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IMF Working Paper

The Nature of Islamic Banking and Solvency Stress Testing—Conceptual Considerations

Andreas A. Jobst and Juan Solé

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IMF Working Paper

Monetary and Capital Markets Department

The Nature of Islamic Banking and Solvency Stress Testing—Conceptual Considerations

Prepared by Andreas A. Jobst and Juan Solé¹

Authorized for distribution by Martin Čihák

August 2020

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Abstract

This paper provides a conceptual overview of key aspects of the design and implementation of solvency stress testing of Islamic banks. Based on existing regulatory standards and prudential practice, the paper explains how Islamic finance principles and their impact on various risk drivers affect the capital assessment of asset-oriented financial intermediation under stress. The formal specification of these risk factors helps operationalize and integrate the stress testing of Islamic banks within established frameworks for financial stability analysis.

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Authors' email addresses: ajobst@imf.org; jsole@imf.org

¹ Corresponding authors: Andreas (Andy) A. Jobst, European Department; Juan Solé, Monetary and Capital Markets Department. We are grateful for comments from Marco Espinosa, Giancarlo Gasha, Abdullah Haron, Maher Hassan, Jad Khallouf, Divya Kirti, Mindaugas Leika, Abozer Majzoub Mohammed, Mohamed Norat, Ghiath Shabsigh, Zeine Zeidane, and an anonymous reviewer from the Bank Negara Malaysia, as well as attendees of the departmental QUANTM Seminar (July 2019) and a workshop on Islamic bank stress testing, which was organized by the Istanbul School of Central Banking in June 2019. We thank Cathy Lips and Lilly Siblesz de Doldan for their editorial support.

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I. PREFACE

This paper pre-dates the current COVID-19 crisis and does not reflect the Fund staff's evolving analysis of potential financial stability implications and advice on financial regulation (IMF, 2020c).² However, its general guidance on the conceptual foundations of stress testing remains highly relevant to articulate the capital impact of economic contraction on Islamic banks, which are likely to face rising capital and liquidity pressures due to shrinking profits, deteriorating asset quality, and adverse funding conditions similar to their conventional peers.

Evaluating the extent to which banks are resilient to the adverse impact of the current crisis puts significant emphasis on stress testing as an integral part of overall risk governance and market surveillance. Stress testing are traditionally prospective—they help banks and supervisors assess capital adequacy and liquidity risk under severe but plausible scenarios when there is time to remedy identified vulnerabilities. However, when shocks have already occurred, such as in the case of the current COVID-19 crisis, the role of stress tests changes. Findings from past stress test exercises on pre-existing vulnerabilities (if available) can help inform timely policy decisions as developments unfold—ideally in the form of scenario analyses of evolving shocks (potentially in combination with selective data updates), especially if the deterioration of economic conditions and their impact on the financial system remains highly uncertain.

The relevance of stress tests during the current crisis also applies to Islamic banks, which share many characteristics with their conventional peers but are also exposed to additional risks due to the specific nature of their business models (Chattha, 2020). Islamic banks are particularly affected by liquidity and commodity price shocks given the scarcity of short-term liquid assets and deep money markets as well as the comprehensive collateralization of all borrowing and lending activities, which is mostly done via precious metals or certain agricultural goods. Most Islamic banks also operate in emerging market and developing economies (EMDEs), for which the multi-faceted nature of the shock raises complex (and in many ways unprecedented) macro-financial challenges. Many EMDEs face acute strains from a sharp reversal of capital inflows due to a deterioration of investor sentiment, with the attendant pressure on exchange rates and credit spreads raising the likelihood of credit defaults, financial distress, and macroeconomic instability.³ For instance, the recent fall in oil prices is bound to result in a tightening of domestic liquidity conditions in oil-exporting

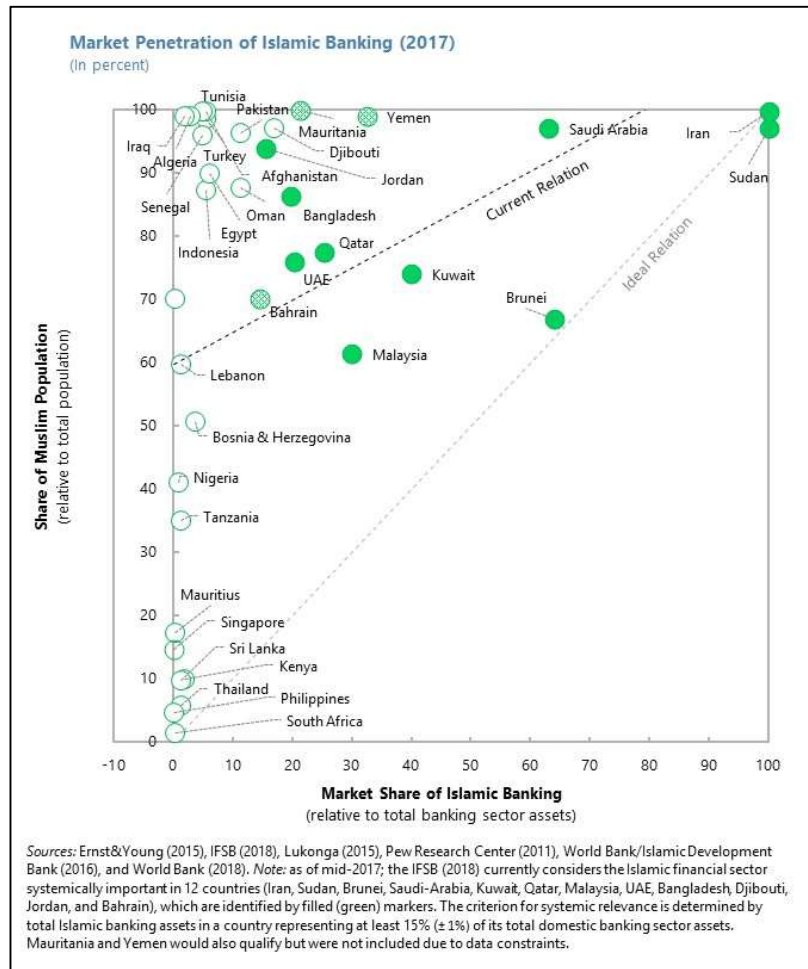
² Readers may consult the IMF's [COVID-19 website](#), which includes a tracker of [key policy measures](#) and staff recommendations with regard to the COVID-19 global outbreak as well as a current analysis of financial stability implications in the [April 2020 issue of the Global Financial Stability Report](#) (IMF, 2020a).

