ONLINE ANNEX 4.1. TECHNICAL NOTE[1]

This annex accompanies Chapter 4 of the April 2020 *Global Financial Stability Report* and provides additional details on the analytical work supporting the chapter. This work consists of three separate but related parts that are discussed in turn in the different sections of this annex. Section A explains the econometric exercise used to analyze the main drivers of changes in bank profitability that have occurred to date. Section B describes the methodology used to estimate the effective repricing maturities of banks' loans and deposits and how to use them to simulate the paths of banks' yields on loans and costs of deposits for a given future path of economic growth and inflation. Section C explains how these simulated paths are combined with bank-level information to conduct a forward-looking assessment of banks' profitability. In addition, Section D describes the method for estimating the market-implied cost of equity for banks that is used in Chapter 4.

The chapter discusses trends and challenges to profitability for banks from nine advanced economies—the Group of 7 economies (Canada, France, Germany, Italy, Japan, United Kingdom, United States) plus two economies that have or have had negative central bank policy rates (Sweden, Switzerland). While all three parts of the analytical work cover these nine countries, the actual number of banks used in the various parts vary because of the different data requirements involved in each type of exercise. Each of the sections that follow explain the criterial used to select the sample of banks in detail, but in all cases the goal was to maximize bank coverage.

A. Econometric Analysis of Bank Profitability[2]

Data

The analysis relies on financial statements of banks from the nine economies studied throughout the chapter. Bank-level balance sheet and income statement data come from Fitch Connect.[3] Macroeconomic data on GDP growth, inflation, forecasts, and interest rates (three-month rate and terms spread) come from the World Bank World Development Indicators and Consensus Economics. The analysis is based on an unbalanced sample of banks covering the period from 2000 to 2018. The exact number of banks included varies across exercises depending on the data availability for the included balance sheet items. For the higher-level items, which are more broadly available, it includes 11,802 banks.

[1] This is an annex to Chapter 4 of the April 2020 *Global Financial Stability Report*.

[2] This section was prepared Yizhi Xu.

[3] The bank-level statements are consolidated at the country. Such design allows us to pick up the impact on domestic parent banks.

Econometric Model

The econometric model builds on previous work by Borio, Gambacorta, and Hofmann (2017), Claessens, Coleman, and Donnelly (2018), and Altavilla, Boucinha, and Peydró (2018) and considers the following empirical specification to study the relationship between the interest rate environment and banks' net interest margin (NIM) controlling for macroeconomic conditions:

$$\begin{aligned} NIM_{i,c,t} = \beta_0 &+ \beta_1 NIM_{i,c,t-1} + \beta_2 Bank_{c,t-1} + \beta_3 Macro_{c,t} + \beta_4 ST3M_{c,t} + \beta_5 TermSpread_{c,t} \\ &+ \beta_6 ST3M_{c,t} \times Negative_{c,t} + \beta_7 TermSpread_{c,t} \times Low_{c,t} + \beta_8 Negative_{c,t} \\ &+ \beta_9 Low_{c,t} + \beta_{10} GFC_t + \beta_{11} EDC_t + \gamma_c + \varepsilon_{i,c,t} \quad (1) \end{aligned}$$

where $ST3M_{c,t}$ is the annual average 3-month government bonds yield (short-term rate) in country c, $TermSpread_{c,t}$ is 10-year to 3-month government bonds spread, $Negative_{c,t}$ is a dummy that equals 1 if the short-term rate is less than zero, $Low_{c,t}$ is a dummy that equals 1 if the 10-year to 3-month spread is less than 1 percentage point (the 10th percentile of the empirical distribution of spreads in the sample), GFC_t and EDC_t are dummies for the Global Financial Crisis (2008–09) and the European debt crisis (2010–12), respectively. $Bank_{c,t-1}$ and $Macro_{c,t}$ are bank controls (capital ratio, deposit-to-liability ratio, security-to-asset ratio) and macro controls (real GDP growth, inflation rate, and 1-year ahead GDP growth and inflation rate forecast). γ_c are country fixed effects. All standard errors are clustered at the bank-level.

This specification permits studying the effect of changes in short-term rates on banks' net interest income and test whether the elasticities differ between "normal" times and periods with negative short-term rates (or low spreads) depending on the values of $\beta_4, \beta_5, \beta_6, \beta_7$. For instance, positive values for β_4 and β_5 indicate that a decline in the short-term rate or term-spread reduces bank profitability, and that this decline is larger when short term rates are negative or term spreads are compressed if β_6 and β_7 are also positive. As Online Annex Table 4.1.1 shows, in the negative rate or low spreads environment, decreasing short-term rates or term spreads is associated with significant declines in bank net interest margin. Such pattern is persistent without controlling the lagged NIM or with time fixed effects.

In addition to the analysis on bank profitability, the same specification was used to analyze the relationship between the interest rate environment and the ratio of loan-loss provisions to total assets and loan maturity ratio (the difference in amount between 5-year or longer maturity loans and 3-month or shorter maturity loans over gross loans) that are also reported in the chapter. The results of these regressions are reported in Online Annex Table 4.1.2. It appears that squeezing term spreads in a low spreads environment is associated with further declines in bank provisions, while decreasing short-term rates in a negative rate environment is associated with additional increases in loan maturities and fee income ratio.

