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An integrated shortfall measure for Basel III

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Non-technical summary

Research Question

Regulators typically report the impact of the capital and liquidity requirements of the new global banking regulation framework Basel III in form of shortfalls for each Pillar 1 requirement individually. However, the Pillar 1 requirements of the Basel III package show certain interdependencies. Due to these interdependencies, covering the shortfall due to one Basel III requirement can increase or decrease the shortfall due to another one. What is an appropriate measure for all shortfalls which takes the interdependencies into account? How large is the effect of omitting the interdependencies of the ratios on the shortfalls given in the Basel III monitoring reports?

Contribution

We propose measuring a bank's non-compliance with regulatory requirements as a portfolio that the bank has to add to its balance sheet in order to comply with the requirements. The portfolio measure allows incorporating the interdependencies of all requirements in a natural way. We derive the portfolio that the bank is most likely to choose using a microeconomic banking model which minimizes the cost involved.

Results

Based on data from 46 German banks, our results suggest that large banks need to increase their total assets by $\sim 3\%$ and small banks by $\sim 4.5\%$ in order to comply with the Pillar 1 requirements of the Basel III package as published until June 2013. Due to the interdependencies of the Basel III ratios the shortfalls given in the Basel III monitoring reports tend to underestimate the need for capital and to overestimate the need for stable funding. However, compared to the overall level of the reported shortfalls, the effects of omitting the interdependencies are found to be relatively small.

Nichttechnische Zusammenfassung

Fragestellung

Bankenaufseher berichten über die Auswirkungen der neuen Eigenkapital- und Liquiditätsstandards (Basel III-Rahmenwerk) typischerweise in Form eines Anpassungsbedarfs für jede einzelne Säule 1-Anforderung getrennt. Zwischen den Säule 1-Anforderungen des Basel III-Rahmenwerks bestehen jedoch gegenseitige Abhängigkeiten, die dazu führen können, dass durch notwendige Anpassungen aufgrund einer Säule 1-Anforderung sich der Anpassungsbedarf aufgrund einer anderen Anforderung erhöht oder verringert. Was ist ein angemessenes Maß des Anpassungsbedarfs unter Berücksichtigung der gegenseitigen Abhängigkeiten? Wie groß ist die Auswirkung auf den im Basel III-Monitoring berichteten Anpassungsbedarf, wenn die gegenseitigen Abhängigkeiten berücksichtigt werden?

Beitrag

Wir messen den Anpassungsbedarf einer Bank aufgrund regulatorischer Anforderungen in Form des Portfolios, um das eine Bank ihre bestehende Bilanz erweitern muss um den Anforderungen zu genügen. Dieses Portfolio-Maß erlaubt es, die gegenseitigen Abhängigkeiten der Anforderungen auf nachvollziehbare Weise zu berücksichtigen. Aus der Vielzahl der möglichen Portfolien leiten wir unter Verwendung eines mikroökonomischen Modells das Portfolio ab, das die geringsten Anpassungskosten verursacht.

Ergebnisse

Auf Grundlage unseres Datensatzes, der 46 deutsche Banken umfasst, stellen wir fest, dass große Banken ihre Bilanz um $\sim 3\%$ erweitern müssen, um den Säule 1-Anforderungen gemäß dem bis Juni 2013 veröffentlichten Basel III-Rahmenwerk zu genügen, kleine Banken um $\sim 4.5\%$. Aufgrund der gegenseitigen Abhängigkeiten der Anforderungen tendiert der im Rahmen des Basel III-Monitorings berichtete Anpassungsbedarf dazu, den Kapitalbedarf zu unterschätzen und den Bedarf an stabiler Refinanzierung zu überschätzen. Jedoch sind die Effekte, die durch die Vernachlässigung der gegenseitigen Abhängigkeiten entstehen, im Verhältnis zum absoluten berichteten Anpassungsbedarf eher klein.

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An Integrated Shortfall Measure for Basel III *

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Abstract

We propose a new method for measuring how far away banks are from complying with a multi-ratio regulatory framework. We suggest measuring the efforts a bank has to make to reach compliance as an additional portfolio which is derived from a microeconomic banking model. This compliance portfolio provides an integrated measure of the shortfalls resulting from a new regulatory framework. Our method complements the descriptive reporting of individual shortfalls per ratio when monitoring banks' progress toward compliance with a new regulatory framework.

We apply our concept to a sample of 46 German banks in order to quantify the effects of the interdependencies of the Basel III capital and liquidity requirements. Comparing our portfolio approach to the shortfalls reported in the Basel III monitoring, we find that the reported shortfalls tend to underestimate the required capital and to overestimate of the required stable funding. However, compared to the overall level of the reported shortfalls, the effects resulting from the interdependencies of the Basel III ratios are found to be rather small.

Keywords: Basel III, linear programming, impact studies, integrated shortfall

JEL classification: G21, C61.

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1 Introduction

The financial crisis of 2007 to 2012 demonstrated that banks' capital and liquidity buffers were insufficient to withstand major systemic disruptions. As a response, the Basel Committee for Banking Supervision (BCBS) was mandated by the leaders of the G20 countries to develop the reform agenda Basel III in order to make banks more resilient against both sector-internal and sector-external shocks. The Basel III framework builds on the Basel II framework, which requires banks to fulfill a total capital (TC) ratio and a tier 1 (T1) ratio. Under the Basel III framework these two existing ratios have been tightened and, more importantly, four new ratios were introduced: a common equity tier 1 (CET1) ratio, a leverage ratio (LR), a short-term liquidity coverage ratio (LCR) and a net stable funding ratio (NSFR). All banks fulfill the requirements of Basel II but not all banks fulfill the new ones. Those that do not fulfill the new requirements will have to take action in order to become compliant before the Basel III requirements enter into force as binding minimum standards. How is it possible to measure the effort a bank has to make if compliance is defined across multiple constraints and falling short on one constraint cannot be offset by exceeding another one?