³ On the supply side, production, trade and travel disruptions are slowing the delivery of intermediate goods and foreign labor/expertise in EMDEs that are tightly integrated into global supply chains. On the demand side, commodity exporters and those countries with large tourism sectors suffer from a deterioration of their terms of trade, further exacerbating the contraction domestic real activity.

countries and a rise in banks' nonperforming exposures due to the deterioration of the balance sheets of the government, household, and nonfinancial corporate sectors (IMF, 2020b).

II. INTRODUCTION

Over the past two decades, Islamic finance has undergone a rapid expansion in many emerging market and developing economies (EMDEs) (Chart), where religious principles often favor the use of financial services and products that are compliant with Islamic finance principles (Imam and Kpodar, 2015). The key characteristics of Islamic finance (مصرفية إسلامية)—such as the concept of profit- and loss-sharing between lenders and borrowers, the focus on investments that are socially responsible, and the requirement of linking finance with real economic activities—have grown in popularity, especially since the global financial crisis, and provide an alternative to more traditional financial products (IMF, 2015). They define an asset-oriented system of ethical financial intermediation and investment built on the principles of risk-sharing in lawful activities (*halal* or *حلال*) rather than rent-seeking gains. In particular, the use of Islamic finance principles for infrastructure projects has provided significant stimulus for Islamic banking (with many institutions entering the Islamic finance field for the first time).⁴

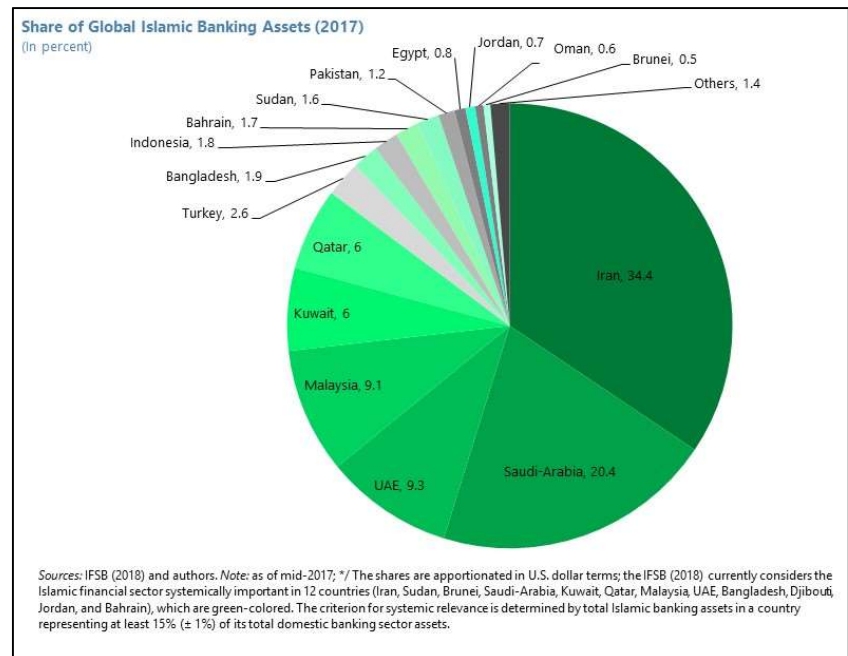


⁴ The conventions of Islamic finance are particularly suitable for infrastructure development. The asset-backed and project-specific nature of Islamic finance structures and their emphasis on risk sharing make them a natural fit for public-private partnerships in infrastructure development. Islamic finance can be flexible, as reflected in the wide variety of structures that are available to those who want to either (1) finance the purchase of land and equipment to build assets; or (2) lease assets upon completion and pay for their use (Levy and Iqbal, 2018).

Islamic finance already accounts for more than half of total financial assets in some EMDEs, and the Islamic financial services industry is estimated to amount to \$2.6 trillion (or about 0.7 percent of total financial assets [Financial Stability Board {FSB}, 2019]). The potential for growth of this form of finance is nonetheless considerable, given that its penetration rate in large and populous economies, such as Indonesia and Turkey, is still below 20 percent.