Online Annex Table 4.1.1.
Relation Between Interest Rates and Bank NIM

VARIABLES	(1)	(2)	(3)	(4)
Dependent Variable (Lag)	0.581***	0.581***		
	(0.013)	(0.014)		
Deposit/Liability (Lag)	0.000	0.001	0.000	0.002*
	(0.000)	(0.001)	(0.001)	(0.001)
Capital Ratio (Lag)	–0.009***	–0.009***	–0.000	–0.000
	(0.002)	(0.002)	(0.003)	(0.003)
Security/Assets (Lag)	0.001**	0.001***	–0.005***	–0.005***
	(0.000)	(0.000)	(0.000)	(0.000)
Real GDP Growth	–0.000	–0.024***	–0.001	–0.022***
	(0.001)	(0.002)	(0.001)	(0.002)
Inflation Rate	–0.004***	–0.005*	0.012***	0.006*
	(0.002)	(0.003)	(0.002)	(0.004)
Real GDP Growth Forecast	0.043***	0.057***	0.059***	0.052***
	(0.002)	(0.004)	(0.003)	(0.005)
Inflation Rate Forecast	0.023***	0.012***	–0.022***	0.003
	(0.003)	(0.005)	(0.004)	(0.007)
ST3M	0.063***	0.008**	0.147***	–0.002
	(0.003)	(0.004)	(0.005)	(0.006)
Term Spread	0.043***	–0.016***	0.078***	–0.071***
	(0.003)	(0.004)	(0.006)	(0.006)
ST3MxNegative	0.054***	0.187***	0.122***	0.282***
	(0.010)	(0.011)	(0.015)	(0.016)
Term Spread x Low	0.170***	0.166***	0.290***	0.270***
	(0.007)	(0.009)	(0.009)	(0.011)
Negative	–0.025***	–0.035***	–0.050***	–0.099***
	(0.005)	(0.006)	(0.009)	(0.009)
Low	–0.136***	–0.112***	–0.294***	–0.208***
	(0.007)	(0.008)	(0.008)	(0.010)
Global financial crisis	–0.011*		–0.009	
	(0.006)		(0.008)	
European debt crisis	0.041***		0.065***	
	(0.004)		(0.005)	
Observations	156,940	156,940	156,968	156,968
R-squared	0.882	0.883	0.820	0.823
Bank fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Crises	Yes	Crises	Yes

Source: IMF staff.

Note: This table reports the association between bank net interest margin (NIM) and interest rates. The dependent variable is bank NIM expressed as a fraction of bank total assets. ST3M is the short-term rate proxied by 3-month government bond yields. Term spread is the 10-year minus 3-month spread. Negative and Low are dummies indicating whether ST3M is below zero and whether the term spread is below 1.25 percentage points respectively. The specification also includes macro and bank-level controls, and global financial crisis (2008–09) and European debt crisis (2010–12) dummies. Columns (1) and (3) report specifications with crises dummies, and Columns (2) and (4) report specifications with year fixed effects. Column (1)(2) include lagged NIM, while Column (3)(4) do not. All errors are clustered at the bank-level. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Online Annex Table 4.1.2.
Relation Between Interest Rates and Other Bank Variables

VARIABLES	(1) NIM	(2) Provision/Assets	(3) Loan Maturity Ratio
Dependent Variable (Lag)	0.581***	0.329***	0.586***
	(0.013)	(0.008)	(0.020)
Deposit/Liability (Lag)	0.000	–0.002***	0.030
	(0.000)	(0.000)	(0.033)
Capital Ratio (Lag)	–0.009***	0.001	–0.027
	(0.002)	(0.001)	(0.056)
Security/Assets (Lag)	0.001**	–0.000	0.044**
	(0.000)	(0.000)	(0.019)
Real GDP Growth	–0.000	–0.012***	–0.334***
	(0.001)	(0.001)	(0.087)
Inflation Rate	–0.004***	–0.047***	0.255
	(0.002)	(0.002)	(0.369)
Real GDP Growth Forecast	0.043***	–0.051***	1.983***
	(0.002)	(0.002)	(0.295)
Inflation Rate Forecast	0.023***	–0.030***	–2.461***
	(0.003)	(0.004)	(0.642)
ST3M	0.063***	0.059***	0.823***
	(0.003)	(0.002)	(0.172)
Term Spread	0.043***	0.098***	–5.300***
	(0.003)	(0.003)	(0.396)
ST3MxNegative	0.054***	–0.107***	–4.429***
	(0.010)	(0.014)	(0.533)
Term Spread x Low	0.170***	0.065***	12.338***
	(0.007)	(0.007)	(1.351)
Negative	–0.025***	–0.026***	–1.514***
	(0.005)	(0.009)	(0.431)
Low	–0.136***	0.020***	–11.752***
	(0.007)	(0.007)	(1.039)
Global financial crisis	–0.011*	0.118***	4.055***
	(0.006)	(0.008)	(0.541)
European debt crisis	0.041***	0.059***	5.053***
	(0.004)	(0.005)	(0.453)
Observations	156,940	152,320	26,618
R-squared	0.882	0.459	0.940
Bank fixed effects	Yes	Yes	Yes
Time fixed effects	Crises	Crises	Crises

Source: IMF staff.

