresponds to $lim_{h\to\infty}\phi_h = 1$. That is why the coefficient of determination $R^2_{a,h}$ decreases with respect to the horizon $h$.

The quantity effect $b_h$ , i.e. the effect on the net interest margin due to balance sheet adjustments, can be modelled as follows in the model from above:

$$b_h = c \cdot (w_h - w_0) + \nu_h \tag{5}$$

where $c$ is a constant and $\nu_h$ is an error term that introduces some noise with variance $\sigma^2_\nu$.[2] We assume that a bank cannot immediately reach the new optimal weight $\bar{w}$, but approaches it following an autoregressive process of order 1, which can be motivated by adjustment costs (see Appendix 1), where $0 < \beta < 1$:

$$w_h = \alpha + \beta \cdot w_{h-1} \tag{6}$$

**Proposition** 2: Given the model above, concerning the quantity effect $b_h$, the explanatory power of the current balance sheet composition (here: $w_0$) is increasing with the length of the forecast horizon $h$.

Proof: Using some conversions, one can express the weight $w_h$ as a function of the original weight $w_0$:

$$w_h = \beta^h \cdot w_0 + \alpha \cdot \frac{1-\beta^h}{1-\beta} \tag{7}$$

combining this expression with Equation (5), one can determine the variance of $b_h$as

$$var\,(b_h) = c^2 \cdot (1-\beta^h)^2 \cdot \sigma^2_w + \sigma^2_\nu \tag{8}$$

and its covariance to the original weight $w_0$ as

$$cov\,(b_h, w_0) = -c \cdot \sigma^2_w \cdot \left(1-\beta^h\right). \tag{9}$$

Again, defining the (positive) ratio $\eta_\nu := \sigma^2_\nu/\sigma^2_w$, we obtain for the coefficient of determination $R^2_{b,h}$ for the regression of the quantity effect $b_h$ on the original weight $w_0$:

$$R^2_{b,h} = \frac{c^2 \cdot (1-\beta^h)^2}{c^2 \cdot (1-\beta^h)^2 + \eta_\nu} \tag{10}$$

With the help of some conversions, one sees that the derivative of $R^2_{b,h}$ with respect to the horizon $h$ is positive, proving the statement in Proposition 2.

Concerning the increasing coefficient of determination $R^2_{b,h}$, the intuition is that, due to adjustment costs and subsequent partial adjustments, the current balance sheet composition has all the more explanatory power, the longer the horizon $h$.

[2] Again, the noise term $\nu_h$ is assumed to be independent from the weight $w_0$.

# 4 Data

## 4.1 Low-interest-rate survey

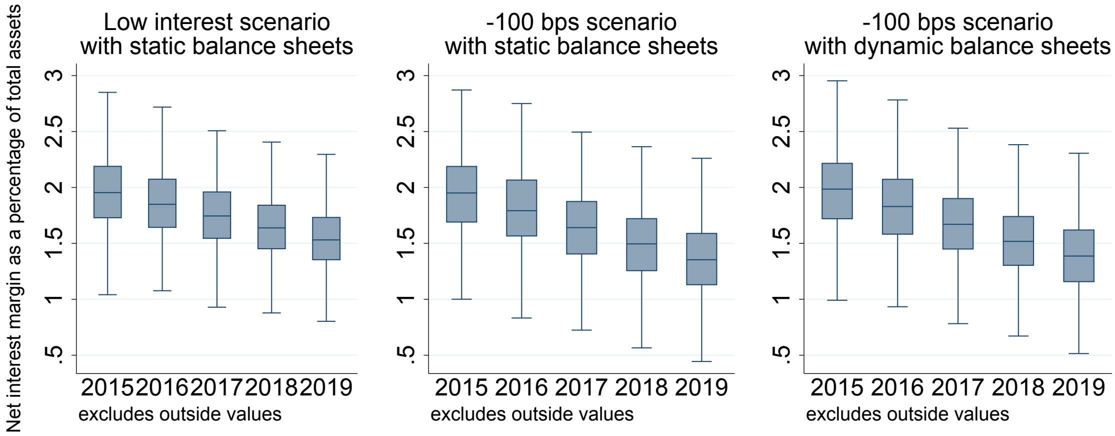
The empirical analyses are based on data from the supervisory survey "Profitability and resilience of German credit institutions in the low-interest-rate setting 2015", which includes approximately 1,500 German small and medium-size universal banks directly supervised by the Bundesbank and Federal Financial Supervisory Authority (BaFin). This survey was conducted in 2015 to track how banks intend to tackle the prevailing challenges of the low-interest-rate environment until 2019. First, in a low-interest-rate environment, expiring assets need to be replaced by lower remunerated assets. Second, history still shows that most deposit rates are de facto floored at zero by banks due to intense competition and endeavoring not to lose customers to rivals. The floor means for banks that in a continuing low-interest-rate environment deposit funding becomes more expensive than market funding. For banks with high deposit-funding, the combination of lower asset remuneration and de facto floored deposit rates yields to decreasing net interest margins (see Drescher, Ruprecht, Gruender, Papageorgiou, Tows, and Brinkmann (2016)).

Against this backdrop, the Bundesbank and BaFin asked banks to populate the supervisory survey, which contains a bank-specific planning scenario, four additional supervisory interest rate stress test scenarios as well as separate credit and market risk stress tests. With regard to the interest rate stress test scenarios, banks had to simulate in a bottom-up approach manner the impact on their income statements and balance sheets. We focus on the following three interest rate stress test scenarios. First, the supervisory low-interest-rate environment scenario presumes interest rates will remain at levels as of 31 December 2014. Each of the following supervisory interest rate scenarios assumes an abrupt and persistent change in the yield curve. Second and third, the two supervisory scenarios with a negative interest rate shock assume a sudden downward shift of the yield curve by 100 basis points as of 31 December 2014; one with a static balance sheet and one with a dynamic balance sheet. The assumption of a static balance sheet implies that maturing business is being replaced by similar new business, i.e. matching in terms of credit quality, asset and liability structure and total assets. This assumption is not made in the dynamic balance sheet scenario, where banks are allowed to adjust their balance sheets as a response of the shock. In the dynamic scenario, banks were allowed to take countermeasures in terms of portfolio shifts.

In order to disentangle banks' simulated price and quantity effects for the negative interest rate shock scenario in a meaningful way, we applied a thorough cleaning algorithm. First, we dropped those banks that provided missing data in at least one of the relevant scenarios. This cleaning is considered necessary to ensure a balanced panel for aggregating the results. Second, we dropped those banks that used a static balance sheet structure or adapted the dynamic balance sheet structure of its planning scenario to the negative interest rate shock scenario. This cleaning is considered necessary since the balance sheet structure should deviate between different scenarios against the backdrop of endogenous and exogenous drivers. Third, we dropped all price and quantity effects for the net interest margins below the first and above the 99th percentile. In the end, we obtain a data set consisting of around 400 banks compared with around 1,500 that took part in the survey. In what follows, the empirical results are derived from this restricted sample.