For readers who are not familiar with the Basel III framework, we briefly define the six Basel III requirements and discuss their objectives. The six requirements can be written as ratios that have to be maintained above the regulatory minimum thresholds[1]:

$$
\begin{array}{lrcccr}
\text{Common equity tier 1 ratio} & \text{CET1R} & := & \dfrac{\text{CET1}}{\text{RWA}} & \geq & 0.07 \\[2ex]
\text{Tier 1 capital ratio} & \text{T1R} & := & \dfrac{\text{T1}}{\text{RWA}} & \geq & 0.085 \\[2ex]
\text{Total capital ratio} & \text{TCR} & := & \dfrac{\text{TC}}{\text{RWA}} & \geq & 0.105 \\[2ex]
\text{Leverage ratio} & \text{LR} & := & \dfrac{\text{T1}}{\text{LevExp}} & \geq & 0.03 \\[2ex]
\text{Liquidity coverage ratio} & \text{LCR} & := & \dfrac{\text{HQLA}}{\text{NCO}} & \geq & 1 \\[2ex]
\text{Net stable funding ratio} & \text{NSFR} & := & \dfrac{\text{ASF}}{\text{RSF}} & \geq & 1.
\end{array}
\tag{1}
$$

The model-based capital ratios CET1R, T1R, and TCR, which we subsume under CR, set risk-sensitive limits on the three types of capital depending on the amount of risk-weighted assets (RWA). The CRs are complemented by a model-free leverage ratio (LR) which requires the T1 to be at least 3% of the leverage exposure (LevExp). The T1 comprises CET1 and additional tier 1 (aT1), while the TC includes T1 and T2 capital.

The LCR and the NSFR are introduced in order to increase the resilience of banks against liquidity shocks. The LCR requires that the net cash outflow (NCO) in a stress

[1] These capital requirements include a capital conservation buffer of 2.5%. In addition, they are increased for global systemically important banks.

situation, which is assumed to last 30 days, is covered by a liquidity reserve consisting of high-quality liquid assets (HQLA). The short-term horizon of the LCR of 30 days contrasts with the long-term horizon of the NSFR of one year. The required stable funding (RSF) represents the long-term portion of assets which has to be smaller than the long-term portion of liabilities represented by the available stable funding (ASF).

Regulators measure and publish the efforts banks have the make to achieve compliance on a semi-annual basis in the form of Basel III monitoring reports[2]. Typically, these efforts are quantified for every requirement as a shortfall in the numerator. For example, the CET1R results in a CET1 shortfall amounting to $\max(0.07 \cdot \text{RWA} - \text{CET1}, 0)$ and the HQLA shortfall due to the LCR is calculated as $\max(\text{NCO} - \text{HQLA}, 0)$, etc. The shortfalls per ratio are aggregated across all monitored banks, leading to the published monitoring shortfalls. These shortfalls provide a descriptive view and are not intended to provide a compliance strategy. Nevertheless, a possible interpretation is that compliance could be achieved by raising the given amounts of CET1, T1, TC, ASF and HQLA. We refer to these shortfalls which are calculated for each ratio separately as *isolated shortfalls*.

Raising these isolated shortfalls does not necessarily guarantee overall compliance. For example, raising equity by the amount of the isolated shortfall only reduces the shortfall completely if the equity is invested in assets with a zero risk weight. If it was invested in assets with a higher risk weight, more equity than the initial shortfall needs to be raised to achieve compliance. Another example is increasing HQLA in order to fulfill the LCR which lengthens the balance sheet and implies a reduction of the LR. If the HQLA have a credit risk weight different from zero, this action also worsens the CRs. The double function of HQLA as a liquidity reserve and as a potential RWA contributor can lead to an underestimation of the required capital.

CRs and NSFR present an example where interdependencies potentially lead to a reduction of the isolated shortfalls. Capital counterbalances the RWA in the CRs while at the same time it fully qualifies as stable funding in the NSFR framework. Nevertheless, raising capital directly reduces the stable funding shortfall if the capital is invested in instruments with a RSF-weight of zero.

In the sense of these examples, we talk of interactions between the Basel III ratios as soon as modifying a one position of the balance sheet changes the value of more than one ratio. As a consequence, varying one position of the balance sheet will potentially affect the shortfalls resulting from more than one Basel III requirement.

Unlike isolated shortfalls, shortfalls which are calculated in an integrated approach take into account these interactions. Such shortfalls provide a business strategy which explicitly states how funding is invested and how investments are funded. Raising these shortfalls guarantees to reach compliance with all regulatory thresholds at the same time. We call shortfalls which satisfy these criteria *integrated shortfalls*.

We propose measuring integrated shortfalls using a compliance portfolio which describes the banks' efforts that are required to achieve compliance. Portfolios are a concept widely used within the banking and accounting community. They describe an implementable strategy, allow taking all ratio interdependencies into account in a natural way, and the cost of compliance results simply as the contribution of the compliance portfolio to the profit-and-loss (PnL) of the bank.

Although of practical relevance, the portfolio idea alone is theoretically not convincing

[2] See for example http://www.bis.org and https://www.eba.europa.eu for the history of reports.

because typically there exists an infinite number of possible compliance portfolios. To obtain portfolios with a sound economic reasoning, we derive them in a microeconomic banking model. We assume that among all feasible portfolios banks pick the one with the lowest implementation cost. Although currently only imposing Basel III constraints, other internal and/or external constraints, for example volume limits, asset encumbrance limits, or limits on the total loss absorbing capacity, could be incorporated as well.

Our portfolio concept allows us to calculate integrated shortfalls and to quantify the interaction effects omitted in the isolated shortfalls. For this objective, we determine compliance portfolios for 46 German banks. The resulting integrated shortfalls are subsequently compared with the isolated shortfalls published in Basel III monitoring reports.

Our analysis reveals two interaction terms which are of rather secondary importance compared to the overall shortfall levels. Isolated shortfalls tend to underestimate the need for aT1 by 9% for large banks and by 22% for small banks. At the same time, they tend to overestimate the shortfall in stable funding due to the NSFR by 14% for large banks and by 9% for small banks. Taking into account the interactions reduces the cost of compliance by about 3% for large banks and 2% for small banks.

Please note that our framework can be used in combination with banking models of virtually any degree of sophistication. In this paper, we use a simple linear banking model. Furthermore, we exclude all de-leveraging portfolios containing negative volumes, assuming that our banks do not want to change their existing balance sheets. Finally, we chose compliance portfolios that contain only capital market positions.

There are three main reasons for opting for a simplified setup. First, we do not need a sophisticated setup to introduce our innovation of compliance portfolios. Second, our dataset provides valuable regulatory insights but does not contain information about the profitability of positions. Estimating such information unnecessarily increases the number of parameters to which our model is sensitive. Third, we use our method to assess the effects of the interdependencies of the ratios. This requires that we remain close to the calculation of the isolated shortfalls in terms of the positions considered in the compliance portfolio.

Although we present our framework in the context of the transition from Basel II to Basel III, our concept of compliance portfolios is sufficiently general to be applied to any future transition from one regulatory framework to another.