Note: This table reports the association between other bank variables and interest rates. ST3M is the short-term rate proxied by 3-month government bond yields. Term spread is the 10-year minus 3-month spread. Negative and Low are dummies indicating whether ST3M is below zero and whether the term spread is below 1.25 percentage points respectively. The specification also includes macro and bank-level controls, and global financial crisis (2008–09) and European debt crisis (2010–12) dummies. The dependent variables are net interest margin for Column (1), loan loss provisions to assets ratio for Column (2), and loan maturity ratio (more than 5-year maturity minus less than 3-month maturity) for Column (3). All errors are clustered at the bank-level. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Online Annex Table 4.1.3.
Elasticities of Changes in Provisions and Fee Income Ratio

VARIABLES	(1) Provisions/Assets (Growth in Percent)	(2) Fee Income/Assets (Change in Percentage Points)
Dependent Variable (Lag)	–0.112***	–0.104***
	(0.003)	(0.026)
Deposit/Liability (Lag)	–0.004***	–0.001
	(0.001)	(0.001)
Capital Ratio (Lag)	0.005	–0.007***
	(0.005)	(0.002)
Security/Assets (Lag)	–0.001	–0.000
	(0.002)	(0.000)
Real GDP Growth	–0.035***	0.006***
	(0.007)	(0.001)
Inflation Rate	–0.079***	–0.002
	(0.011)	(0.002)
ST3M	0.188***	0.007***
	(0.013)	(0.003)
Term Spread	0.127***	0.014***
	(0.014)	(0.003)
ST3MxNegative	–0.361***	–0.011
	(0.124)	(0.013)
Term Spread x Low	0.466***	0.028***
	(0.053)	(0.009)
Negative	-0.030	0.020**
	(0.061)	(0.008)
Low	–0.290***	–0.031***
	(0.045)	(0.008)
Global financial crisis	0.880***	–0.048***
	(0.042)	(0.008)
European debt crisis	0.039*	–0.020***
	(0.022)	(0.003)
Observations	113,590	109,842
R-squared	0.125	0.107
Bank fixed effects	Yes	Yes
Time fixed effects	Crises	Crises

Source: IMF staff.
Note: This table reports the elasticities of changes in loan loss provisions and fee income (relative to assets) with respect to changes in the interest rate environment and economic activity (real GDP growth and inflation rate). ST3M is the short-term rate proxied by 3-month government bond yields. Term spread is the 10-year minus 3-month spread. Negative and Low are dummies indicating whether ST3M is below zero and whether the term spread is below 1.25 percentage points respectively. The specification also includes macro and bank-level controls, and global financial crisis (2008–09) and European debt crisis (2010–12) dummies. The dependent variables are change in provisions to assets ratio in percent in Column (1), and growth in fee income to assets ratio in percent in Column (3). All errors are clustered at the bank-level. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, similar econometric analysis is used to support some aspects of the forward-looking simulation (described in Section B and C). For example, the elasticity of growth in loan-loss provisions and fee income (relative to assets) with respect to changes in the interest rate environment and economic activity (real GDP growth and inflation rate) is used to project the path of bank provisions in the simulation (Table 4.1.3). Differences in the sensitivity of global systemically important banks' (GSIBs) interest income to loans ratio to changes in interest rates, relative to the sensitivity of smaller banks is also used to calibrate the relative sensitivity of yields to short-term rates of these two group of banks in the simulation (Table 4.1.4). Based on the estimates in Table 4.1.4, the sensitivity of GSIBs' net interest margin to the short-term rate is about 40 percent less than that of non-GSIBs.

Online Annex Table 4.1.4.
Difference in Sensitivities between GSIBs and Non-GSIBs

VARIABLES	Interest Income/Loans
Dependent Variable (Lag)	0.545***
	(0.034)
Deposit/Liability (Lag)	0.000
	(0.004)
Capital Ratio (Lag)	–0.024
	(0.017)
Security/Assets (Lag)	0.004
	(0.002)
Real GDP Growth	0.035***
	(0.010)
Inflation Rate	0.021*
	(0.011)
Real GDP Growth Forecast	–0.152***
	(0.023)
Inflation Rate Forecast	–0.134***
	(0.016)
ST3M	0.459***
	(0.031)
Term Spread	0.217***
	(0.026)
ST3MxGSIBs	–0.183***
	(0.039)
Term Spread x GSIBs	–0.188***
	(0.043)
Global financial crisis	0.083*
	(0.044)
European debt crisis	0.148***
	(0.037)
Observations	100,327
R-squared	0.782
Bank fixed effects	Yes
Time fixed effects	Crises

Source: IMF staff.
Note: This table reports the difference between the sensitivity of GSIBs' interest income to loans ratio to interest rates and that of non-GSIBs. ST3M is the short-term rate proxied by 3-month government bond yields. Term spread is the 10-year minus 3-month spread. GSIBs is a dummy indicating whether a bank belongs to the Financial Stability Board list of global systemically important financial institutions. The specification also includes macro- and bank-level controls, and global financial crisis (2008–09) and European debt crisis (2010–12) dummies. All errors are clustered at the bank-level. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Decomposition of Bank Net Interest Margin into Contributing Factors

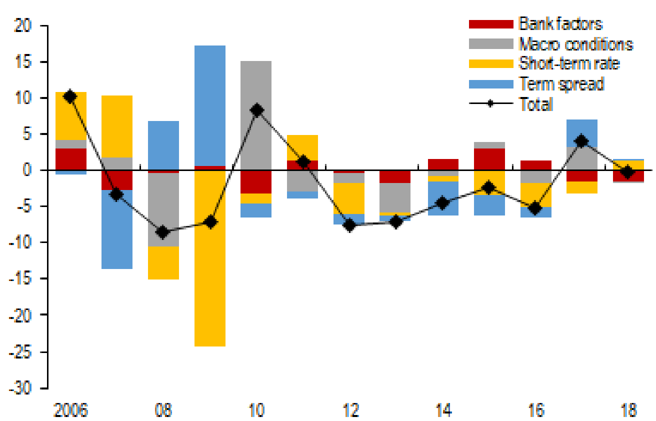
The historical decomposition of the contribution of different factors (the short-term rate, term-spread, other macro conditions, and bank-specific characteristics) to variations in NIM is complicated by the presence of the lagged dependent variable in the econometric model described in equation (1). To sort out this issue, the contributions from the above-mentioned five groups of factors are computed from the difference in estimated NIM paths under two difference scenarios. The first scenario, thereafter "flexible" path, takes into account of the changes in various factors included in the econometric specification after the initial year (labeled t_0), whereas the second scenario with a "rigid" path assumes that all these factors remain at their initial levels for the rest of the period.