Additionally, we provide the results for the full sample in the robustness checks in Section 5.4

Figure 1: Scenario-based net interest income simulations




Starting from 2014, German small and medium-size banks provided Bundesbank and BaFin with simulations on net interest margin components over the next five years, until 2019 (see Figure 1). In a persistent low-interest-rate environment scenario and static balance sheet, the median bank simulates the net interest margin to go down to 1.53% of total assets. Assuming a 100 basis points downward shift of the yield curve, the median bank simulates the net interest margin to drop to 1.35% of total assets with a static balance sheet respectively to 1.38% of total assets with a dynamic balance sheet. All developments also apply beyond the median bank for different deciles.

Given these scenario designs, our study focuses on the low-interest-rate scenario (here: scenario $k = 0$, which we will use as our benchmark) and the two negative interest rate shock scenarios with a static (here: scenario $k = 1$) and dynamic balance sheet (here: scenario $k = 2$), respectively. We chose these three scenarios because they enable us to carry out the separation of the simulated price and the quantity effects.[3]

As we normalise the net interest margin, interest income and expenses with total assets, it is worthwhile starting by also taking a look at how banks' total assets evolve in the negative interest rate shock scenario. Given lower interest rate levels, the vast majority of banks expects total assets to increase from 2014 to 2019 respectively, being higher in the dynamic balance sheets scenario compared to the static balance sheet scenario in 2019. For instance, total assets of banks grouped in deciles are expected to increase between -7.0% and 4.8% (see Table 1). Contemporarily, banks expect costumer loans to increase relative to costumer deposits. With respect to the banks grouped in deciles, these ratios are expected to grow from 0.9% to 6.6% (see Table 1). Nevertheless, most banks still expect to have more costumer deposits than costumer loans (see Figure 3).

In Figure 2, we illustrate how the survey data are used for the analyses. For instance, if we assume that in the first year ($h = 1$) the bank $i$'s interest income margin ($IIM$) is 300 bp (per total assets of 31 December 2014) in the benchmark scenario $k = 0$ with

[3]Please note that there is no mechanism to ensure that the individual responses of the banks add up to a macroeconomic equilibrium where aggregated supply meets aggregated demand.

Table 1: Comparing balance sheet size and structure in 2019 in the negative interest rate shock scenarios under static and dynamic balance sheet assumptions

| | Total assets 2019 (in thousand EUR) | | | Asset-Liability-Side-Ratio 2019 | | |
|---|---|---|---|---|---|---|
| Deciles | static | dynamic | difference | static | dynamic | difference |
| 1rst | 156,917 | 152,976 | -2.5% | 52.7% | 54.9% | 4.3% |
| 2nd | 314,481 | 300,908 | -4.3% | 63.7% | 65.5% | 2.9% |
| 3rd | 535,254 | 506,420 | -5.4% | 71.4% | 72.1% | 0.9% |
| 4th | 784,973 | 753,586 | -4.0% | 77.6% | 80.8% | 3.7% |
| 5th | 1,023,651 | 992,114 | -3.1% | 82.0% | 87.3% | 6.6% |
| 6th | 1,458,039 | 1,355,540 | -7.0% | 88.2% | 92.% | 5.0% |
| 7th | 1,943,698 | 1,882,735 | -3.1% | 95.2% | 99.7% | 4.7% |
| 8th | 2,600,000 | 2,609,900 | 0.4% | 103.5% | 106.5% | 2.9% |
| 9th | 4,223.469 | 4,427,158 | 4.8% | 118.0% | 120.5% | 2.2% |

static balance sheets and no change in interest rates, 280 bp in scenario $k = 1$ (with static balance sheets and a negative interest rate shock) and 285 bp in scenario $k = 2$ (with dynamic balance sheets and a negative interest rate shock). In the first year, the price effect can be calculated as $a_{1,i} = 280bp - 300bp = -20bp$, the quantity effect amounts to $b_{1,i} = 285bp - 280bp = 5bp$ and the total effect is $tot_{1,i} = 285bp - 300bp = -15bp$.

The scenario $k = 2$ with dynamic balance sheets (allowing for adjustments in the composition and size) and a negative interest rate shock was not at the center of attention of the participating banks. The banks seemed to have put more effort in determining other scenarios, for instance the scenario where they used the parameters with which they are planning for the future. To take into account the considerable reduction in observations, we run a robustness check to determine whether the results qualitatively remain the same under less severe cleaning.

## 4.2 Balance sheet composition

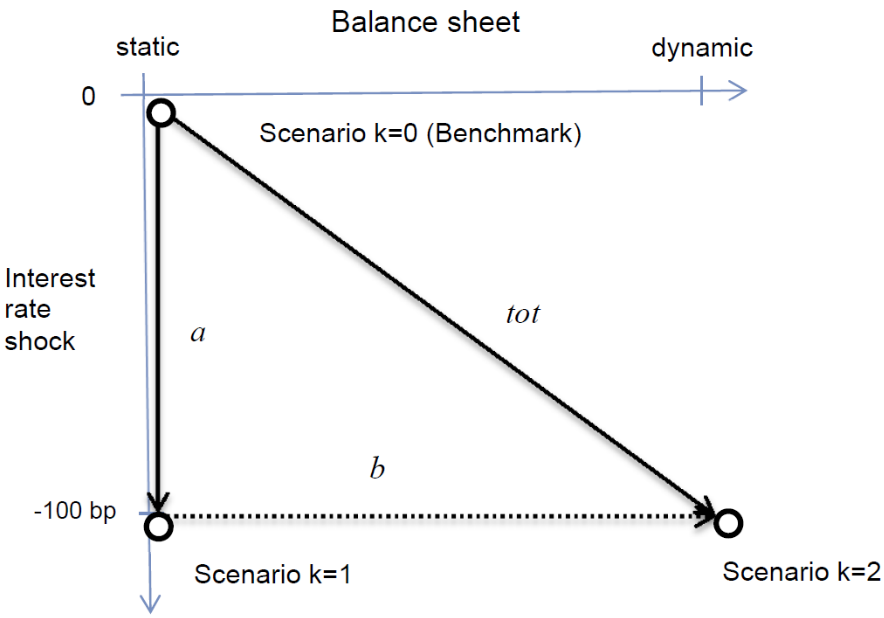
We use each bank's balance sheet composition as of 31 December 2014 (base year) to evaluate its power of determination for the simulated price and quantity effects. The banks' asset side is broken down into customer loans (three brackets concerning the loans' initial maturity: up to one year, one to five years, and more than five years), interbank loans (four brackets) and bond holdings. Concerning the liabilities, we split them into deposits from non-financials, savings deposits, interbank loans (four brackets: overnight, up to one year; more than one to two years, and more than two years) and issued bonds. The weighted balance sheet composition of our restricted sample of banks can be seen in Figure 3.[4]

## 4.3 Notation

Using the supervisory survey data (see Subsection 4.1), we investigate the banks' P&L components that are directly related to interests rates, namely the net interest margin

[4]For more information to the balance sheet positions, see Memmel and Schertler (2013).