2 Literature review

Impact studies, like our paper, estimate the likely response of banks to regulatory changes. Table 1 reports the most important impact studies for the transition from Basel II to Basel III and benchmarks them against our paper regarding three criteria: considered Basel III ratios, omitted interaction terms, and derivation of strategies. Our paper is located in the last row. Table 1 suggests that all but our paper do not include all six ratios. Furthermore, there are many studies that do not consider the interactions between capital and liquidity ratios. Finally, the majority of studies assume ad hoc compliance strategies without an economic justification. By contrast, our framework includes all ratios, internalizes all ratio interaction terms, and derives strategies using a sound economic basis. It is obvious that the generality of our approach comes at the price that we need to test the sensitivity of our results to the parameters of the microeconomic model.

Table 1: Summary of the literature review. C&L represents the interactions between capital and liquidity requirements.

Author	Basel III ratios not included	Interactions not considered	Derivation of strategies
Macroeconomic Assessment Group (2010)	LR	C&L	ad hoc
Basel Committee on Banking Supervision (2010)	LR	C&L	ad hoc
Angelini et al. (2011)	LR	C&L	ad hoc
King (2010)	LR, LCR	—	ad hoc
Allen et al. (2012)	LCR, NSFR	—	ad hoc
Yan et al. (2012)	LCR,LR	C&L	ad hoc
Slovik and Cournede (2011)	LCR, NSFR, LR	C&L	ad hoc
Cosimano and Hakura (2011)	LCR, NSFR, LR	C&L	ad hoc
Kopp et al. (2010)	LR, LCR, NSFR	C&L	ad hoc
Andrae et al. (2014)	Two CRs	—	model-based
Durant (2013)	Two CRs	—	ad hoc
This paper	—	—	model-based

Our contribution to the literature is threefold: First, we propose portfolios to measure the banks' efforts to reach compliance. Second, we propose deriving the portfolios in microeconomic banking models to give them a sound economic rationale. Third, by applying our concept, we identify the interaction terms typically omitted in the calculation of isolated shortfalls and find their importance to be of secondary order.

The remainder of this paper is organized as follows. Section 3 describes the methodology, Section 4 introduces the sample of banks and explains the reasons for the chosen parameters of the model. The results are presented in Section 5. We study the robustness of our results in Section 6 and conclude with Section 7.

3 Methodology

We propose measuring the efforts a bank has to make to achieve compliance as an additional portfolio, the so-called *compliance portfolio*. The compliance portfolio is the portfolio that has to be added to the initial balance sheet of the bank in order to achieve compliance. One might think of a bank as an entity that is (economically) happy with its current balance sheet mix. Suddenly, this mix turns out to be non-compliant under

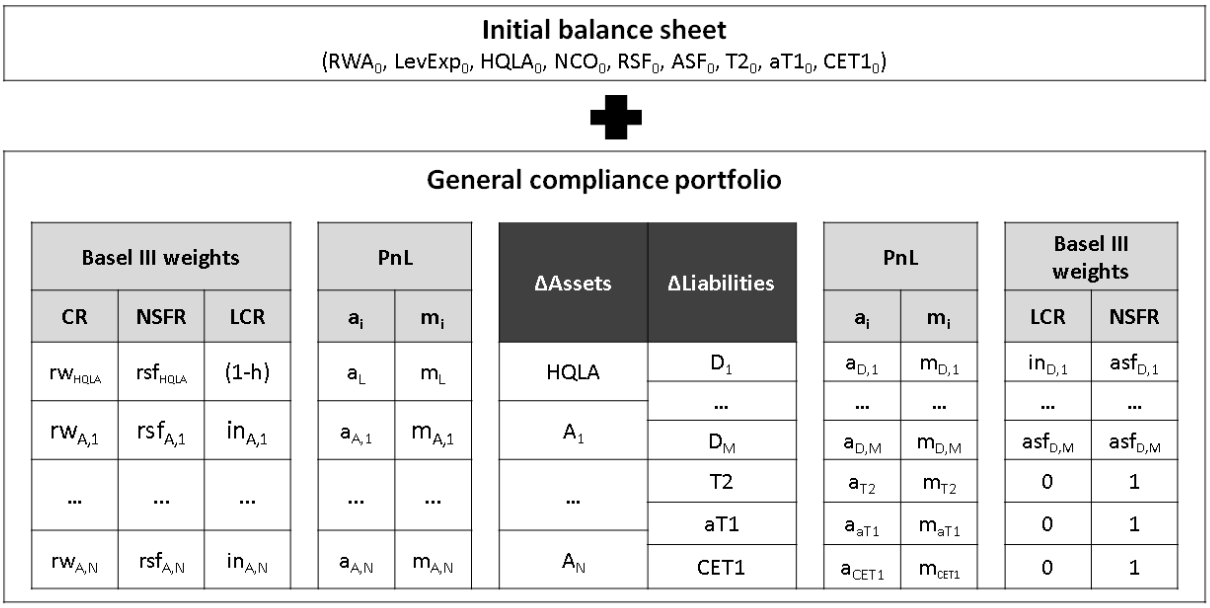

Figure 1: General case of the additive compliance portfolio. The portfolio consists of HQLA, N types of asset $A_{1\ldots N}$, M types of liabilities $D_{1\ldots M}$ and the three types of capital, T2, aT1, and CET1. The compliance portfolio is added to the initial balance sheet. The only input data used from the initial balance sheet are the numerators and denominators of the Basel III ratios. The Basel III framework defines the values of the risk weights rw_i, the LCR weights out_i and in_i, and the NSFR weights rsf_i and asf_i. Under the LCR framework, the HQLA are subject to a potential haircut, which is represented by the parameter h. The margins m_i and adjustment cost a_i parameterize the contribution of each position to the PnL.

Basel III. For this bank, adding a compliance portfolio is a way to reestablish compliance without adjusting its current business represented by its initial balance sheet.

The complexity of the approach scales with the granularity of the compliance portfolio. We subsequently discuss in Section 3.1 the general case where the compliance portfolio can contain up to N assets and M funding positions. As every asset and funding position of the compliance portfolio is a decision variable, this approach is the most flexible one. The downside is that it requires a large set of parameters which are usually only available to bank insiders. More suitable for bank outsiders, like regulators or academics, are setups where the compliance portfolio contains only capital market instruments. This is the setup on which our empirical application is based. We discuss its methodology in Section 3.2.

3.1 General case

The bank which is not compliant with Basel III adds a compliance portfolio to its initial balance sheet, as illustrated in Figure 1. The compliance portfolio is funded by CET1, aT1, T2 and M debt positions $D_{1\ldots M}$. The funding is invested in HQLA and N non-liquid asset positions $A_{1\ldots N}$. The model needs only numerators and denominators of the regulatory ratios as input (RWA_0, LevExp_0, T2_0, aT1_0, CET1_0, HQLA_0, NCO_0, RSF_0,

ASF_0). No further data of the initial balance sheet are required.