A few calculations show that the difference in the two paths correspond to:

$$\Delta NIM_t \equiv NIM_t^{Flexible} - NIM_t^{Rigid} = \sum_{j=0}^{t-t_0} \alpha^j \beta'(X_{t-j} - X_{t_0}) \qquad (2)$$

Figure 4.1.1 shows the estimations of different contributing factors (that is, short-term rate, term-spread, other macro conditions, and bank-specific characteristics). In this decomposition, the bank fixed effects are grouped with other bank characteristics into "bank factors" and the crises dummies are grouped with other macro conditions. The role of short-term rates and term spreads includes the respective variables and their interactions with the dummies for negative rates and low term spreads, as well as the direct effect of those dummies.

Online Annex Figure 4.1.1.
Decomposition of Bank Net Interest Margins
(Basis points)



Source: Fitch Connect.
Note: The decomposition is based on estimated elasticities from nine economies and a sample of realized contributing factors from six countries (three large European countries and three low interest rate countries). The numbers represent percentage changes in a representative bank's net interest margin.

B. Estimation of Bank Interest Rates and Credit Growth[4]

This section describes the estimation of two key inputs that are used in the forward-looking simulation of bank profitability: (1) bank interest rates on assets and liabilities; and (2) bank credit growth.

The estimation was carried out for each of the nine countries using annual bank-level unbalanced panel data available during 2005–18. The sample contains 1,390 banks in total. The set of banks is smaller than that used in the econometric exercise because the methodology requires banks to separately report interest income for loans and for other interest-earning assets, and interest expense separately for deposits and other interest-bearing liabilities. Data are obtained from Fitch Connect and partially complemented with data from SNL. Data on market yields are zero coupon yield curve for each currency were downloaded from Bloomberg Finance L.P., Thomson Reuters Datastream, and partially complemented with the data set in Wright (2011). Estimation is carried out using country-level pools of sample banks.

Modeling Yields on Loans and Cost of Deposits

The chapter uses a parametric model to estimate the effective repricing maturities of banks' interest earning assets and liabilities and the elasticity of the yields of those assets and liabilities to benchmark interest rates based on their historical relationship. Once the parameters of the model have been estimated, the trajectories of banks' interest income and cost of deposits can be simulated forward, conditional on the market expected forward interest rate path and the macroeconomic environment projected by the *World Economic Outlook*.

In many jurisdictions, bank financial statements report only the yield on the current portfolio—so called "back-book" yield. However, the "front-book" yield (the interest charged on loans that are repriced or on new loans, henceforth "new loans") of bank i at time t can be estimated by assuming that it corresponds to a weighted average of the interest rates charged for new loans of different maturities indexed by s, $Y_{i,t}(s)$:

$$Yield\ on\ Loans_{i,t}^{FrontBook} = \sum_{s=1}^{N} w_{i,t}(s) \times Y_{i,t}(s) \quad (3)$$

where the weights $w(s)$ correspond to the share of new loans of maturity s in the overall portfolio of new loans and are assumed constant across banks and time.

Under the additional assumption that spread between interest rates $Y_{i,t}(s)$ and benchmark market rates of the same maturity $MarketYield_t(s)$ is an affine function of the benchmark rate, front book yields can be written as:

$$Yield\ on\ Loans_{i,t}^{FrontBook} = \alpha_i + (1+\beta)\sum_{s=1}^{N} w(s) MarketYield_t(s) + e_t^{Loans} \quad (4)$$

[4] This section was prepared by Tomohiro Tsuruga.

Since the back-book yield is the accumulation of interest paid by loans underwritten in the past but not yet matured, it corresponds to:

$$Yield\ on\ Loans_t = \frac{\sum_{s=0}^{N} \sum_{k \geq s}^{N} w(k) \left(New\ Loans_{t-s}(k) \times Y_{i,t-s}(k) \right)}{Loans_t} \quad (5)$$

where $New\ Loans_{t-s}(k)$ is the amount of loans underwritten at time $t-s$ in maturity bucket k with interest rate $Y_{i,t-s}$.

Finally, assuming that the fraction of new loans is constant and noted by ϕ and that the asset size is constant $Loans_t = Loans$, changes in the back-book yield can be written as:

$$\Delta Yield\ on\ Loans_{i,t} = \tilde{\beta} \sum_{s=0}^{N} w(s) \left(MarketYield_t(s) - MarketYield_{t-s}(t-s) \right) + u_t^{Loans} \quad (6)$$

where $u_t^{Loans} \sim N(0, \sigma_{Loans}^2)$ and $\tilde{\beta} = \phi(1+\beta)$ is the overall sensitivity of the back-book yield to the current market yield, which is a product of the fraction of new loans and the sensitivity of the margin spread to the market yield.

The common maturity structure of banks in a given country w is assumed to follow a log-normal distribution with parameters (μ, σ), which can be adequately integrated to obtain an approximation of the weight of each 1-year maturity buckets used in the estimation[5].