Most Islamic finance assets are concentrated in the banking sector,⁵ which has grown in systemic importance. While Islamic banks account for only one percent (or \$1.6 trillion) of global banking sector assets (\$146.6 trillion) (Chart), they represent at least 15 percent of the total banking sector in 14 countries, of which Iran and Sudan are the only ones where the entire financial system operates in compliance with Islamic law (*shari'ah* or شريعة).⁶ The market share of Islamic banks in most of these countries has continued to increase over the past few years, further deepening the penetration of Islamic finance principles. Islamic banking is also expanding in countries that have few Islamic banks despite substantial Muslim populations—in Africa (such as Algeria, Egypt, Mauritania, Mauritius, Nigeria, Senegal, Tanzania, and

Tunisia), the Middle East and Central Asia (Afghanistan, Iraq, Kazakhstan, Lebanon, Pakistan, and Oman), and Southeast Asia (Indonesia and Singapore) (World Bank/Islamic Development Bank, 2017). During the last monitoring period by the Islamic Financial Services Board (IFSB, 2018), which tracks an expanded list of 36



countries, Islamic banks have increased their domestic market share in 19 countries while remaining constant in seven others (including Iran and Sudan, where they have a 100 percent

⁵ Despite the bank dominance in Islamic finance, long-term institutional investors and market-based finance are becoming quite relevant. About one quarter of *shari'ah*-compliant financial services are attributable to capital market activities, insurance (*takaful* or تَكَاوُل), microfinance and other nonbank finance (such as investment funds, captive financial institutions and money lenders as well as broker-dealers), and financial auxiliaries.

⁶ The IFSB (2018) currently considers the Islamic financial sector systemically important in 12 countries (Bahrain, Bangladesh, Brunei, Djibouti, Iran, Jordan, Kuwait, Malaysia, Qatar, Saudi Arabia, Sudan, and UAE). Yemen also qualifies based on the current size-based criterion of systemic relevance but was not included due to data constraints.

market share by construction). Iran remains the largest jurisdiction for Islamic banking, accounting for a slightly increased 34.4 percent of the global Islamic banking industry at mid-2017, followed by Saudi Arabia (20.6 percent), UAE (9.6 percent), Malaysia (9.1 percent), and Kuwait (6.0 percent) (Chart).⁷

As Islamic finance helps raise financial inclusion in many EMDEs with substantial Muslim populations, its bank-centric structure places a premium on nurturing the rising demand in a safe and sound manner (Lagarde, 2015). The asset-backed, ring-fenced, and project-specific nature of many Islamic financial activities constitutes unique sources of risk that require a suitable supervisory and regulatory environment to preserve the stability of the financial system and its ability to support growth (Lopez and others, 2014). The IFSB issued several prudential standards and guidance notes for institutions that operate (and are supervised) under Islamic finance principles. However, some of these standards are not applied consistently across jurisdictions (Song and Oosthuizen, 2014), and continued efforts are needed to refine supervisory and regulatory frameworks in line with these recommendations while ensuring greater harmonization.⁸

Stress testing is fundamental to analyzing the financial stability implications of Islamic banking in countries where Islamic finance is growing in significance.⁹ Stress tests are designed to identify vulnerabilities to the impact of a rapidly deteriorating operational and market environment affecting the overall risk profile—from the financial system level down to individual banks and their different lending and trading portfolios (Jobst and others, 2013).¹⁰ Over the past decade, bank stress testing has rapidly evolved and has become a central aspect of the IMF’s financial sector surveillance—as a key component of the [Financial Sector Assessment Program](#) (FSAP)¹¹ assessments, which are now formally part of

⁷ The other countries among the largest Islamic banking jurisdictions are Bahrain, Bangladesh, Indonesia, Qatar, and Turkey (IFSB, 2018).

⁸ For a recent assessment of the performance and regulation of Islamic banks, see World Bank/Islamic Development Bank Group (2017).

⁹ The availability of strong regulation and supervision is a key factor of assessing system-wide vulnerabilities of the capital adequacy of countries’ banking systems to various risks. The IFSB introduced two standards, capital adequacy requirements (IFSB, 2005a and 2013) and risk management practices (IFSB, 2005b), which are particularly relevant for the capital assessment of Islamic banks under stress (Kammer and others, 2015).

¹⁰ Well-formulated stress tests comprise different methods, such as sensitivity and/or scenario analyses, to assess the overall capacity of an individual bank or the entire banking sector to absorb shocks from the realization of key macrofinancial risks. They can also provide a cross-sectoral perspective by capturing the interconnectedness of banks, insurers, and other market participants.

¹¹ The IMF has made it mandatory for 29 jurisdictions with systemically important financial systems to undergo FSAP assessments every five years. These include all FSB member jurisdictions, except Argentina, Indonesia, Saudi Arabia, and South Africa, which are G-20 member countries. FSAP stress tests attempt to cover all relevant sources of risk affecting the performance and capital and liquidity risk assessment of the financial system. The outcomes of stress tests are driven by the initial identification of these risks in detecting, monitoring, and mitigating buildup of risks based on known vulnerabilities from common exposures, risk concentrations, and interdependencies across the financial system.

IMF Article IV consultations, and its use in crisis program work (Ong, 2014; Ong and Jobst, 2020). Stress testing has also grown in importance for many IMF member countries as a forward-looking technique for supervisors and macroprudential authorities. It enables them to identify any vulnerabilities that individual institutions or an entire financial system might have to adverse events that, while unlikely to happen, would have a significant economic impact if they were to occur.