The parameters of the model are the margins, the adjustment cost, and the regulatory weights associated with each position. The margins m_i measure the individual profit contribution of each position i. The adjustment cost a_i captures cost to expand each position. Changing the volume of a position always implies (non-financial) adjustment and/or transaction cost. A bank might need additional staff, additional branches, additional systems, or additional marketing to increase certain positions. Margins and adjustment cost are assumed to be proportional to the volume of each position. The third set of parameters, the regulatory weights, is defined in the Basel III framework.

The bank maximizes the profit-and-loss (PnL) resulting from the positions of the compliance portfolio. This is equivalent to maximizing the total PnL consisting of the PnL of the initial balance sheet plus the PnL of the compliance portfolio under the assumption that the bank already chose the most profitable initial balance before the adjustment process.

The PnL contribution of the compliance portfolio is given by $(m-a)'x$, where the vector

$$x = (\mathrm{HQLA}, A_1 \cdots A_N, D_1 \cdots D_M, \mathrm{T2}, \mathrm{aT1}, \mathrm{CET1})' \tag{2}$$

represents the volume of each position of the compliance portfolio. The regulatory ratios after the adjustment process follow by including the contribution of the compliance portfolio in the numerators and denominators of the initial ratios given in Equation 1

$$\begin{aligned}
\mathrm{CET1R}: &\quad \frac{\mathrm{CET1}_0 + \mathrm{CET1}}{\mathrm{RWA}_0 + \mathrm{rw}_{\mathrm{HQLA}}\mathrm{HQLA} + \sum_i \mathrm{rw}_i A_i} &&\geq r_1 \\
\mathrm{T1R}: &\quad \frac{\mathrm{T1}_0 + \mathrm{aT1} + \mathrm{CET1}}{\mathrm{RWA}_0 + \mathrm{rw}_{\mathrm{HQLA}}\mathrm{HQLA} + \sum_i \mathrm{rw}_i A_i} &&\geq r_2 \\
\mathrm{TCR}: &\quad \frac{\mathrm{TC}_0 + \mathrm{T2} + \mathrm{aT1} + \mathrm{CET1}}{\mathrm{RWA}_0 + \mathrm{rw}_{\mathrm{HQLA}}\mathrm{HQLA} + \sum_i \mathrm{rw}_i A_i} &&\geq r_3 \\
\mathrm{LR}: &\quad \frac{\mathrm{T1}_0 + \mathrm{aT1} + \mathrm{CET1}}{\mathrm{LevExp}_0 + \mathrm{HQLA} + \sum_i A_i} &&\geq r_4 \\
\mathrm{LCR}: &\quad \frac{\mathrm{HQLA}_0 + \mathrm{HQLA}}{\mathrm{NCO}_0 + \sum_i \mathrm{out}_i D_i - \sum_i \mathrm{in}_i A_i} &&\geq r_5 \\
\mathrm{NSFR}: &\quad \frac{\mathrm{ASF}_0 + \sum_i \mathrm{asf}_i D_i + \mathrm{T2} + \mathrm{aT1} + \mathrm{CET1}}{\mathrm{RSF}_0 + \mathrm{rsf}_{\mathrm{HQLA}}\mathrm{HQLA} + \sum_i \mathrm{rsf}_i A_i} &&\geq r_6,
\end{aligned} \tag{3}$$

using the regulatory risk weights rw_i, inflow weights in_i, outflow weights out_i, RSF-weights rsf_i and ASF-weights asf_i associated with each position i of the compliance portfolio. The thresholds of the six Basel III ratios given on the r.h.s. of Equation 1 are represented by r_i[3].

In order to formulate the bank's maximization of the PnL based on this set of equa-

[3] The thresholds r_i are increased to account for capital surcharges for global systemically important banks as applicable. In general, they could be set to any other external or internal threshold.

tions, we introduce the initial shortfall vector

$$b = \begin{pmatrix} \text{CET1}_0 - r_1 \cdot \text{RWA}_0 \\ \text{T1}_0 - r_2 \cdot \text{RWA}_0 \\ \text{TC}_0 - r_3 \cdot \text{RWA}_0 \\ \text{T1}_0 - r_4 \cdot \text{LevExp}_0 \\ \text{HQLA}_0 - r_5 \cdot \text{NCO}_0 \\ \text{ASF}_0 - r_6 \cdot \text{RSF}_0 \end{pmatrix}, \tag{4}$$

which is calculated from the numerators and denominators of the six ratios resulting from the initial balance sheet of the bank, and the matrix

$$A = \begin{bmatrix} r_1 \cdot \text{rw}_{\text{HQLA}} & \cdots & r_1 \cdot \text{rw}_{A_N} & 0 & \cdots & 0 & 0 & 0 & -1 \\ r_2 \cdot \text{rw}_{\text{HQLA}} & \cdots & r_2 \cdot \text{rw}_{A_N} & 0 & \cdots & 0 & 0 & -1 & -1 \\ r_3 \cdot \text{rw}_{\text{HQLA}} & \cdots & r_3 \cdot \text{rw}_{A_N} & 0 & \cdots & 0 & -1 & -1 & -1 \\ r_4 & \cdots & r_4 & 0 & \cdots & 0 & 0 & -1 & -1 \\ -(1-h) & \cdots & -r_5 \cdot \text{in}_{A_N} & r_5 \cdot \text{out}_{D_1} & \cdots & r_5 \cdot \text{out}_{D_M} & 0 & 0 & 0 \\ r_6 \cdot \text{rsf}_{\text{HQLA}} & \cdots & r_6 \cdot \text{rsf}_{A_N} & -\text{asf}_{D_1} & \cdots & -\text{asf}_{D_M} & -1 & -1 & -1 \end{bmatrix}, \tag{5}$$

which translates the volumes of the compliance portfolio x into reductions of the initial shortfalls b. The parameter h accounts for the haircut included in the calculation of the HQLA within the LCR framework.

Given these definitions, the PnL maximization can be written as

$$\begin{aligned} \max_x \quad & (m-a)'x \\ \text{s.t.} \quad & \\ & b \leq -Ax \\ & 0 \leq x \\ & 0 = \text{HQLA} + \sum A_i - \sum D_i - \text{T2} - \text{aT1} - \text{CET1}. \end{aligned} \tag{6}$$

The three constraints enforce compliance with the Basel III requirements, restrict the solution to additive compliance portfolios and ensure the balancing of the balance sheet. From Equation 6, it is clear that the difference of margins and adjustment cost $m - a$ drives the solution of the optimization problem but not the values of m and a directly.

Due to the linearity of the objective function and the constraints, Equation 6 is a linear program which can be solved by standard software and the optimal solution can always be determined if it exists. The solution of is unique as long as the combination of regulatory weights and difference of margins and adjustment cost $m - a$ is unique.