Under the previous assumptions, the relationship between the changes in the observed back book yields and benchmark market rates depends on four parameters: $\tilde{\beta}, \mu, \sigma, \sigma_{Loans}$. These parameters were estimated by Markov Chain Monte-Carlo method. The Bayesian posterior mean is computed by drawing a number of sample parameters Θ from the posterior distribution. This procedure was carried out by using Hamiltonian Monte-Carlo (HMC) algorithm (number of chains = 4, number of samples = 1,000, burn in period = 500).

An analogous procedure is applied to estimate the parameters relating the cost of deposits to benchmark market interest rates, and to simulate trajectories for the cost of deposits.

The parameters can also be used to compute the implied average effective repricing maturity for the front book, which under these assumptions corresponds to $\exp(\mu + \sigma^2/2)$. Furthermore, the assumption that the front-book maturity structure $w(s)$ is constant in time implies that the back-book effective repricing maturity distribution $\boldsymbol{\phi_t} = (\phi_1\ \phi_2 \cdots \phi_{N-1}\ \phi_N)_{\boldsymbol{t}}$ converges to a steady state "ergodic" distribution that is characterized by:

$$\boldsymbol{\phi} = \mathbf{P}\boldsymbol{\phi}$$

where the transition matrix $\mathbf{P}$ is:

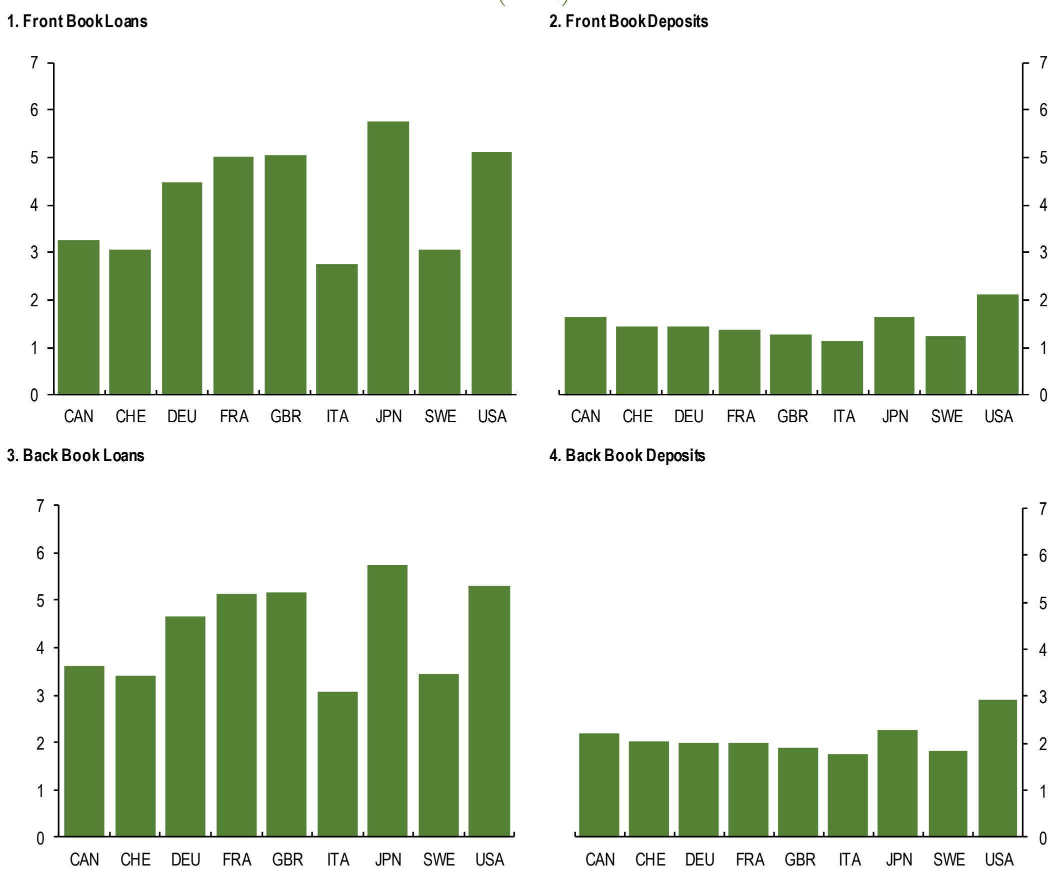
[5] In order for this approximation to be precise, N must be sufficiently large to describe bank portfolio maturity structure. Due to data limitation, in this exercise we suppose N to be 15 years (60 quarters).

$$
\mathbf{P} = \begin{bmatrix} w(1) & 1 & 0 & \cdots & 0 & 0 \\ w(2) & 0 & 1 & \ddots & 0 & 0 \\ \vdots & \vdots & \ddots & \ddots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \ddots & \vdots \\ w(N-1) & 0 & 0 & \ddots & 0 & 1 \\ w(N) & 0 & 0 & \cdots & 0 & 0 \end{bmatrix}
$$

which are the formulae used to compute the effective repricing maturities reported in the chapter and presented in Figure 4.1.2.

Online Annex Figure 4.1.2. Implied Maturity of Loans and Deposits

(Years)



Source: IMF staff.
Note: Data labels use International Organization for Standardization (ISO) country codes.