The development of stress testing approaches has focused largely on conventional banks. While core principles and methods that determine the capital impact of risk factors apply universally, stress tests for Islamic banks would need to acknowledge the distinct characteristics of *shari'ah*-compliant financial intermediation. Many risk factors affecting both Islamic and conventional banks are similar in *form* but markedly different in *substance*.¹² Much like their conventional peers, Islamic banks face credit, market, and operational risks from maturity and liquidity transformation (by managing cash flows over different risk horizons to satisfy payments); however, the capital adequacy of *shari'ah*-compliant banking activities is also affected by risk-and-profit sharing, which implies some loss-bearing by investors and reduces capital intensity of equity-like financing. In particular, specific risk factors that are germane to Islamic banks involve:

- *Displaced commercial risk* (DCR) if shareholders forgo some of their profits to provide competitive (and stable) earnings to unsecured depositors (which would otherwise need to absorb losses);
- *Project and counterparty risks* stemming from partnership-like financing;
- *Rate of return risk* from pricing frictions if Islamic banks need to adjust profit rates of investment accounts (outside actual underlying asset performance) to compete with conventional banks in response to changes in monetary policy; and
- *Operational risk* from the failure to comply with Islamic finance principles.

The distinct risk profile of Islamic banks underscores the need for a coherent and consistent approach to the design and implementation of solvency stress testing. This paper establishes a common understanding of the unique properties of Islamic banking in line with relevant Islamic finance principles (IFSB, 2012b and 2013) and provides a *conceptual overview* of

¹² A common metric of risk factors and shocks allows for an integrated analysis at a system-wide level in mixed banking systems. However, the capital impact of a given scenario defined by changes in economic activity, asset prices, and interest rates/rates of return is likely to differ between conventional and Islamic banking activities under stress. Supplementary sensitivity analyses can usually provide additional insights and help identify how these outcomes can be explained by the differential impact of risk drivers.

key risk factors affecting the capital adequacy of banks under stress.^{13,14} The identification and calibration of risk factors follow the functional components of conventional top-down stress testing model(s) and technique(s) of balance sheet-based methods (Jobst and others, 2013). This approach complements the IFSB’s evolving supervisory guidance on microprudential stress testing, building on its *Technical Note on Stress Testing* (IFSB, 2016) and the associated *User Guide* (IFSB, 2017),¹⁵ consistent with the high-level principles on stress testing issued by the IFSB (2012a) and the Basel Committee (BCBS, 2018).¹⁶ However, several process-oriented considerations (and the technical implementation of stress tests) remain outside the conceptual scope of the paper, such as the treatment of capital resources, the design of stress scenarios, the calculation of losses consistent with prevailing accounting standards, the definition of output measures, the validation of results, and dealing with the outcome of the stress tests.

The paper is structured as follows. The next two sections review the fundamental principles of Islamic finance and describe the nature of Islamic banking (Sections II and III). Section IV provides an overview of the main risks arising from Islamic banking activities. Section V defines the prevailing solvency requirement for Islamic banks, which forms the basis for assessing the combined impact of these risks under stress (Section VI). Section VII concludes.

III. FUNDAMENTALS OF ISLAMIC FINANCE

Islamic finance encompasses all transactions by two or more contractual parties whose actions are subject to prohibitory and permissible norms defined by *shari’ah* principles in keeping with the *qu’ran* (or *قُرْآن*) and the *sunnah* (or *سنة*) as religious sources.¹⁷ These principles are often reduced to the simple notion of prohibited interest (*riba* or *ربا*); however, they instead should be characterized as a *process-driven* view of performance-based profits

¹³ Solvency stress tests remain focused largely on credit and market risks (for example, interest rates, exchange rates, and credit spreads as well as equity and commodity prices).

¹⁴ The scope of the paper is limited to Islamic banks and is aimed at both the institutional level and system-wide stress tests; however, elements of the paper can be readily applied to stress testing “Islamic window” operations of conventional banks, which are self-contained.

¹⁵ The IFSB (2016) also covers liquidity stress testing in its recent guidance note. For a conceptual overview of liquidity stress testing, see Jobst and others (2017).

¹⁶ Note that the capital standard for Islamic financial institutions is in the process of being revised to align several of its elements to the finalized Basel III framework and the International Financial Reporting Standards (IFRS).

¹⁷ *Shari’ah*-compliant financing contracts substitute the profitable sale of assets for the permanent transfer of funds at a specified interest rate (underpinning the “self-generating” profit proposition in conventional finance) (Subhani, 2011). In practical terms, the principle of permissibility under Islamic finance principles is generally taken to mean that profits from bilateral exchanges are considered *shari’ah*-compliant (and serve a public good in a general sense (*maslaha* or *مصلحة*)) in the absence of a clear and specific prohibition through religious censure (*taqlid* or *تقليد*) (Uberoi, 2010).

from financing *real* activities that create heterogeneous goods and/or services (“co-generation”) between two or more parties (see Appendix IV).¹⁸ Investment returns are not guaranteed but derive from transparent rights and obligations regarding the generation and distribution of profits arising from mutual contributions of transacting agents. Investors are entitled to receive commensurate state- or time-contingent payoffs from their direct participation in the performance of the funded asset (that is, payments can vary over time as conditions change). Payments are made in association with the temporary or permanent use of assets and generally not from the time value of money.¹⁹ In contrast, interest payments in conventional finance represent the contractible cost for funds tied to borrowing a certain amount of principal over a prespecified lending period, generating returns without economic conditionality regarding the use of funds. Thus, from the perspective of Islamic finance, interest income is not seen as the effect of business transactions, but as the result of an undesirable process by which such an effect is achieved (Jobst, 2007a; Jobst and others, 2008).²⁰

These overarching requirements distill several specific contractual conditions, which also pertain to *shari’ah*-compliant financial transactions:

- *Price certainty without manipulation of risk.* While the fair value of an asset (and the return from investment) is inherently uncertain, Islamic finance principles prohibit transactions with payment obligations that are incalculable *ex ante* and divorced from (required) asset performance (and/or the rendering of a service). These transactions would be considered gambling (*maisir* or ميسر) if they (i) generate returns from money as a store of value (rather than a medium of exchange to execute trade or shared investment to help create a lawful *usufruct*); and (ii) have the manipulation of risk (without

¹⁸ *Riba* is generally understood as the realization (or prospect) of an economic advantage through excessive compensation, which can occur either (i) as “usury in trade” in the form *riba al-buyu’* (ربا البيوع) when two or more species (*anwar* or أنور) of the same genus (*jins* or جنس) are exchanged in unequal quantities in a spot sale (*riba al-fadl* or ربا الفضل) or with deferred delivery (*riba al-nasi’a* or ربا النسيئة), subject to the same efficient cause (*illah* or إله), or (ii) as “usury in debt” in the form of *riba duyun* (ربا الديون), which defines an unjustified increment in money lent over and above the principal amount at the point of contract (*riba al-qur’an* or ربا القرآن) or for late repayment or failure to repay the loan (*riba jahiliyyah* or ربا الجاهلية). Thus, Islamic finance principles prohibit profits from exchange-based contracts of the same goods and/or services at *different* prices (or quantities) between buyer and seller (*bay al-inah*) or with delayed payment. This practice extends to the trading of debt (or promises) with debt (*bay dayn bi-dayn*) at a price different than its face value (regardless of whether the transaction occurs spot or in the future).

¹⁹ Note that the Shari’ah Advisory Council (SAC) of Bank Negara Malaysia (BNM, 2010) determined that the application of time value of money principle is permissible for exchange-based contracts with deferred payment since the seller sacrifices the present consumption of money due to the delayed payment, and, thus, limiting the scope of *riba al-nasi’a* (or ربا النسيئة). However, this assessment does not affect the prohibited compensation for time in loan contracts (*riba al-qur’an* or ربا القرآن).

²⁰ The general consensus among Islamic scholars is that *riba* covers not only usury but also the charging of interest and any guaranteed rate of return *regardless* of the performance of an investment or granted benefit (Iqbal and Tsubota, 2006). Thus, the process-oriented view of generating return in *shari’ah*-compliant investment aims at mitigating the risk of exploitation from passive income.

commercial interest) as their primary (or sole) purpose. However, contracts that mitigate risks to facilitate trade (and enhance productivity) could be considered permissible.

- *Identifiable characteristics and certainty about delivery results (in terms of quantity and quality).* Sales must be immediate and absolute to avoid being deemed *gharar* (“that with hidden consequences” or “that whose nature and consequences are unknown” or غرر) or *jahl* (ignorance or جهل), which requires that (i) the object of a *bona fide* transaction must exist (or come into existence based on demonstrated real capital input); and (ii) its characteristics are clearly identifiable before the transfer of title takes place.²¹ Exchanges involving asymmetric information between contracting agents imply the risk of delusion or deception (Al-Suwailem, 1999–2000), especially if payment obligations and delivery results differ from rational expectations. Such contractual uncertainty could lead to exploitation (Vogel and Hayes, 1998) if they generated unilateral (or zero-sum) gains from state- or time-contingent prices, resulting in divergent impacts on different agents.
- *Asset ownership and implicit avoidance of leverage (underfunding).* Islamic finance principles align financial claims with investments in real assets, which marginalizes the possibility of underfunding through leverage and fosters equity ownership (in lieu of financial leverage from debt creation without underlying asset values). Thus, any reference asset is required to be in the (constructive) ownership and possession of the creditor (or, in the context of risk management, the protection seller) at the inception of a transaction. This ensures the asset-backing of financial obligations (which also “collateralizes” the performance of contractual obligations) and the risk and reward sharing that follows from it.

IV. ISLAMIC BANKS’ BALANCE SHEETS AND IMPLICATIONS FOR STRESS TESTING

The typical balance sheet of an Islamic bank resembles that of a conventional bank but implies a higher sensitivity to monetary dynamics (see Table 1).²² Much like in conventional financial intermediation, Islamic banks engage in maturity/liquidity transformation by accepting short-term deposits and issuing commoditized payment obligations (similar to debt securities) to fund longer term lending and investment. However, Islamic banks can only intermediate funds with *shari’ah*-compliant contracts and financial instruments, which tends to result in a larger (positive) duration gap than that of conventional banks.²³ While they generate mostly predefined returns (due to religious requirements), their cost of funding is

²¹ The delayed delivery or payment is permissible if its commercial value (“diversity of trade”) overrides term contingencies, such as in the case of *salaf* (forward trade or سلف), which restricts any contingency risk limited to predefined timing mismatch of delivery or payment.

²² Note that interest rate risk is equivalent to the change in the cost of funding relative to the expected return from *shari’ah*-compliant investment/lending in response to changing monetary conditions affecting Islamic banking.

²³ See Solé (2008) for a discussion of requirements for conventional banks that offer Islamic finance products.

largely variable,²⁴ making them generally more vulnerable to a higher (nominal) cost of capital under monetary tightening.²⁵

Islamic banks also exhibit a stronger connection between the sources and uses of funding. *Shari'ah*-compliant financial intermediation is characterized by pervasive risk sharing, which implies that (most) depositors enter into a wide range of *profit- and loss-sharing* (PLS) agreements that participate in the bank's asset performance (at varying degrees), but rank senior to capital instruments.²⁶ There are four types of "Islamic deposits:" (i) *restricted* investment accounts (RIAs); (ii) *unrestricted* investment accounts (UIAs); (iii) exchange-based contracts using reverse sales, and (iv) current accounts (see Table 1). Many Islamic banks obtain a significant part of their funding from UIAs, which are typically commingled with the bank's own funds and current accounts;²⁷ however, in some countries, reverse commodity *murabahah* (مُرَابَحَة) sale contracts have become the main source of deposit funding (e.g., Malaysia) for Islamic banks. UIAs do not constrain the bank from using these funds (as long as investments are *shari'ah* compliant).²⁸ In contrast, funds from RIAs are separately managed funds (and often reported as off-balance sheet items) that can be invested only in a limited set of pre-agreed activities whose market and credit risk losses are fully borne by account holders (that is, loss-absorbing from a capital perspective).