Figure 2: Scenarios




In this figure, the three survey scenarios that we use in our study are displayed as small circles, namely the benchmark scenario $k = 0$ with static balance sheets and no interest rate shock, the scenario $k = 1$ with static balance sheets and a parallel interest rate shock of -100 bp and the scenario $k = 2$ with dynamic balance sheets and the parallel interest rate shock of -100bp. The price effect $a$ and the total effect $tot$ (relative to the benchmark) are shown as arrows with solid lines. The quantity effect $b$ (which is calculated as the difference from the total effect and the price effect) is depicted as a dotted line.

Figure 3: Stylized Balance Sheet

| Asset side | Liability side |
|---|---|
| Claims against banks (9.5%) | Debt against banks (13.6%) |
| Claims against non-banks (58.7%) | Debt against non-banks (72.1%) |
| Residual assets (31.8%) | Residual liabilities (14.3%) |

$NI^k_{h,i}$, the interest income $II^k_{h,i}$ and the interest expenses $IE^k_{h,i}$, where the index $h = 0, 1, 2, .., 5$ denotes the forecast horizon (in years),[5] the index $i = 1, 2, ..., N$ the bank and the index $k = 0, 1, 2$ the scenario. The following definition applies:

$$NI^k_{h,i} := II^k_{h,i} - IE^k_{h,i} \tag{11}$$

We define the price effect $a$ as

$$a^{NIM}_{h,i} := \frac{NI^1_{h,i} - NI^0_{h,i}}{TA^0_{0,i}}, \tag{12}$$

where the index $k = 0$ denotes the benchmark (yield curve and banks' balance sheets are held constant as of 31/12/2014) and $k = 1$ the scenario with interest rate change, but static balance sheets. For reasons of standardization, we divide the euro amount by the bank $i$'s total assets $TA^k_{h,i}$ at the point in time that the prognosis was established (i.e. with $h = 0$ and $k = 0$).[6] Note that the assumption of a static balance sheet may itself induce a price effect. One can think of an interest rate shock which makes the customers put more money in some bank product. To keep the balance sheet weights constant, the bank has to make this bank product less attractive by lowering the bank rate for this product. In the following, we neglect this kind of price effect.

The quantity effect $b$ is defined as

$$b^{NIM}_{h,i} := \frac{NI^2_{h,i} - NI^1_{h,i}}{TA^0_{0,i}}, \tag{13}$$

where $k = 2$ denotes the scenario with the interest rate change and the dynamic balance sheets. Using the Equations (12) and (13), we define

$$tot^{NIM}_{h,i} := a^{NIM}_{h,i} + b^{NIM}_{h,i}, \tag{14}$$

[5] The time where the prognosis is established is $h = 0$.

[6] Therefore, we denote $a$ as a margin (added $M$), knowing that the net interest income and the total assets may come from different points in time ($h = 0, 1, 2, .., 5$ vs. $h = 0$).

which is depicted in Figure 2. Note that, in the survey, $a$ (from scenario $k = 1$) and $tot$ (from scenario $k = 2$) are given (from which $b$ is calculated), and not – as Equation (14) suggests – $a$ and $b$.

Correspondingly, Equations (12) to (14) can be defined for the interest income margin ($p = IIM$) and for the interest expense margin ($p = IEM$). To sum up, we look at three dimensions: first, the P&L components ($p = NIM$, $IIM$, $IEM$); second, the different effects (total effect $tot$, price effect $a$, quantity effect $b$) and, third, the time dimension (base year $h = 0$ and prognosis $h = 1, 2, .., 5$).

In the following, we assess the contribution of banks' simulated price and quantity effects, respectively, to the total effect by their respective shares of the total variation. To some extent, one can think of these shares as $R^2s$ (coefficients of determinations) of regressions of the simulated total effect on the simulated price effect and quantity effect, respectively.

Finally, we calculate balance sheet weights $w^k_{h,i,j}$ (see Subsection 4.2):

$$w^k_{h,i,j} = \frac{A^k_{h,i,j}}{TA^k_{0,i}}, \tag{15}$$

where the index $j = 1, 2, ..., J$ denotes the balance sheet position and $A^k_{h,i,j}$ gives the euro amount of the respective balance sheet position.

# 5 Empirical Results

## 5.1 Descriptive Analysis

In this subsection, we present a descriptive analysis of the impact of a -100 basis points drop in the yield curve on the banks' net interest margin and the respective income and expense margins.

In Figures 4-6, the mean of the difference from the benchmark scenario is shown on the left hand side. As said above, the scenarios are designed such that a decomposition of the simulated total effect ($tot$) in the simulated price effect ($a$) and the simulated quantity effect due to balance sheet adjustments ($b$) is possible. All the effects are normalized by the total assets as of 31 December 2014.

We expect the price effect for interest income and interest expenses to be negative since falling interest rates are passed through to bank interest rates. For Banks that are engaged in term transformation the interest rate pass-through should be faster for interest expenses. In this case, the price effect for the net interest rate margin will be positive in the first months after the interest rate shock. However, the sign of the price effect on the net interest margin is expected to change after certain time because the long-run pass-through on the asset-side is usually larger than on the liability-side.

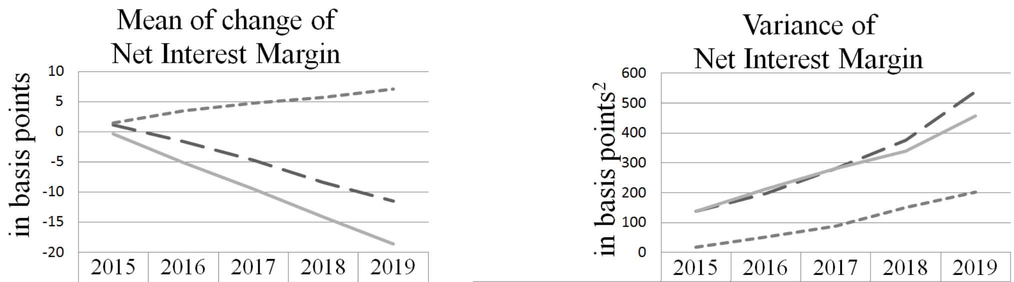
It seems very likely that the quantity effect is positive in all cases, since rationality requires that a bank steers its investment and funding in an advantageous way. However, in practice banks are not able to fully steer their investment and funding sources. For example, the amount of overnight deposits is mostly determined by the clients and, to some extent, beyond the banks' control.