Modeling and Simulating Yield on Other Assets and Expenses on Other Liabilities

For income on other assets and expenses for other liabilities, the repricing mechanism may not apply. This is because these items include various transactions such as securities, repos, central bank reserves, etc. where banks can either purchase or sell those assets. Thus, only the front-book is considered for those items in this exercise:

$$\Delta Yield\ on\ Other\ Assets_t = \tilde{\beta}^{OA} \sum_{s=0}^{\infty} w^A(s) \Delta MarketYield_t(s) \quad (7)$$

$$\Delta \text{Cost of } Other\ Liabilities_t = \tilde{\beta}^{OL} \sum_{s=0}^{\infty} w^{OL}(s) \Delta MarketYield_t(s) \quad (8)$$

Under similar functional form assumptions, the underlying parameters of the maturity structures and elasticities can be recovered applying Markov Chain Monte-Carlo to the historical relationship between these income components and benchmark market rates and used to conduct forward looking simulations of their paths.

Estimating Trajectories of Benchmark Market Rates at Different Maturities

The simulation of banks yields on assets and cost of liabilities requires benchmark market rates for all maturity buckets considered. Market interest rates for other tenors are estimated using a latent dynamic three-factor model following Diebold and Li (2006).

The measurement equation is constructed as:

$$\begin{pmatrix} MarketYield_t(T_1) \\ MarketYield_t(T_2) \\ \vdots \\ MarketYield_t(T_N) \end{pmatrix} = \begin{pmatrix} 1 & T_1 & (T_1)^2 \\ 1 & T_2 & (T_2)^2 \\ \vdots & \vdots & \vdots \\ 1 & T_N & (T_N)^2 \end{pmatrix} \begin{pmatrix} Level_t \\ Slope_t \\ Curve_t \end{pmatrix} + \begin{pmatrix} \epsilon_t^1 \\ \epsilon_t^2 \\ \vdots \\ \epsilon_t^{30} \end{pmatrix} \quad (9)$$

for $t = 1,2, \dots, T$, where $Level$, $Slope$, and $Curve$ are latent level, slope, and curvature factor, respectively. T_s $(s = 1, \cdots, N)$ represent the years of maturity of the corresponding benchmark market rate with maturity bucket *s*. We set $T_1 = 0$ and $T_s = T_{s-1} + 0.25$ (years) for all *s*>0, so that $MarketYield_t(1)$ equals to $Level_t$, which corresponds to the overnight riskless rate. The method of simulating these latent factors are explained later.

The system equation is a BVAR system (lag = 2) with macroeconomic variables, following Diebold and Li (2006) and Diebold, Rudebusch, and Aruoba (2006), as follows:

$$\boldsymbol{F}_t = \mathbf{B_1} \boldsymbol{F}_{t-1} + \mathbf{B_2} \boldsymbol{F}_{t-2} + \boldsymbol{u}_t \quad (10)$$

where factors $\boldsymbol{F}$ consists of level, slope, curvature factors as well as (HP filtered) series of (log) GDP, CPI, and total credit to the nonfinancial sector from banks as a share of GDP.[6]

The model was estimated using quarterly time series data from 1991:Q1 to 2019:Q2.[7] Estimation is carried out for each currency following the two-step procedure of Diebold and Li (2006),

[6] Quarterly data of GDP, CPI inflation, Bank Credit to nonfinancial sector per GDP are downloaded and constructed from Organisation for Economic Co-operation and Development and Bank for International Settlement. All variables are HP filtered ($\lambda = 1600$).

[7] For euro area the sample period is 1999:Q1 to 2019:Q2. The estimation was carried out using the whole sample period including the zero and negative rate periods. One caveat of this method is that these estimates can be biased if these countries have already been bounded by the effective lower bound (ELB).

although in the second step the VAR system is estimated via Bayesian methods as in Arias, Rubio-Ramírez, and Waggoner (2018).[8]

The fitness of the first step of the model to data is shown below (Online Annex Table 4.1.5).

Online Annex Table 4.1.5. Implied Maturity of Loans and Deposits

	CAD	CHF	EUR	GBP	JPY	SEK	USD
Fit (%)	98.6	98.3	97.5	98.8	98.8	94.2	98.0

Source: IMF staff.
Note: Data labels use International Organization for Standardization (ISO) country codes.

Once the model has been estimated, the parameters can be used to simulate trajectories for conditional forecast of bank credit-to-GDP that are consistent with the forecasted trajectories for GDP, CPI, and interest rates.

Scenario Building

The estimated path of the whole yield curve is specified by the dynamic factor model. According to the observation equation (9), the overnight short-term rate corresponds to the $Level$ factor. We set the path for the level factor according to the market forward rate. Given the level factor set by the forward rate, we assume 10 years tenor to follow the 10 years forward rate, and set $Curve_t$ to be in the long-run mean. This way, the path for the $Level_t$ and $Slope_t$ are pinned down. Regarding the macroeconomic variables, expected path for GDP growth and CPI inflation are set in line with the *World Economic Outlook*. The path of other tenors and other macroeconomic variables are specified by a conditional forecast based on the dynamic factor model. To forecast the conditional path of credit growth, the BVAR system was used. The assumptions are summarized in the Table 4.1.6 and the trajectories of these variables are shown in Online Annex Figure 4.1.3.

Online Annex Table 4.1.6. Scenario Assumptions

Category	**Yield Curve**			**Macroeconomic Variables**		
Item	Short-term rate	10-year spread	Other tenors	GDP growth	CPI inflation	Bank credit-to-GDP
Assumption	Implied forward rate	WEO	Dynamic Factor Model	WEO	WEO	Dynamic Factor Model

Source: IMF Staff.
Note: CPI = consumer price index; WEO = *World Economic Outlook*.