Since checking accounts are interest-free loans (*qard hasan* or قَرْضٌ حَسَنٌ) with guaranteed principal and exchange-based contracts are fully collateralized by design, their economic characteristics are akin to secured (conventional) deposits. However, investment accounts (IAs) are not liabilities of the bank but unsecured sources of funding. UIAs are viewed as

²⁴ Many Islamic banks have limited access to central bank liquidity and lack sufficient long-term funding, which makes them structurally vulnerable to funding shocks. In most cases, liquid (but expensive) short-term assets and illiquid (but profitable) long-term assets are funded by short-term deposits, investment accounts, and, to a lesser extent, long-term exchange-based/profit- and loss-sharing contracts. The risk from a "long-short mismatch" is exacerbated by the underdeveloped inter-bank money market in *shari'ah*-compliant instruments.

²⁵ Conventional banks generally benefit from rising interest rates as long as they can pass on higher funding costs to borrowers so that their net interest income at least offsets the lower valuation of fixed income investments through the profit and loss statement.

²⁶ Note that the recognition of capital instruments for regulatory purposes is complicated by the principle of subordination arising in both equity-based and exchange-based contracts when used for structuring additional Tier 1 and Tier 2 capital instruments supplementing common equity Tier 1 capital (which is the subordinated claim to a bank as a gone concern). Sairally and others (2013) suggest *musharakah sukuk* for additional Tier 1 and convertible *murabahah* or *ijarah sukuk* for Tier 2 instruments to achieve the effect of subordination among qualifying capital instruments relative to depositors and general creditors of an Islamic bank.

²⁷ However, in some countries, such as Malaysia, investment accounts represent only a small portion of total funding, which is dominated by deposits in the form of current accounts and reverse sales. For instance, UIAs account for less than five percent of total funding of Islamic banks in Malaysia.

²⁸ While UIAs are loss-bearing in principle, there is an expectation that some losses are cushioned by reserves, creating so-called *displaced commercial risk* (DCR).

puttable instruments (that is, investors have the right of withdrawal) under IAS 32,²⁹ whereas RIAs do not guarantee repayment of either principal or return.³⁰ This results in additional risk factors that impact the solvency and liquidity conditions of Islamic banks.

Consistent with the concept of permissible profits from risky capital investment, there are three basic forms of *shari'ah*-compliant uses of funds by Islamic banks *without* explicit interest:

- Lending (*debt-based contracts*) through cost-plus sale-repurchase agreements (or back-to-back sales) of existing assets provided by the borrower (or a third party) through *murabahah* or مُرَابَحَة (or reverse *murabahah/tawarruq*), which may contain deferred payment (*bay bithaman ajil* or مَرَابَحَة) and/or delivery (*salam* or سَلَام / *istisna'a* or اسْتِصْنَاع);
- Leasing (*asset-based contracts*) through sale-leaseback agreements (operating leases) or the leases of third party-acquired assets with purchase obligation components (financing lease) (*ijara* or إِجَارَة); and
- Profit-and loss-sharing (*equity-based contracts*) funding the production of future assets (*musharakah* or مُشَارَكَة / *mudarabah* or ضَرْب) through principal-agent relationships with a predetermined allocation of shared profits and full (or limited) risk-sharing.³¹ In contrast, lending and leasing contracts are “exchange based,” that is, they are initiated by a temporary (permanent) transfer of existing (future) assets from the borrower to the lender (for example, via the sale of commodities), or the acquisition of third-party assets by the lender on behalf of the borrower.

²⁹ IAS 32 specifies the presentation for financial instruments according to the IFRS. For presentation, financial instruments are classified into financial assets, financial liabilities, and equity instruments. The differentiation between a financial liability and equity depends on whether an entity has an obligation to deliver cash (or some other financial asset).

³⁰ See Iqbal and Mirakhor (2006) for a short description of these instruments. Note that in Malaysia, also UIAs do not guarantee the full repayment of principal and return.

³¹ Both types of equity-based contracts are considered profit- and loss-sharing. However, in a *mudarabah* contract (similar to a general and limited partnership), the financier (*rabb-ul-mal*) provides all of the funding while the entrepreneur (*mudarib*) provides specialized knowledge in managing the investment project without making a financial contribution. Thus, any capital losses accrue to the financier whereas the entrepreneur will incur the opportunity cost of the time and effort invested in the project. Hence, only the *musharakah* (joint-venture) is genuinely profit- and loss-sharing from a financial perspective. The same distinction applies to the use of these contracts in the funding structure of Islamic banks (see Table 1).