3.2 Capital market portfolio

This section describes a special case of the general compliance portfolio introduced in Equation 2. We call it *capital market portfolio (CM-portfolio)*, since it contains only capital market instruments which are directly or indirectly accessible for all banks. Compared to the general case, the considered CM-portfolio is more suitable for bank outsiders, such as regulators or academics, since less granular information is required to calibrate the

Initial balance sheet

(RWA_0, $LExp_0$, $HQLA_0$, NCO_0, RSF_0, ASF_0, $T2_0$, $aT1_0$, $CET1_0$)

+

Capital market portfolio

Basel III weights			PnL		ΔAssets	ΔLiabilities	PnL		Basel III weights	
CR	NSFR	LCR	a_i	m_i			a_i	m_i	LCR	NSFR
0	0	1	0.1	0	HQLA	$NBF^D_{(30d,1y)}$	0.3	0	0	0
						CM_{1y}	0.5	0	0	1
						T2	0.8	-1	0	1
						aT1	1.5	-2	0	1
0.2	0	0	0.1	0.2	$NBF^A_{(30d,1y)}$	CET1	4.0	-3	0	1

Figure 2: The CM-portfolio is a concrete realization of the general compliance portfolio. The CM-portfolio is derived from the general case by choosing capital market instruments for the free assets and liability positions. The regulatory Basel III weights, margins m_i, and adjustment cost a_i follow from the choice of the capital market instruments. Margins and adjustment cost are given in per cent.

model.

We apply our concept to assess the difference between the isolated and integrated shortfalls. To identify this difference, the CM-portfolio must contain the numerators of the regulatory ratios as decision variables: CET1, aT1, T2, stable funding from the capital market with a maturity of more than one year (CM_{1y}) and HQLA; see Figure 2. Furthermore, it contains mid-term lending to and funding from non-bank financial corporates $NBF_{(30d,1y)}$. The latter two can be considered as buffer positions which allow ensuring the balancing of the balance sheet. Due to their specific regulatory weights they do not affect any of the regulatory ratios. The corresponding concrete realization of the linear program given in Equation 6 follows by setting

$$x = (\mathrm{HQLA}, \mathrm{NBF}^A_{(30d,1y)}, \mathrm{NBF}^D_{(30d,1y)}, \mathrm{CM}_{1y}, \mathrm{T2}, \mathrm{aT1}, \mathrm{CET1})'. \tag{7}$$

Although the initial motivation for the CM-portfolio is to stay as close as possible to the calculation of the isolated shortfalls, such a CM-portfolio yields additional advantages:

1. Every bank has direct or indirect access to the capital market and can implement the portfolio.[4]

2. The CM-portfolio is likely to be the quickest way to achieve compliance. Large volumes can quickly be funded and invested at the capital market without a substantial

[4] It might be objected that some smaller savings and cooperative banks do not have direct access to the capital market. Although this is true in the narrow sense of the capital market, it is not true in a broader sense. Being part of the savings banks' and cooperative banks' network, the central bank of the network organizes a sort of capital market for its members.

deterioration in interest rates. This contrasts sharply with retail positions where substantially adjusting the lending or funding volume is likely to take months.

3. Capital market rates are observable such that the margin income of the portfolio can be estimated with a fair degree of confidence.

4. The cost of compliance is the contribution of the CM-portfolio to the PnL.

5. Capital market positions exhibit a low degree of ratio interdependencies. They often have non-zero regulatory weights for only one or two Basel III ratios.

6. With such a uniform and standardized approach, compliant banks (and regulators) could easily compare compliance strategies across banks.

The CM-portfolio represents a strategy that exclusively aims to reach compliance because it contains only capital market positions but no classic intermediation positions such as retail/corporate loans and deposits.

The calculation considers two points in time, before and after the transition from one regulatory framework to another. Effects from any following periods are not taken into account, especially effects that occur when the new instruments reach their maturity. For example, outflows from the new stable funding will affect the liquidity buffer at some point in the future. In addition, margins can be realized during several years, while the adjustment cost occurs only once.

As an extension of this paper, one could combine compliance and business strategy by allowing intermediation positions to be part of the compliance portfolio. This would have the additional advantage that the compliance portfolio would be less costly as intermediation positions usually exhibit higher margins than capital market products. However, we leave this extension for further research.

4 Data and Calibration

In this section, we document the three types of input data required by our approach:

1. The thresholds r_i for every ratio,

2. The initial shortfall b resulting from the thresholds, and

3. The regulatory weights and the PnL parameters (m_i, a_i) for all positions of the compliance portfolio.

4.1 Compliance thresholds

Throughout the paper, the capital and liquidity requirements are set according to the Basel III rules after full implementation and phase-in arrangements; see Equation 1. In addition, the capital thresholds are increased by the capital conservation buffer and surcharges for global systemically important banks (G-SIBs) as applicable. Note that we could easily set the thresholds to other values reflecting internal target ratios or different regulatory standards, like domestic surcharges.

Table 2: Initial numerators and denominators of the Basel III ratios for eight large (LB) and 38 small banks (SB) in billions of euros. The aggregates are obtained as the sum across the quantities reported by each bank.

	$CET1_0$	$T1_0$	$T2_0$	RWA_0	$LevExp_0$	$HQLA_0$	NCO_0	ASF_0	RSF_0
Σ LB	94.1	94.3	40.6	1127.9	4282	401.4	402.4	1634	1708
Σ SB	55.6	56.7	8.5	432.9	1311	118.7	91.7	774	803

Table 3: Average and quantiles of the initial Basel III ratios and their thresholds including the capital conservation buffer, in per cent. The weighted average ratios are obtained by dividing the total numerators by the total denominators given in Table 2.

	CET1R	T1R	TCR	LR	LCR	NSFR
Basel III	≥ 7	≥ 8.5	≥ 10.5	≥ 3	≥ 100	≥ 100
LB weighted average	8.3	8.4	12.0	2.2	99.7	95.7
LB average	8.0	8.1	12.0	2.5	114.3	93.1
LB median	8.3	8.4	12.4	2.7	98.1	92.8
SB weighted average	12.8	13.1	15.1	4.3	129.5	96.4
SB average	11.5	11.7	13.6	4.5	403.8	103.4
SB 25%-quantile	8.6	8.9	9.8	3.1	99.9	92.1
SB median	10.3	10.5	11.6	3.8	151.1	102.0
SB 75%-quantile	13.6	14.2	15.8	5.4	320.7	113.6

4.2 Initial Shortfalls

Our sample covers 46 German banks which provided confidential information on shortfalls to the Bundesbank as of June 2013. The data set corresponds to 2.5% of the German banking sector in terms of the number of banks but to 70% in terms of total assets. Although all calculations are based on bank-level data, confidentiality reasons require all reported figures to be aggregated. We report figures for a subset of eight large banks (denoted 'LB') and 38 smaller banks (denoted 'SB'). Unless stated otherwise, absolute amounts are given in billions of euros.