[8] As a prior distribution for Bayesian estimation, uninformative Normal-Inverse-Wishart prior is used. The closest-to-median impulse model is chosen as the baseline model (number of lags = 2, number of draws = 100, number of transformations per draw = 100).

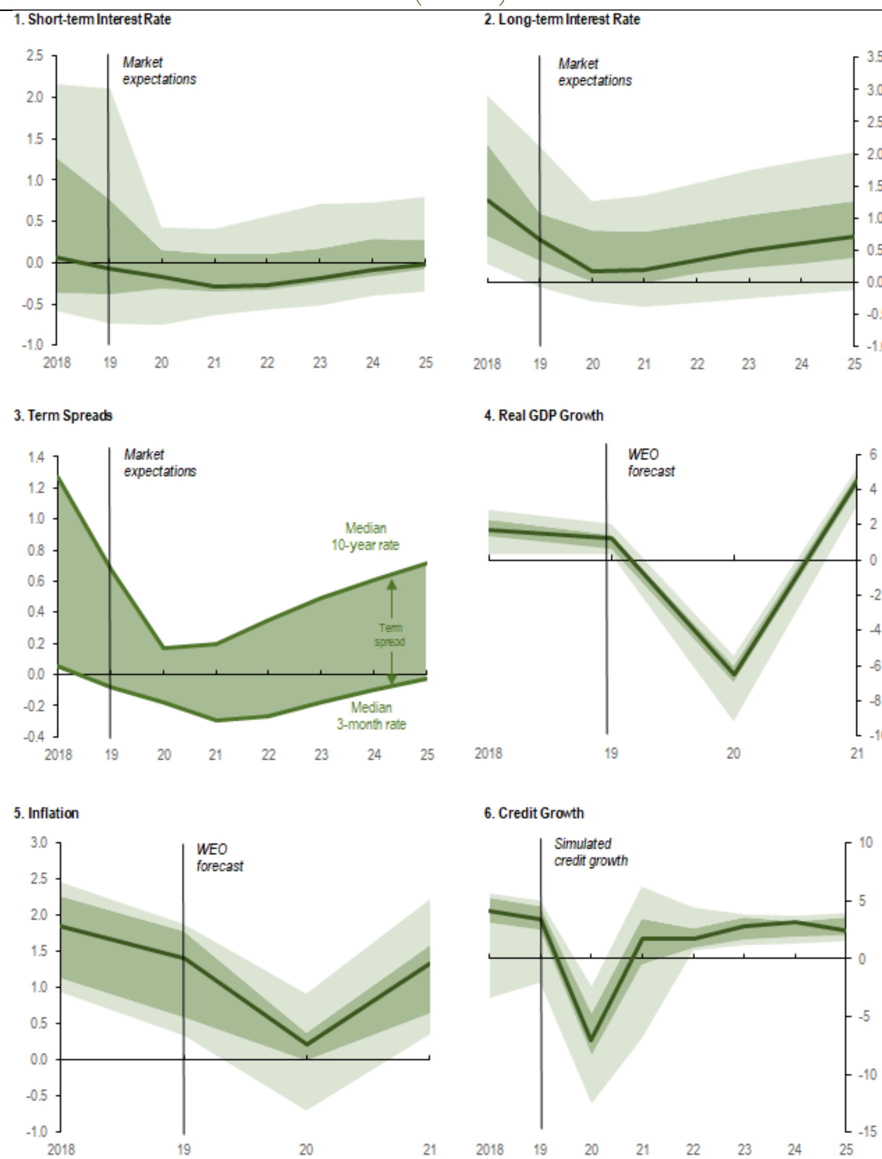
Simulating future yields on loans and cost of deposits

Once the parameters of the model are estimated, equations (6–10) can be used to simulate the yield on assets and costs for liabilities for given future trajectory of benchmark market rates. However, in simulating these trajectories, the model incorporates an effective lower bound of interest rates on deposits as this reflects the cost of the entire retail and corporate deposit base, as follows:

$$\underline{Cost\ of\ Deposits_t} = max(Cost\ of\ Deposits_t, 0) \quad (11)$$

Online Annex Figure 4.1.3. Simulation Scenario

(Percent)



Sources: Bloomberg Finance L.P and IMF.
Note: The trajectories for *World Economic Outlook* forecasts are truncated up to the last period that is publicly available.

C. Forward-Looking Simulation of Bank Profitability[9]

The simulated paths for banks' yields on loans and other interest earning assets, cost of deposits and other expenses, as well as the macro-consistent trajectories for GDP and credit growth are used to simulate bank profitability, using a bottom-up model that projects the income statements and selected balance sheet items for a sample of banks from 2019 through 2025.

The analysis is carried out on a sample of about 900 banks headquartered in nine countries, including three North Atlantic countries (Canada, United Kingdom, United States) that represent 47 percent of the sample by assets, three large euro area countries (France, Germany, Italy) that represent 27 percent of the sample, and three other countries employing negative policy rates (Japan, Sweden, Switzerland) that represent 26 percent of the sample. The sample size is constrained by the modeling requirement that a bank separately reports its interest income on loans and on other interest-earning assets, and its interest expense on deposits and on other liabilities.

Balance Sheet

The growth of banks' balance sheet is anchored to loan growth. Banks' *gross loans* are assumed to follow the BVAR-based simulated credit growth (as described in Section B of this annex). The model projects assets assuming each bank's *loan-to-assets ratio* remains constant at its 2018 level. Asset and loan growth are subject to the constraint that each bank's *Tier1 ratio* remains above 8 percent and its *leverage ratio* above 3 percent. (there is an assumption that banks do not raise new capital during the simulation). *Risk weighted asset density* (risk-weighted assets divided by total assets) is assumed to remain constant at the 2018 level.