The total effect ($tot$) on the net interest margin ($NIM$) is positive for the first year, whereas the price effect ($a$) is on average negative from the first year on. Busch and Memmel (2015), using aggregate data for German banks for the period 1968-2013, find that this critical horizon is about 1.5 years, which is in line with the simulated total effect $tot$, which corresponds to the actual observed accounting data.

Also, in general, the simulated effect $b$ due to balance sheet adjustments works on average in favor of the banks. This, however, is not the case for the interest expense margin ($IEM$), where the mean value of the simulated quantity effect due to balance sheet adjustments ($b$) is in fact slightly negative.

In 2019, the simulated price effect ($a$) of the 100 bp decrease in the yield curve on the interest income margin ($IIM$) is on average -49.1 bp. By contrast, banks' simulated total effect ($tot$) is on average -40.9 bp, meaning that the simulated quantity effect due to balance sheet adjustments ($b$) is sizable (8.2 bp on average). This serves as a good example of the asymmetry mentioned above: Whereas the total effect is -40.9 bp (= -49.1 bp + 8.2 bp) in the case of a downward shift in the term structure, it will presumably be 57.3 bp (= 49.1 bp + 8.2 bp) in case of a corresponding upward shift in the term structure.

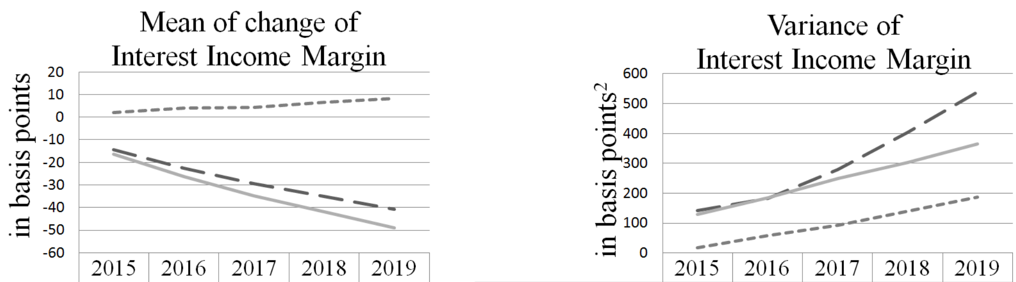
Figure 4: Effect on the NIM effect of a parallel downward shift (100 bp) of the term structure




| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| total | 1.1 | -1.6 | -4.7 | -8.4 | -11.5 |
| price effect | -0.4 | -5.1 | -9.5 | -14.2 | -18.6 |
| quantity effect | 1.5 | 3.5 | 4.8 | 5.7 | 7.1 |

| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| total | $11.7^2$ | $14.1^2$ | $16.8^2$ | $19.4^2$ | $23.2^2$ |
| price effect | $11.7^2$ | $14.6^2$ | $16.8^2$ | $18.4^2$ | $21.4^2$ |
| quantity effect | $4.2^2$ | $7.2^2$ | $9.4^2$ | $12.3^2$ | $14.2^2$ |

Figure 5: Effect on the IIM effect of a parallel downward shift (100 bp) of the term structure

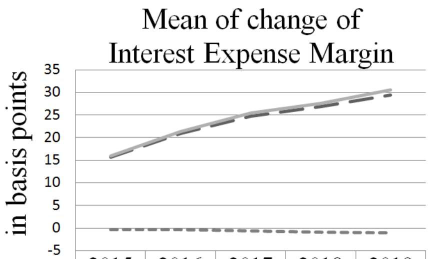



| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| total | -14.5 | -22.5 | -29.4 | -35.2 | -40.9 |
| price effect | -16.4 | -26.4 | -34.9 | -41.8 | -49.1 |
| quantity effect | 1.9 | 3.9 | 4.3 | 6.6 | 8.2 |

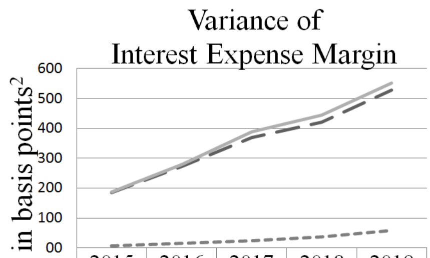
| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| total | $11.9^2$ | $13.5^2$ | $16.7^2$ | $20.1^2$ | $23.2^2$ |
| price effect | $11.4^2$ | $13.6^2$ | $15.8^2$ | $17.4^2$ | $19.1^2$ |
| quantity effect | $4.3^2$ | $7.6^2$ | $9.6^2$ | $11.8^2$ | $13.7^2$ |

The Figures 4-6 show on the right-hand side the variances of the net interest margin, interest income margin and interest expense margin for the five year time horizon as

Figure 6: Effect on the IEM effect of a parallel downward shift (100 bp) of the term structure




| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| total | 15.6 | 20.9 | 24.8 | 26.8 | 29.4 |
| price effect | 15.9 | 21.3 | 25.4 | 27.6 | 30.5 |
| quantity effect | -0.4 | -0.4 | -0.6 | -0.9 | -1.1 |




| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| total | $14^2$ | $17^2$ | $19^2$ | $21^2$ | $23^2$ |
| price effect | $14^2$ | $17^2$ | $20^2$ | $21^2$ | $24^2$ |
| quantity effect | $03^2$ | $04^2$ | $05^2$ | $06^2$ | $08^2$ |

difference from the benchmark. The corresponding tables next to the variances (figures with square roots), also give the the cross-sectional standard deviation (figures without square roots). Both can also be used to compare the importance of the price effect relative to the quantity effect.

Note that – in contrast to the mean – the standard deviation of the simulated total effect ($tot$) is not the sum of the standard deviations of the simulated price ($a$) and quantity effects ($b$). We present the standard deviation because its magnitude can be more easily assessed than that of the variance. The standard deviation increases with the forecast horizon. This holds true for all P&L components ($NIM$, $IIM$ and $IEM$) and all effects ($tot$, $a$ and $b$). Moreover, we also present the variances because we think that the variance comparison is more meaningful since it corresponds to the ratio of the coefficients of determination. In principle, this comparison could also be done by looking at the respective means. In good approximation, it is possible to sum up the variances because the covariance between the price effect and the quantity effect is rather small.[7]

The increase in the standard deviation is far more pronounced for the simulated quantity effect ($b$) than it is for the two other effects ($tot$ and $a$). For instance, in 2015, the simulated price effect ($a$) on the net interest margin ($NIM$), measured by the variances, is nearly eight times as large as the effect due to the balance sheet adjustment ($b$) ($11.7^2$ vs. $4.2^2$).[8] This finding is line with Memmel and Schertler (2013) who find that – on a yearly horizon – the coefficient of determination for the price effect is more than three times that of the one for the quantity effect. In 2019, however, this ratio of the simulated price effect ($a$) to the simulated quantity effect ($b$) is barely above two ($21.4^2$ vs. $14.2^2$). This indicates that in the short term primarily the simulated price effect is important and in the medium-term (and presumably in the long-run) both effects are important.