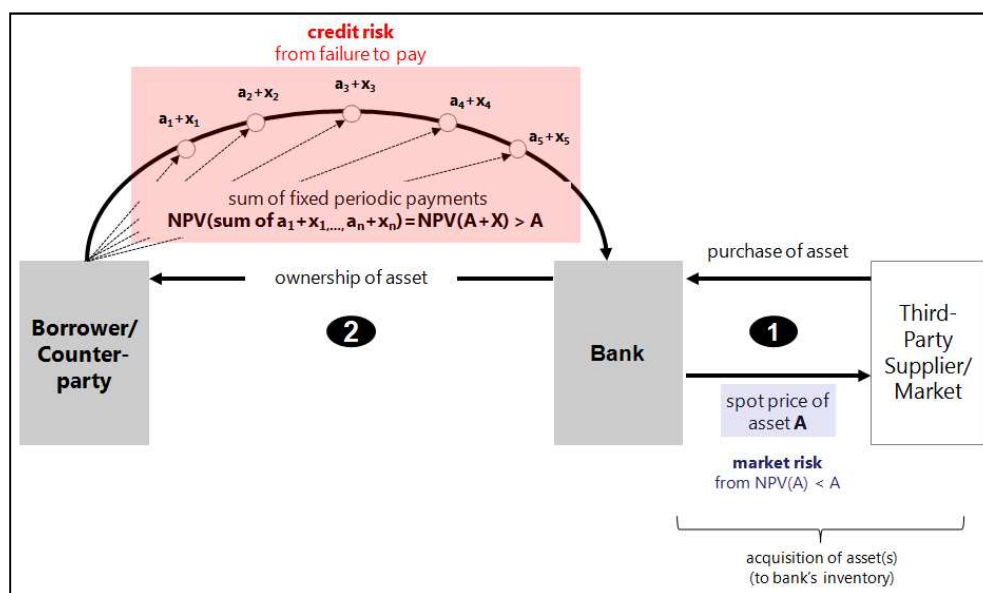
Table 1. Stylized Balance Sheet of an Islamic Bank

ASSETS	LIABILITIES
Cash and cash equivalents	Demand deposits: checking and savings accounts
Interbank deposits (short-term <i>murabahah</i>)	Investment accounts
Financing/lending portfolio	<i>of which:</i> profit- and loss-sharing contracts (<i>musharakah/mudarabah</i>)
<u>Exchange-based</u> contracts	Restricted investment accounts (RIA) 1/
Ordinary sales 2/	Unrestricted investment accounts (UIA)
<i>of which:</i> <i>murabahah</i> (secured)	<i>of which:</i> agency contracts (<i>wakalah</i>)
<i>of which:</i> commodity <i>murabahah</i> (unsecured)	Restricted investment accounts (RIA)
Special sales (delayed settlement)	Unrestricted investment accounts (UIA)
<i>of which:</i> <i>salam/istisna</i> (delayed delivery)	
<i>of which:</i> <i>bay bithaman ajil</i> (delayed payment)	
Leases	Funding liabilities
<i>of which:</i> <i>ijara</i> (operating lease)	<u>Exchange-based</u> contracts
<i>of which:</i> <i>ijara muntahia bittamleek</i> (financing lease)	Ordinary sales 2/
<u>Profit- and loss-sharing</u> contracts	<i>of which:</i> reverse <i>murabahah</i> (secured)
<i>of which:</i> <i>mudarabah</i>	<i>of which:</i> reverse commodity <i>murabahah</i> (unsecured)
<i>of which:</i> <i>musharakah</i> /diminishing <i>musharakah</i>	Special sales (delayed settlement)
	<i>of which:</i> parallel <i>salam/istisna</i> (delayed delivery)
	<u>Profit- and loss-sharing</u> contracts
Investment/trading portfolio	<i>of which:</i> investment certificates (<i>sukuk</i>)
<u>Inventory</u> (commodities)	<i>of which:</i> Islamic collective investment schemes (ICIS)
<i>of which:</i> <i>murabahah</i> inventory—available for sale (AFS)	<i>of which:</i> equity securities
<i>of which:</i> <i>salam</i> commodities	
<i>of which:</i> <i>ijara</i> assets—available for lease (AFL)	Reserves
<i>of which:</i> <i>mudarabah/musharakah investments</i> (cost basis) 3/	Profit equalization reserves (PER)
<i>of which:</i> investment properties	<i>of which:</i> attributable to UIA (PER _{UIA})
<u>Profit- and loss-sharing</u> contracts	<i>of which:</i> attributable to equity (PER _{Equity})
<i>of which:</i> investment certificates (<i>sukuk</i>)	Investment risk reserve (IRR)
<i>of which:</i> Islamic collective investment schemes (ICIS) 4/	<i>of which:</i> attributable to UIA (IRR _{UIA})
<i>of which:</i> equity securities	<i>of which:</i> attributable to RIA (IRR _{RIA})
Net foreign exchange position	
Fixed assets	Capital (equity)
	Long-term syndicated <i>musharaka/mudarabah</i>

Source: authors. Note: 1/ restricted investment accounts (RIAs) are often recorded as off-balance sheet items; 2/ cost-plus sale-trade financing; 3/ for trading, shares, and commodities; 4/ Islamic collective investment schemes (ICIS) are a structured financial scheme that pools investors' capital contributions in a fund that is established and managed in accordance with Islamic finance principles.