Total interest earning assets are assumed to grow at the three-year average growth rate of total assets. Other interest earning assets are calculated as the difference between total interest earning assets and gross loans; and non-interest earning assets is the difference between total assets and total interest earning assets. Other elements of bank assets, such as insurance assets and fixed assets, are assumed to grow proportionally with total assets assuming constant ratio at 2018 level.

Similarly, *total interest-bearing liabilities* grow proportionally with *total interest-earning assets*, assuming constant ratio at 2018 level. *Customer deposit* is derived assuming constant *loan-to-deposit ratio* at 2018 level, with *non-deposit funding* being the residual of *total interest-bearing liabilities* and *customer deposit*.

Income Statement

Net interest income is calculated by applying the bank yields and funding costs (that are estimated as explained in Section B of this annex) to the projected balance sheet. Specifically, *total interest income* is the sum of *interest income from loans* (*average gross loans* times *yield on loans*) and *interest income*

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[9] This section was prepared by John Caparusso and Yingyuan Chen.

from other interest-earning assets (*average other interest-earning assets* times *yield on other interest-earning assets*); and *total interest expense* is similarly derived.

Loan-loss provisions and *net fee income* are calculated based on historical elasticities to macroeconomic factors (as discussed in Section A of this annex, Online Annex Table 4.1.3).

Other key elements of revenue and expense items are projected assuming either trend-based or constant ratio to respective balance sheet item (Online Annex Table 4.1.7).

A key goal of these assumptions is to establish a fairly neutral backdrop against which to highlight the income statement elements of particular interest for this analysis–net interest income and loan-loss provisions. Rather than attempting to forecast discontinuous shifts in business strategy, the chapter focuses on the magnitude of revenue or operating cost improvement that would be necessarily for a bank to reach sustainable profitability.

Online Annex Table 4.1.7.
Summary of Income Statement Projection Assumptions

Income Statement Item	Projection assumption
1. Net interest income	Model-based, as described above
2. Fees and Commissions	3-year average ratio to average total assets
3. Dividend income	3-year average ratio to average other interest-bearing liabilities
4. Trading & invt income	3-year average ratio to average other interest-earning assets
5. Insurance income	Constant ratio to average insurance assets
6. Other operating income	Constant ratio to average total assets
7. Total non-interest income	Sum of 2 to 6
8. Total revenue	Sum of 1 and 7
9. Operating expense	Constant ratio to average total assets
10. Loan loss provision	Model-based (elasticities based on panel regression)
11. Other impairment charges	3-year average ratio to average total securities
12. Non-operating profit	3-year average ratio to average total assets
13. Pre-tax profit	8 less the sum of 9 to 12
14. Tax expense	Constant ratio to pretax profit
15. Profit transfer	Constant ratio to pretax profit
16. Net income	13 less the sum of 14 and 15
17. Total dividend	Constant ratio to net income
18. Retained earnings	16 less 17

Source: IMF staff.

D. Market-Implied Cost of Equity[10]

There are many ways to estimate a bank's cost of equity—the return that shareholders require to hold a bank's shares—but in Chapter 4 we use a market-implied estimate. This method is based on the price-to-book and return on equity valuation model in Wilcox (1984). The starting point is the Gordon Growth model from Gordon (1962):

$$P_t = \frac{DPS_{t+1}}{c-g} \qquad (1)$$

where P_t is today's share price, c is the cost of equity, $DPS = EPS \times d$ is expected dividends per share, EPS is earnings per share, d is the dividend payout ratio, $g = (1-d)r$ is the long-term growth rate of earnings, and r is return on equity.

Because $r = \frac{EPS.S}{BV.S}$, where BV is the book value of equity per share and S is the stock of shares outstanding, then the share price can be restated as:

$$P_t = \frac{r.BV.d}{c-g} \qquad (2)$$

The price-to-book ratio ($pb = \frac{P}{BV}$) can then be defined as a function of return on equity, the growth rate of earnings and the cost of equity in the price-to-book and return on equity model:

$$pb = \frac{r-g}{c-g} \qquad (3)$$

A simple re-arrangement, along with an assumption used by market analysts that the long-term growth of earnings (g) is approximately zero (see, for example, Ghose and others 2020 and Patel and others 2020), allows the cost of equity to be estimated from the ratio of expected return on equity and the price-to-book ratio:

$$c = \frac{r}{pb} \qquad (4)$$

This method implies that a bank's return on equity will be below its cost of equity when the price-to-book ratio is below one. This means that the price-to-book value can be thought of as an indicator of the difficulty that banks may have in raising new equity in the market. The further the price-to-book ratio falls below one, the harder it is likely to be for the bank to obtain new equity from investors.

Finally, because return on equity (r) is the product of return on assets (ρ) and leverage—the ratio of a bank's assets to the book value of equity ($\frac{A}{BV.S}$)—then this method can be used to show that the market-implied cost of equity is a function of profitability and market-adjusted leverage—the ratio of a bank's assets to its market capitalization ($M = P.S$):

$$c = \rho \frac{A}{M} \qquad (5)$$

[10] This section was prepared by Will Kerry.

The cost of equity therefore rises when the market-adjusted leverage increases, assuming a constant level of return on assets. Because market-adjusted leverage can be used an indicator of bank stress (Kerry 2019) a rising cost of equity can be a sign of elevated investor concerns about a bank's health.

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