Table 2 reports the share of improvements relative to the benchmark. For instance,

[7] Using the identity as laid down in Equation (14), one obtains $var(tot) = var(a) + var(b) + 2cov(a, b)$. The covariances are considerably small, so they are assumed to be zero. For instance, when the return of a stock is split up into the market component and an idiosyncratic component, the cross sectional mean of the idiosyncratic components should be close to zero. Moreover, no one would say that the idiosyncratic component of the shocks is (close to) zero. By contrast, looking at the second moments (standard deviation or variance), one obtains a meaningful comparison of the relative importance of the market and idiosyncratic components.

[8] In terms of standard deviations, the effect is more than twice as strong.

Table 2: Effect on the share of improvements of a parallel downward shift in the term structure

| Effect | Year | Share of improvements (rel. to benchm.) | | | Nobs |
|---|---|---|---|---|---|
| | | NIM | IIM | IEM | |
| tot | 2015 | 51.9 | 6.1*** | 92.6*** | 376 |
| tot | 2016 | 45.2* | 3.5*** | 95.3*** | 405 |
| tot | 2017 | 38.5*** | 3.5*** | 97.0*** | 397 |
| tot | 2018 | 29.9*** | 6.0*** | 97.5*** | 398 |
| tot | 2019 | 24.4*** | 5.5*** | 98.0*** | 397 |
| a | 2015 | 44.4** | 2.1*** | 93.9*** | 376 |
| a | 2016 | 35.6*** | 1.2*** | 96.8*** | 405 |
| a | 2017 | 25.2*** | 1.5*** | 98.0*** | 397 |
| a | 2018 | 17.1*** | 2.3*** | 98.5*** | 398 |
| a | 2019 | 12.6*** | 1.5*** | 98.7*** | 397 |
| b | 2015 | 80.3*** | 85.1*** | 56.4** | 376 |
| b | 2016 | 84.9*** | 87.4*** | 58.0*** | 405 |
| b | 2017 | 84.1*** | 87.9*** | 57.7*** | 397 |
| b | 2018 | 83.7*** | 87.2*** | 59.3*** | 398 |
| b | 2019 | 84.4*** | 88.2*** | 59.4*** | 397 |

This table shows the share (in per cent) of improvements relative to the benchmark (Scenario k=0). Two scenarios are compared: the scenario of a downward shift in the yield curve and the benchmark scenario with constant yield curve. The difference of three income components are analysed, namely $NIM$,$IIM$ and $IEM$ which denote the net interest margin, the interest income margin and the interest expense margin, where the respective income components are divided by the total assets as of end 2014 (and not as of the respective year). The effects $a$ and $b$ denote the impact due to the price and the quantity effects (as defined in the Equations (12) and (13)), respectively; *tot* means the total effect, the sum of $a$ and $b$ (as defined in Equation (14)). *** , ** and * denote significance at 1%, 5% and 10% level, respectively, concerning the hypothesis that the true share is 50%.

in 2015, in 51.9% of the cases, the $NIM$ is higher in the downward shift scenario than in the benchmark scenario of a constant term structure. Special attention should be paid to the simulated quantity effect $b$, the difference in the outcomes between the assumption of dynamic balance adjustment and constant balance sheets. If we assume that banks optimize their balance sheets, there must be an improvement – or at least no deterioration – in all cases, i.e. we expect 100 per cent in the respective columns. This is not the case, however. Even on the asset side, only round 85% of all cases lead to an improvement; in more than 10% of the cases, the balance sheet adjustment leads to a deterioration in the interest income margin ($IIM$). In case of the interest expense margin ($IEM$), the share is just above 50 per cent, meaning that the balance sheet adjustments lead to a deterioration nearly as often as to an improvement. It seems as though banks cannot solely optimize their balance sheet structure; instead, they are subject to exogenous factors as well. Such exogenous factors may be customers who want to deposit their money at banks that are reluctant or not allowed to turn their deposit rates negative.

## 5.2 Size Effects

In this section we analyse how the price, quantity, and total effects of the interest rate margin are affected by bank size. We compare these effects for the 25% smallest and 25% largest banks (measured by total assets). In general, we observe a similar pattern for both size groups regarding the development of the price effect, quantity effect and the total effect, but with different absolute levels (Figure 7). While the total effect for the group of small banks is positive in the first two years, the total effect of large banks is negative. Also regarding the price effect we observe more favourable values for small banks. For small banks the price effect is positive in the first year. We expect such an effect for banks that are engaged in term transformation. In contrast, the average quantity effect is higher for larger banks. In order to quantify the effects, we run a regression analysis for a sample of banks covering the 25% smallest and the 25% largest banks. We regress each effect (the price effect, the quantity effect and the total effect) on a size dummy (D75), which takes the value 1 for banks belonging to the 25% largest banks. Furthermore, we include year dummies and interact the time dummies with the size dummy.

The results shown in Table 3 confirm that large banks are more strongly hit by the price effect. Nevertheless, we also see that large banks are better able to adjust their balance sheets. Furthermore, the time trend is negative for the price effect and the total effect. It is positive for the quantity effect. However, the interaction dummies do not indicate differences between size groups becoming smaller through time. An explanation for the differences in the levels of the size groups with less competition for small banks and more flexible business models of large banks is that smaller banks usually operate in rather rural areas while larger banks are located in urban areas which are more competitive. Therefore, we expect smaller banks to react less competitively to market rate changes resulting in smaller changes in interest margins after an interest rate shock. However, large banks usually offer a broader product portfolio which enables them to adjust their balance sheet composition more easily compared to small banks. In total, the price effect dominates the quantity effect leading to a less favourable development of the total effect for large banks. The results qualitatively remain the same if we include the remaining banks in the sample and let the size dummy taking the value 1 for the 50% largest banks. Only for the regression of the quantity effect is the size dummy not statistically significant.