Initial numerators and denominators of the regulatory ratios for the two groups are reported in Table 2. The corresponding average ratios and the aggregated shortfalls for large and small banks are reported in Table 3 and Table 4. Table 3 documents that, on average, small banks have higher capital and leverage ratios than large banks. Furthermore, the table shows that neither large nor small banks meet the NSFR, on average. Apart from the NSFR, large banks do not meet the LCR requirement on an aggregated level[5]. The resulting initial shortfalls are reported in Table 4. These values represent the aggregation of the shortfall vector b in the optimization model. According to Table 4, achieving compliance with the NSFR implies the largest changes in volume.

[5]In Europe, the LCR requirement is still in a transition phase and the NSFR requirement has not yet been implemented.

Table 4: The initial shortfall for each Basel III requirement is calculated as the sum across individual banks where a shortfall is observed. It is given in billions of euros. The capital conservation buffer and the capital surcharges for G-SIBs are included as applicable. The shortfalls are determined on an isolated basis ignoring potential interdependencies. The initial aT1 shortfall is calculated based on the maximum of the T1R shortfall and the LR shortfall minus the CET1R shortfall. By analogy, the T2 shortfall is given by the TCR shortfall minus the aT1 and CET1 shortfalls.

	CET1R	T1R	TCR	LR	LCR	NSFR	aT1	T2
Σ LB	4.7	12.4	9.3	37.0	33.6	104.3	32.3	1.6
Σ SB	1.2	2.0	2.9	4.2	10.8	57.8	3.7	1.1

4.3 Parameters

The CM-portfolio consists of HQLA, mid-term lending and funding, long-term funding and the three types of capital, as illustrated in Figure 2. As pointed out in Section 3.2, one advantage of the CM-portfolio is that the majority of the regulatory weights are known because they are fixed by the Basel III framework. Nevertheless, some weights could have been different and require two more additional assumptions. First, we assume the HQLA to be of Level 1, implying a haircut of zero and a risk weight $\mathrm{rw}_{\mathrm{HQLA}}$ of zero. Examples of such assets are EU-government bonds. Second, we assume the mid-term asset position to be lending to non-bank financial corporates (NBF) with a risk weight of 20%.

The adjustment cost a_i and margins m_i are listed in Figure 2. In our setup the solution of the optimization problem, the CM-portfolio x, does not directly depend on the values of a and m but only on the hierarchy between them, more precisely, on the hierarchy of the difference of margins and adjustment cost $m - a$; see Section 6. Nevertheless, the value of the objective function, the PnL, depends directly on the choice of these two parameters.

Volume changes of HQLA and lending to NBF show the lowest adjustment cost because transactions are easily scalable in size without major changes in infrastructure. By contrast, raising capital is typically expensive, as it involves engaging and agreeing with shareholders. The debt funding has a slightly higher adjustment cost than the investment position. This reflects the intuition that it is slightly more difficult to raise funding (one might need to contact and convince several potential investors) than to invest it. Long-term funding is assumed to be slightly more expensive than mid-term funding because long-term funding requires professional investor relations.

Concerning the margins m_i, we assume that only the investment yields a positive margin. Capital yields a negative margin because it requires a risk premium that is added to the debt funding and/or shareholders expect a higher return than debt capital provider.

5 Empirical Findings

The calculations are performed on bank level but we can disclose only aggregated findings for large and small banks in order to ensure confidentiality.

Table 5: Resulting aggregate CM-portfolio in billions of euros. The column PF reports the size of the portfolio.

	Assets		Liabilities					
	HQLA	$NBF^{A}_{(30d,1y)}$	$NBF^{D}_{(30d,1y)}$	CM_{1y}	T2	aT1	CET1	PF
Σ LB	33.6	100.7	3.5	89.4	1.6	35.2	4.7	134.3
Σ SB	10.8	48.8	0.0	52.9	1.1	4.5	1.2	59.7

Table 6: Average and quantiles of the Basel III ratios after the adjustment process, i.e. after including the determined CM-portfolio for each individual bank, in per cent. The weighted average ratios are obtained by dividing the total numerators by the total denominators. The Basel III requirements are displayed for comparison.

	CET1R	T1R	TCR	LR	LCR	NSFR
Basel III	≥ 7	≥ 8.5	≥ 10.5	≥ 3	≥ 100	≥ 100
LB weighted average	8.8	11.9	15.6	3.0	108	103
LB average	8.6	10.6	14.7	3.1	124	102
LB median	8.3	9.6	13.5	3.1	101	100
SB weighted average	13.1	14.4	16.6	4.6	141	104
SB average	11.8	12.9	14.9	4.6	416	110
SB 25%-quantile	8.5	9.3	10.6	3.2	100	100
SB median	10.3	11.4	13.1	4.0	151	103
SB 75%-quantile	13.6	14.8	17.4	5.3	321	114

5.1 Comparison of the different shortfall estimations

Table 5 summarizes the results for the CM-portfolio. The aggregated CM-portfolios of large banks add up to €134 billion whereas the CM-portfolios of small banks add up to €60 billion. This implies that in order to reach compliance with the Basel III thresholds, total assets need to increase by 3% and 7% for large and small banks, respectively.

By definition, each individual bank complies with all six Basel III requirements after the adjustment process, which results in an increase in the ratios. The ratios including the CM-portfolio of each bank are summarized in Table 6 where significant increases of every ratio are observed compared to the initial values given in Table 3. All average weighted ratios lie well above their threshold except the leverage ratio for large banks which is at the 3% threshold for the sample containing the eight large banks.

The CM-portfolio provides a (multi-dimensional) measure of the integrated shortfall. But in order to compare the CM-portfolio with the isolated shortfalls, we refer to the volume of CET1 of the CM-portfolio as the integrated CET1 shortfall. In analogy, we refer to the volumes of aT1, T2, and HQLA of the CM-portfolio as integrated shortfalls in these dimensions. Since the CM_{1y} position fully qualifies as stable funding, we refer to the volume of CM_{1y} as integrated ASF shortfall.

Table 7 presents by how much the integrated shortfalls differ from the isolated ones. The main observations are:

- The integrated CET1 and HQLA shortfalls are identical to the isolated ones.
- The integrated shortfalls of aT1 amounts to €2.9 billion and €0.8 billion for large

Table 7: Summary and comparison of integrated and isolated shortfalls in billions of euros. The aggregated isolated shortfalls on the left-hand side are those from Table 4. The right-hand side displays the difference between integrated and isolated shortfalls aggregated over all banks where a shortfall is present.