## 5.3 Balance sheet composition

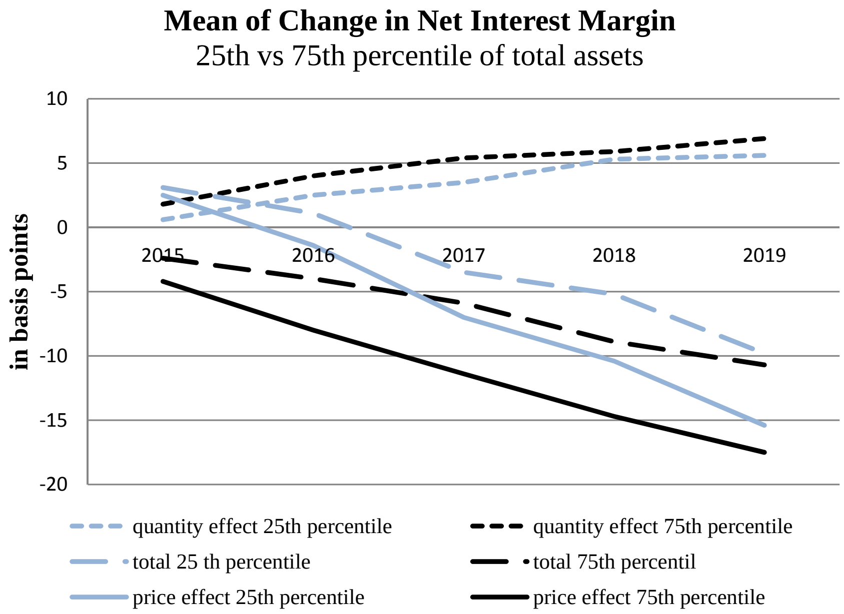
In our empirical analysis, we regress $a^p_{h,i}$, $b^p_{h,i}$and $tot^p_{h,i}$ with $p = NIM$, $IIM$, $IEM$ on the bank $i$'s balance sheet composition in $h = 0$, i.e. on the weights $w^0_{0,i,j}$ , thereby obtaining 45 (= 3 effects x 3 P&L-components x 5 years) $R^2$ (coefficients of determination). These $R^2$ are reported in Table 4. In Section 3, the stylized empirical model showed that the coefficients of determination $R^2_{a,h}$ and $R^2_{b,h}$ should fall for the price effect $a$ (Proposition 1) and increase for the quantity effect $b$ (Proposition 2), with respect to the horizon $h$. In fact, we find that the simulated price effect (variable $a$) shows a relationship to the balance sheet weights of the base year (as of 31 December 2014) which becomes weaker as the forecast horizon $h$ increases. This more or less holds true for all P&L components. What is more, we find the opposite result for the simulated quantity effect (variable $b$). The explanatory power of the balance sheet weights (of the year 2014) tends to become stronger with the length of the forecast horizon $h$. For instance, whereas the 2014 balance

Table 3: Effect of bank size on price effect, quantity effect, and total effect

| Variable | Price effect NIM | Quantity effect NIM | Total effect NIM |
|---|---|---|---|
| D75 | -0.0007 *** | 0.0001* | -0.0006*** |
| | (0.0002) | (0.0001) | (0.0002) |
| D2016 | -0.0004*** | 0.0002*** | -0.0002 |
| | (0.0002) | (0.0001) | (0.0002) |
| D2017 | -0.0010*** | 0.0003*** | -0.0007*** |
| | (0.0002) | (0.0001) | (0.0002) |
| D2018 | -0.0013*** | 0.0005 *** | -0.0009*** |
| | (0.0002) | (0.0001) | (0.0002) |
| D2019 | -0.0018*** | 0.0005 *** | -0.0013*** |
| | (0.0002) | (0.0001) | (0.0002) |
| D75 x D2016 | 0.000 | 0.0000 | 0.0003 |
| | (0.0003) | (0.0001) | (0.0003) |
| D75 x D2017 | 0.0002 | 0.0001 | 0.0003 |
| | (0.0003) | (0.0001) | (0.0003) |
| D75 x D2018 | 0.0002 | -0.0000 | 0.0002 |
| | (0.0003) | (0.0002) | (0.0003) |
| D75 x D2019 | 0.0005 | 0.0000 | 0.0005 |
| | (0.0003) | (0.0002) | (0.0004) |
| Cons | 0.0003*** | 0.0001 | 0.0003 |
| | (0.0001) | (0.0000) | (0.0001) |
| $R^2$ | 13.25 % | 3.8 % | 6.23% |
| N of obs | 1,000 | 1,000 | 1,000 |

This table shows the effect of bank size on price effect, quantity effect, and total effect. This specification incorporates the 25th and the 75th Percentile of banks measured by total assets. The variable D75 is a dummy variable that takes the value 1 for banks belonging to the 75th percentile of largest banks. The variables D2016, D2017, D2018, and D2019 are time dummies. Furthermore, we interact time dummies and the size dummy. *** , ** and * denote significance at 1%, 5% and 10% level, respectively, concerning the hypothesis that the true share is 50%.

Figure 7: Effect on the NIM effect of a parallel downward shift (100 bp) of the term structure: 75% vs 25% percentile of total assets




sheet weights explain only 2.8% of the simulated quantity effect on the interest income margin in 2015, the explanatory power increases and reaches 3.2% in 2019.

We compare the $R^2$ among each other to see whether there is a statistically significant dynamic as predicted by the model above. In Table 5, we show that, in the case of the simulated price effect $a$, the coefficients of determination in the first year of the forecast horizon are in some cases significantly smaller than at future points in time, which holds true for all three parts of the P&L (See Appendix 2 for a derivation of the test statistics). In the case of banks' simulated quantity effect $b$, we find significance only for the $IIM$ compared to the year 2016; for $NIM$, the signs of the test statistics correspond to the theoretical prediction, but they are not significant. The total effect, which is, by definition, the sum of the direct and indirect effects ($tot = a + b$), often shows a u-form development. According to the model in Section 3, the economic intuition is as follows: At first, the explanatory power of today's balance sheet weights is falling because the extents of the pass-through of the single bank products are becoming more similar. Then, this explanatory power is increasing again because the second effect, the adjusting of the balance sheet weights, is getting stronger.

## 5.4 Robustness checks

First, as stated above, our data cleaning considerably reduces our sample size. To take this into account, we apply a less rigorous data cleaning for the robustness check. Hence,

Table 4: $R^2$ of a regression on today's balance sheet weights

| Effect | Year | $R^2$ | | | Nobs |
|---|---|---|---|---|---|
| | | NIM | IIM | IEM | |
| tot | 2015 | 11.2% | 19.2% | 8.2% | 376 |
| tot | 2016 | 5.4% | 7.0% | 4.6% | 405 |
| tot | 2017 | 4.7% | 8.8% | 3.7% | 397 |
| tot | 2018 | 7.2% | 7.1% | 3.4% | 398 |
| tot | 2019 | 8.0% | 6.2% | 4.8% | 397 |
| a | 2015 | 10.6% | 23.1% | 8.4% | 376 |
| a | 2016 | 7.8% | 15.0% | 4.3% | 405 |
| a | 2017 | 4.7% | 12.2% | 3.4% | 397 |
| a | 2018 | 5.5% | 8.6% | 3.0% | 398 |
| a | 2019 | 7.3% | 8.5% | 4.4% | 397 |
| b | 2015 | 6.5% | 2.8% | 3.7% | 376 |
| b | 2016 | 10.8% | 9.6% | 1.8% | 405 |
| b | 2017 | 7.8% | 4.6% | 1.5% | 397 |
| b | 2018 | 6.6% | 4.2% | 2.1% | 398 |
| b | 2019 | 6.0% | 3.2% | 2.0% | 397 |

This table shows the $R^2$s of the regressions where, in each year, the respective effects $a$, $b$ and *tot* are regressed on the balance sheet weights of 2014. Two scenarios are compared: the scenario of a downward shift in the yield curve and the benchmark scenario with constant term structure. The difference of three income components are analysed, namely $NIM$,$IIM$ and $IEM$ which denote the net interest margin, the interest income margin and the interest expense margin, where the respective P&L components are divided by the total assets as of end 2014 (and not as of the respective year). The effects $a$ and $b$ denote the impact due to the price and the quantities (as defined in the Equations (12) and (13)), respectively; *tot* means the total effect, the sum of $a$ and $b$ (as defined in Equation (14)).

Table 5: Difference in $R^2$s (compared to 2015)

| Effect | Year | $\Delta R^2$ | | | Nobs |
|---|---|---|---|---|---|
| | | NIM | IIM | IEM | |
| tot | 2016 | -5.83** | -12.23*** | -3.68*** | 351 |
| | | (2.94) | (2.76) | (1.32) | |
| tot | 2017 | -6.50** | -10.42** | -4.56** | 345 |
| | | (3.31) | (4.74) | (2.00) | |
| tot | 2018 | -4.03 | -12.11* | -4.84* | 339 |
| | | (4.16) | 6.19 | 2.53 | |
| tot | 2019 | -3.25 | -12.99* | -3.41 | 332 |
| | | (4.59) | (7.84) | (3.38) | |
| a | 2016 | -2.77 | -8.14*** | -4.05*** | 351 |
| | | (2.15) | (2.53) | (1.28) | |
| a | 2017 | -5.87** | -10.95** | -4.97** | 345 |
| | | (2.82) | (4.65) | (2.02) | |
| a | 2018 | -5.09 | -14.53** | -5.33** | 339 |
| | | (3.58) | (6.01) | (2.62) | |
| a | 2019 | -3.28 | -14.67* | -3.95 | 332 |
| | | (4.08) | (7.80) | (3.39) | |
| b | 2016 | 4.35 | 6.87** | -1.86 | 351 |
| | | (3.31) | (3.33) | (1.38) | |
| b | 2017 | 1.32 | 1.82 | -2.18 | 345 |
| | | (3.14) | (2.74) | (1.47) | |
| b | 2018 | 0.11 | 1.41 | -1.60 | 339 |
| | | (3.09) | (2.17) | (1.35) | |
| b | 2019 | -0.50 | 0.39 | -1.76 | 332 |
| | | (3.23) | (2.24) | (1.40) | |

This table shows the difference in $R^2$s (compared to the ones of the year 2015) of regressions of the effects $a$, $b$ and $tot$ on the balance sheet weights of the year 2014. Two scenarios are compared: the scenario of a downward shift in the yield curve and the benchmark scenario with a constant yield curve. The difference of three income components are analysed, namely $NIM$,$IIM$ and $IEM$ which denote the net interest margin, the interest income margin and the interest expense margin, where the respective income components are divided by the total assets as of end 2014 (and not as of the respective year). The effects $a$ and $b$ denote the impact due to price and quantity effects (as defined in the Equations (12) and (13)), respectively; $tot$ means the total effect, the sum of $a$ and $b$ (as defined in Equation (14)). Standard errors in brackets. *** , ** and * denote significance at 1%, 5% and 10% level, respectively.

we retain observations no matter whether the balance sheet development is the same in different scenarios that allow for balance sheet adjustments.[9] This way of data cleaning yields a data set of about 1,200 banks. Overall, the results remain qualitatively the same. However, several points have to be highlighted. First, the total effect of the interest rate shock on the net interest margin is on average positive for the first two years, not only on the first year as in the restricted sample (see Subsection 5.1). Second, the standard deviation of banks' simulated quantity effect for the $NIM$ is larger than that of banks' simulated price effect in 2019 (and not the other way around as in the restricted sample). Third, when using the extended data set, the significances for the comparisons of the $R^2$ (see Subsection 5.3), become stronger.

Second, we check whether the calculations are robust to changes in the definitions of asset and liability components. First, we take together assets and liabilities of the same maturities. Here, we observe a lower absolute level of the $R^2$, but the same pattern of the coefficient of determination.

Third, we differentiate regarding the type of customer and loan type. Here, we classify balance sheet positions into positions originated by business relationships with corporate customers, private persons, banks, government, non-profit organizations and foreign customers. Applying this specification also indicates a rising coefficient of determination regarding banks' simulated quantity effect, while the explanatory power in the specifications for banks' simulated price effect declines over time.

Fourthly. we analyse the effects of balance sheet alignments separately for expansions and reductions. It turns out that the average effects on the P&L components $NIM$ and $IIM$ are negative in the event that banks expect balance sheet expansions, whereas in the case of balance sheet reductions the average effects are positive. These results demonstrate that expectations concerning balance sheet growth are a major determinant.

# 6 Conclusion

Using unique supervisory survey data of German small and medium-size banks we are able to shed light on the question if a static balance sheet assumption seems to be justified in stress testing exercises. For understandable reasons, eg comparability of results, stress tests with a horizon of even several years are often carried out under the assumption of static balance sheets. In its pure nature, such a setting does not allow for changes in the composition and size of the balance sheet. Our results suggests that over a horizon of several years banks' simulated quantity effects due to balance sheet adjustments may have noticeable effects. Our results show that in the first year the variance of banks' simulated price effect – derived from a scenario with static balance sheets – is nearly eight times as large as the simulated quantity effect – derived from the same scenario but with dynamic balance sheets. After five years, however, the importance of both effects converges as banks' simulated price effect is just about twice as large as the simulated quantity effect. We come to the conclusion that in interest rate stress tests with a short forecast horizon a static balance sheet assumption might be justified, but not for the medium term. In general, the current trend to create stress test exercises with constrained dynamic balance

[9] This procedure can be justified by the argument that the balance sheet structure planning is not significantly different.

sheets is consistent with our conclusion.

Furthermore,our results show that balance sheet adjustments are not always in favor of banks. This might be explained by the fact that banks are subject to exogenous factors, such as the behavior of depositors. The planning of the balance sheet structure seems to account for these considerable effects. We also find that the current balance sheet composition can to some extent answer the question of how banks are affected by a macroeconomic shock. Our results indicate that the simulated quantity effects are explained better by a bank's current balance sheet composition, the longer the forecast horizon. This is likely mirroring the only partial adjustment to the new equilibrium of portfolio composition. The opposite holds for banks' price effect.