	Isolated shortfalls					Integrated minus isolated shortfalls				
	CET1	aT1	T2	HQLA	ASF	CET1	aT1	T2	HQLA	ASF
Σ LB	4.7	32.3	1.6	33.6	104.3	–	2.9	–	–	−14.9
Σ SB	1.2	3.7	1.1	10.8	57.8	–	0.8	–	–	−4.9

Table 8: The aggregated integrated shortfall relative to the corresponding aggregated initial quantity in per cent. The integrated ASF shortfall is given relative to the initial ASF_0 and relative to the initial total assets (TA).

	ΔCET1	ΔT1	ΔTC	ΔHQLA	ΔASF	ΔASF_{TA}	ΔTA
Ø LB	5	42	31	8	6	2	3
Ø SB	2	10	10	9	7	4	5

and small banks. This corresponds to an increase of 9% for large banks and 22% for small banks compared to the isolated shortfalls. The increase is mainly a consequence of the LR which requires raising more T1 to cover the extension of the balance sheet.

- The shortfall in stable funding decreases by €15 billion (-14%) and €4.9 billion (-9%) in the integrated case. The reduction is driven mainly by the fact that capital fully qualifies as stable funding in the sense of the NSFR.

Compared to the corresponding initial quantity, the integrated CET1 shortfall corresponds to 5% of the initial CET1 as of reporting date June 2013 for large banks and 2% for small banks; see Table 8. On average, the large banks need to increase their T1 by 42%. Correspondingly, their total capital will have to increase by 31%, while the LCR and NSFR result in moderate relative integrated shortfalls which are smaller than 10%. For small banks, the relative integrated shortfalls amount to 10% or less. The volume of the CM-portfolio corresponds to 3% of the aggregated total assets of all large banks and to 5% of all small banks.

5.2 Consideration of the cost

The cost of covering the integrated shortfalls is given by the negative value of the objective function, Equation 6; see row 'CM-portfolio' in Table 9. For comparison, we determine the total cost of covering the isolated shortfalls by multiplying the difference between adjustment cost and margins, given in Figure 2, with the isolated shortfalls of Table 7. The resulting total cost of covering the isolated shortfalls is given in row 'total (no portfolio)' of Table 9.

Comparing the cost of the isolated shortfalls and the integrated shortfalls (for example €2.05 billion as against €1.98 billion for large banks) ignores the fact that the isolated shortfalls do not represent a valid business strategy because they result in unbalanced

Table 9: Cost of the isolated and the integrated shortfalls in billions of euros. The cost of each isolated shortfall is obtained by multiplying the shortfall with the corresponding difference between adjustment cost and margins.

		Σ LB	Σ SB
Isolated	CET1R	0.33	0.08
	T1R, LR	1.13	0.13
	TCR	0.03	0.02
	LCR	0.03	0.01
	NSFR	0.52	0.29
	Total (no portfolio)	2.04	0.53
	$\text{NBF}^{A}_{(30\text{d},1\text{y})}$	-0.08	-0.05
	$\text{NBF}^{D}_{(30\text{d},1\text{y})}$	0.01	0
	aT1	0.08	0.02
	Total (portfolio)	2.05	0.50
Integrated	CM-portfolio	1.98	0.49

accounts. In order to make them comparable with the integrated shortfall, we complement the isolated shortfall of each bank by adding lending to and funding from NBFs such that the balance sheet balances.

For large banks, we obtain €83.5 billion lending to NBF and €3.5 billion funding from NBF, which translates into additional cost of €-0.08 billion for the lending (in fact a profit) and €0.01 billion for funding from NBFs. For small banks, we obtain €50 billion lending to and no funding from NBFs which translates into additional cost of €-0.05 billion for the lending from NBFs.

Note that, at this stage, we compare the cost of two portfolios of which the CM-portfolio leads to compliance with all Basel III requirements, while the other portfolio still violates the LR threshold. The LR is violated because the extension of the balance sheet leads to an increase of the leverage exposure and a new T1 shortfall. Achieving compliance with the LR leads to a further demand of €2.9 billion aT1 for large banks and €0.8 billion for small banks. These adjustments generate additional cost of €0.08 billion for large banks and €0.02 billion for small banks; see row aT1 of Table 9.

Overall, the total cost of covering the isolated shortfalls, after ensuring the balancing of the balance sheet and the compliance with all thresholds, amounts to €2.05 billion and €0.50 billion for large and small banks, respectively.

However, the absolute cost needs to be interpreted with caution because they are based on assumptions. Nevertheless, for a bank that knows its margins and adjustment cost, it is straightforward to quantify its integrated compliance cost using our approach. Also note that margins can be realized during several years, whereas adjustment cost are a one-off. In its current form, our framework minimizes the cost of the first year. If a bank uses the present value of the margins instead of the annual margins, our framework could also correctly handle the one-off character of adjustment cost and the periodic character of margins.

5.3 Interpretation

If all banks implemented their CM-portfolios, they would achieve compliance with all Basel III requirements by construction. Neglecting the interactions in the isolated shortfalls leads to an underestimation of the aT1 shortfall by €3.7 billion and an overestimation of the required stable funding by €19.8 billion. For the chosen set of parameters the cost of becoming compliant with Basel III for the 46 banks amounts to €2.46 billion. These numbers have to be regarded as a benchmark. Choosing other strategies, for example a reduction of the denominators (RWA, net outflows, LR exposure and RSF), will lead to different cost.

Depending on the structure of the balance sheet of each individual bank, these strategies are likely to be more expensive because they are accompanied by a reduction of the bank's core business. This implies a reduction of the revenues plus additional unwinding cost (captured in our model by adjustment cost) from laying off staff, exiting renting agreements or exiting IT systems. Therefore, a deleveraging strategy is likely to be more costly. Nevertheless, deleveraging will be preferred, if a growth strategy including an increase of capital turns out to be less cost-effective.

5.4 Sensitivity to the choice of regulatory thresholds

The regulatory thresholds of the Basel III ratios are not necessarily fixed to the standards defined in the Basel III framework. First, the CRs might be increased by national regulators via the discretionary counter-cyclical buffer or domestic surcharges. Second, the precise implementation of some ratios, for example the LR or the NSFR, are currently still under discussion in some jurisdictions.

We consider three hypothetical scenarios. In the first scenario, the three minimum CRs are increased by one percentage point. In the second scenario, the minimum leverage ratio is increased by one percentage point. Finally, in the third scenario the minimum capital and the minimum leverage ratios are increased by one percentage point. The thresholds for the LCR and the NSFR remain unchanged[6]. Table 10 summarizes the resulting isolated and integrated shortfalls.

As expected, we observe that raised minimum CRs result in increased isolated shortfalls especially in terms of CET1 and T2, while a raised minimum LR leads to an increased shortfall of aT1. Especially in the scenarios with an increased LR, the size of interaction-effects concerning the NSFR shortfall increases. For large banks, omitting the interactions leads to an overestimation of the NSFR shortfall by 34% when the LR is increased by one percentage point. Without increased CRs and LR, the overestimation amounts only to 14%. In the scenarios with increased CRs, the isolated shortfalls show to a slight overestimation of the need for T2. Considering the scenario with only increased CRs, the integrated approach leads to a T2 shortfall €0.5 billion smaller than in the isolated approach; see Table 10. The T2 shortfalls can be overestimated in the isolated approach because the increased T1 shortfall in the integrated approach leads to a reduced need for T2 to fulfill the TCR requirement.

[6] At the time of writing, the thresholds for LCR and NSFR were fixed, while different calibrations of the CRs and LR were under discussion

Table 10: Comparison of integrated and isolated shortfalls for three hypothetical scenarios where the threshold of the named ratios is increased by one percentage point is given in billions of euros. The integrated shortfalls are presented as the difference between integrated and isolated shortfalls.

	Isolated shortfalls					Integrated minus isolated shortfalls				
	CET1	aT1	T2	HQLA	ASF	CET1	aT1	T2	HQLA	ASF
	Base case									
Σ LB	4.7	32.3	1.6	33.6	104.3	–	2.9	–	–	−14.9
Σ SB	1.2	3.7	1.1	10.8	57.8	–	0.8	–	–	−4.9
	Increased CRs									
Σ LB	8.6	32.0	2.3	33.6	104.3	–	1.5	−0.5	–	−17.3
Σ SB	1.8	4.1	1.7	10.8	57.8	–	0.8	–	–	−6.0
	Increased LR									
Σ LB	4.7	72.4	–	33.6	104.3	–	6.2	–	–	−35.5
Σ SB	1.2	10.8	1.0	10.8	57.8	–	1.6	–	–	−8.8
	Increased CRs and increased LR									
Σ LB	8.6	68.4	0.3	33.6	104.3	–	6.2	−0.3	–	−35.5
Σ SB	1.8	11.1	1.5	10.8	57.8	–	1.6	–	–	−9.9

6 Robustness Checks

Our model, the resulting integrated shortfalls, and the PnL-impact of the required adjustments rely on parameters that bank outsiders, such as the authors, need to estimate. The solutions of linear programs are sensitive to parameter changes. High robustness against these parameter changes is a desirable property because margins of capital market products can change and adjustment cost are subject to measurement uncertainty even if internally estimated. Thus, it is important to know whether a compliance strategy involving large amounts of funds is not crucially sensitive to small variations in parameters.

As a measure of robustness, we compute the solution radius of the parameters. The solution radius is the uniform percentage by which parameters could increase or decrease in any random combination without changing the solution of the optimization problem. It can be interpreted as robustness within a certain interval of the parameters.

For the specific calibration given in Figure 2, we find that the solution radius amounts to ±33%. Each margin and adjustment cost can vary by up to ±33% without affecting the resulting CM-portfolio. It is obvious, that the PnL contribution of the CM-portfolio varies even though the optimal solution remains unchanged, since we specifically alter the PnL parameters. Alternatively, one could use robust optimization to deal with parameter uncertainty, as described in Bertsimas, Brown, and Caramanis (2011).

Furthermore, it has to be noted that the volumes of the CM-portfolio resulting from the optimization problem do not depend on the absolute value of the adjustment cost and margins but only on their hierarchy, more precisely on the hierarchy of the difference between margin and adjustment cost. This hierarchy is less questionable than the absolute values. In this sense, it is a valid assumption that, for example, the adjustment cost for

HQLA assets is lower than those for other assets because large amounts of HQLA can be traded at lower cost than other product classes. Also looking from the perspective of a bank, the hierarchy of adjustment cost and margin on the liability side, which consists of CET1, aT1, T2, long-term and medium-term funding, is also less questionable in the current economic environment than their absolute value.

7 Summary and Conclusions

This paper proposes a portfolio measure to quantify how far away banks are from being compliant with Basel III. The efforts needed to reach compliance are often measured as an isolated shortfall for each Basel III requirement. However, filling up the gaps directly does not guarantee overall compliance with Basel III nor is it necessarily an optimal way to achieve compliance. We propose complementing the isolated shortfalls by using a portfolio measure which provides an explicit description of how a bank can achieve compliance while respecting the balance sheet equality. Furthermore, the portfolio measure is the solution of an optimization problem that has a microeconomic foundation and takes the interactions of capital and liquidity requirements into account in a natural way. Our microeconomic model describes a bank that wants to achieve compliance without downsizing its current business structure. Therefore, the compliance portfolio is chosen to be additive. Among all possible compliance portfolios, the model determines the most cost-efficient one, taking into account margins and adjustment cost for each position of the compliance portfolio.

Our approach can be used to address an important open question: How material is the effect of omitting the interactions of the requirements of pillar one of the Basel III package on the isolated shortfalls published for example in the Basel III monitoring reports? In order to focus exclusively on the interaction effects, our compliance portfolio has to contain positions corresponding to the numerators of the Basel III ratios, since the isolated shortfalls are measured in terms of these numerators. In addition, the compliance portfolio comprises two positions that affect the Basel III ratios as little as possible. These are mid-term positions representing lending to and funding from the market.

In our sample of 46 German banks, we observe no effects of the interactions on the isolated CET1, T2, and HQLA shortfalls. Integrated and isolated shortfalls are identical. We find that the isolated approach underestimates the aT1 shortfall by 9% and 22% for large and small banks, respectively. The isolated shortfalls do not take into account the balance sheet lengthening caused by the additional compliance portfolio. Finally, we find that the integrated shortfall in stable funding is lower (-14% for large banks and -9% for small banks) than the corresponding isolated shortfall. The isolated approach overestimates the NSFR shortfall, ignoring synergies from capital fully qualifying as stable funding in the NSFR framework. Regarding the cost of becoming compliant, we find that covering the integrated shortfalls exhibits cost similar to covering the isolated ones. Taking into account the interactions reduces the cost of compliance by about 3% for large banks and 7% for small banks compared to the isolated shortfalls.

The quantification of effects from the interactions of regulatory requirements is not the only possible application of our portfolio measure. To address the question of realistic adjustment strategies, one would need to extend the model to allow for reductions of positions and to consider an extended set of financial instruments. These extensions are left for further research.

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