# A Appendix

## A.1 Appendix 1: Deviation of the process of $w_h$

We assume that a bank minimizes its losses which stem from deviations of the weight $w_h$ from the optimal weight $\bar{w}$ and from deviations from the past weight $w_{h-1}$ (adjustment costs):[10]

$$Loss = \mu_1(\bar{w} - w_h)^2 + \mu_2(w_h - w_{h-1})^2 \tag{16}$$

When optimizing with respect to the weight $w_h$, we obtain:

$$\frac{\partial Loss}{\partial w_h} = -2\mu_1(\bar{w} - w_h) + 2\mu_2(w_h - w_{h-1}) \tag{17}$$

Setting Equation (17) to zero, the following condition arises, which is an autoregressive process of order 1:[11]

$$w_h = \frac{\mu_1}{\mu_1 + \mu_2}\bar{w} + \frac{\mu_2}{\mu_1 + \mu_2}w_{h-1} \tag{18}$$

Setting $\alpha = \frac{\mu_1}{\mu_1+\mu_2}\bar{w}$ and $\beta = \frac{\mu_2}{\mu_1+\mu_2}$, we obtain the relationship in Equation (6).

## A.2 Appendix 2: Comparision of $R^2$s

In this appendix, we derive the test statistics for a comparison of two coefficients of determination, where we define, for the regression $y_i = x_i^{'}\beta + \varepsilon_i$, the coefficient of determination as

$$R^2 = 1 - \frac{\sigma_\varepsilon^2}{\sigma_y^2} \tag{19}$$

[10]See Baltagi (2008), p. 137.

[11]Note that we take the weight $w_{h-1}$ as given. If we abstained from this assumption, the expressions would be more complicated (the resulting autoregressive process would be of order 2), but the qualitative statements would remain.

with $\sigma_\varepsilon^2 = var(\varepsilon_i)$ and $\sigma_y^2 = var(y_i)$. We determine the asymptotic distribution of the difference

$$\Delta \hat{R}^2_{m,h} = \hat{R}^2_{m,h} - \hat{R}^2_{m,1}, \tag{20}$$

where $\Delta \hat{R}^2_m$ is the difference between the $R^2$ of the end ($h = 2, 3, 4, 5$) and of the beginning ($h = 1$) of the forecast horizon and the index $m = tot$, $a$, $b$ denotes the effect under consideration. After some transformations, we obtain

$$\Delta \hat{R}^2_{m,h} = \frac{\hat{\sigma}^2_{m,\varepsilon,1}}{\hat{\sigma}^2_{m,y,1}} - \frac{\hat{\sigma}^2_{m,\varepsilon,h}}{\hat{\sigma}^2_{m,y,h}} \tag{21}$$

Using the delta method, we can express the asymptotic variance of the term $\Delta \hat{R}^2_{m,h}$ as

$$\lim_{N\to\infty} N \cdot var\left(\Delta \hat{R}^2_{m,h}\right) = N \cdot \left(\frac{\partial \Delta \hat{R}^2_{m,h}}{\partial x}\right)' \Omega \left(\frac{\partial \Delta \hat{R}^2_{m,h}}{\partial x}\right) \tag{22}$$

with $x = \left(\hat{\sigma}^2_{m,y,1}, \hat{\sigma}^2_{m,\varepsilon,1}, \hat{\sigma}^2_{m,y,h}, \hat{\sigma}^2_{m,\varepsilon,h}\right)$, $N$ the number of banks and $\Omega = var(x)$. Accordingly, the derivative of $\Delta \hat{R}^2_m$ with respect of $x$ is

$$\frac{\partial \Delta \hat{R}^2_{m,h}}{\partial x} = \left(-\frac{\hat{\sigma}^2_{m,\varepsilon,1}}{\hat{\sigma}^4_{m,y,1}}, \frac{1}{\hat{\sigma}^2_{m,y,1}}, \frac{\hat{\sigma}^2_{m,\varepsilon,h}}{\hat{\sigma}^4_{m,y,h}}, -\frac{1}{\hat{\sigma}^2_{m,y,h}}\right). \tag{23}$$

The test statistics $ts$ is

$$ts = \frac{\Delta \hat{R}^2_{m,h}}{\sqrt{var\left(\Delta \hat{R}^2_{m,h}\right)}}, \tag{24}$$

where we use the corresponding expressions in Equations (21) and (22). Under the null hypothesis of equal $R^2$, the test statistics $ts$ is asymptotically standard normally distributed.

The covariance-matrix $\Omega$ is estimated as follows, where, for reasons of brevity, we restrict the illustration to two variables (although the matrix $\Omega$ is of dimension $4 \times 4$): Let $y_i$ and $\varepsilon_i$ with $i = 1, ..., N$ be (across the $N$ banks) independent and identically distributed (iid) random variables with expectation $\mu_y$ and zero, respectively.[12] We define $Z_i = (Z_{1,i}, Z_{2,i})'$, $Z_{1,i} = (y_i - \mu_y)^2$ and $Z_{2,i} = \varepsilon_i^2$.[13] By the central limit theorem, we obtain for the arithmetic average $\bar{Z} = \frac{1}{N}\sum_{i=1}^{N} Z_i$

$$\sqrt{N}\left(\bar{Z} - E(Z_i)\right) \to N(0, var(Z_i)) \tag{25}$$

[12]Note that in case there is some positive cross-sectional correlation, for instance due to common shocks, then the test statistics will too often signal significant results.

[13]Note that $\mu_y$ is estimated as the arithmetic average.

with

$$var(Z_i) = \begin{pmatrix} var(Z_{1,i}) & cov\left(Z_{1,i}, Z_{2,i}\right) \\ cov\left(Z_{1,i}, Z_{2,i}\right) & var(Z_{2,i}) \end{pmatrix}. \tag{26}$$

Looking at the single components of the matrix in Equation (26), we obtain

$$\begin{aligned} var(Z_{1,i}) &= var\left((y_i - \mu_y)^2\right) \\ &= N \cdot var\left(\frac{1}{N}\sum_{i=1}^{N}(y_i - \mu_y)^2\right) \end{aligned} \tag{27}$$

and, correspondingly,

$$cov\left(Z_{1,i}, Z_{2,i}\right) = N \cdot cov\left(\frac{1}{N}\sum_{i=1}^{N}(y_i - \mu_y)^2, \frac{1}{N}\sum_{i=1}^{N}\varepsilon_i^2\right). \tag{28}$$

Note that we use the expressions $\hat{\sigma}_y^2 = \frac{1}{N}\sum_{i=1}^{N}(y_i - \mu_y)^2$ and $\hat{\sigma}_\varepsilon^2 = \frac{1}{N}\sum_{i=1}^{N}\varepsilon_i^2$ for the variance and covariance estimators, respectively. Accordingly, we obtain that

$$\Omega = \frac{var\left(Z_i\right)}{N}. \tag{29}$$

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