Islamic banks incur credit and market risks from exchange-based instruments (that is, sales and leases) on both the assets and liabilities sides of the balance sheet. These instruments are not exclusively financial transactions but involve the sale of an asset between the bank and the customer. The sale establishes a strong funding relation to real economic activity in lieu of indebtedness, irrespective of the use of funds. In a *murabahah* contract, the bank acquires an asset (typically a durable good) from a third party and then sells it to the borrower in exchange for future installments on the purchasing price and markup until the maturity date (cost-plus sale); in this manner, the bank is able to finance the purchase of the asset.^{32,33} If the asset is acquired from the borrower in return for funding but cannot be delivered at inception (*salam/istisna'a*), the bank pays an agreed price, and the customer obtains funds (or working capital) instantly in exchange for the promise of delivering a defined commodity (or rendering the specified service) at a future date. In an *ijara* contract, the bank buys an asset that is subsequently leased to a customer (who has the option but not the obligation to acquire the asset) for a prespecified rate of return.

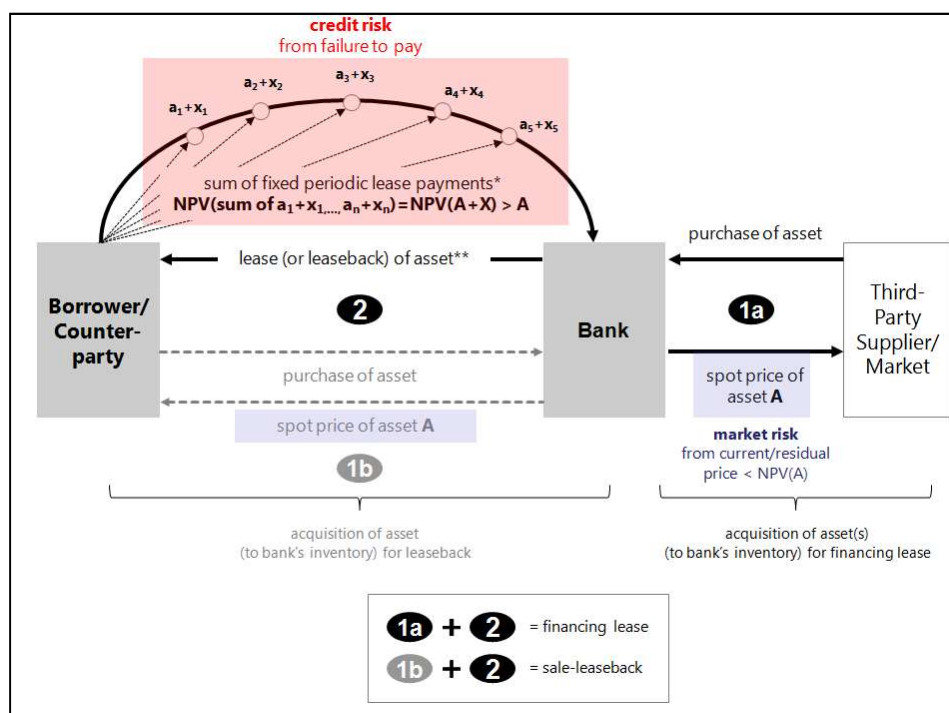
Figure 1. Credit and Market Risks in *Murabahah* (Cost-Plus Sale) Contracts



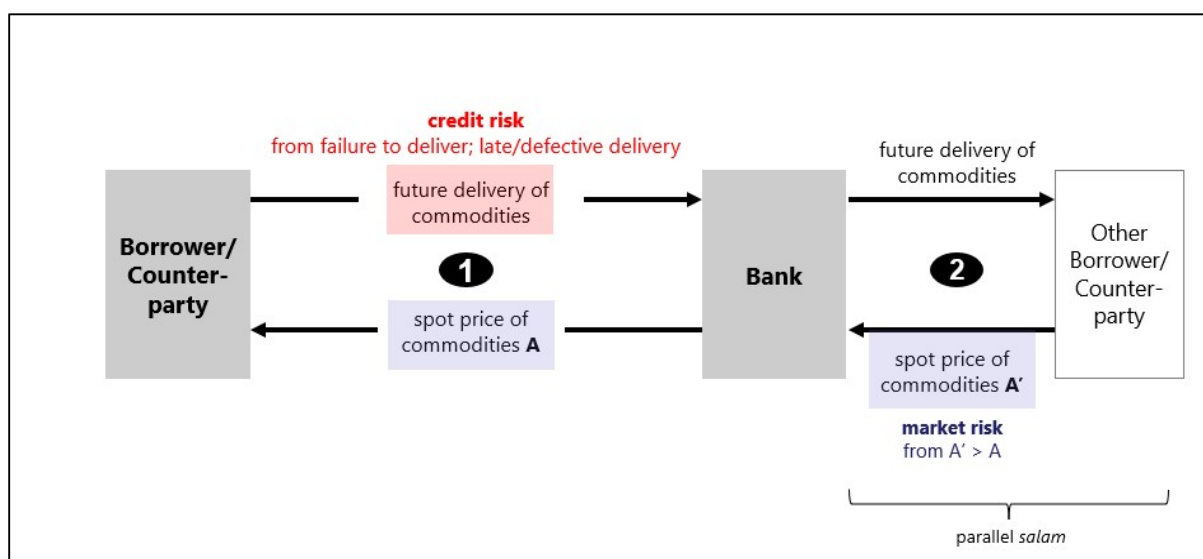
Source: authors. Note: in a "commodity *murabahah*" contract, the bank would sell the asset on behalf of the borrower and generate cash (rather than transferring the asset to the borrower), that is, the transaction is not collateralized.

³² Conversely, the bank (borrower) could also defer all (or some) payment (*bay bithaman ajil*) for receiving the contracted asset from the borrower (bank).

³³ In a reverse *murabahah* (or *tawarruq*) contract, which follows the same process but does not involve a specific asset to be financed, the bank purchases a commodity from a third-party on credit at a higher price to obtain liquidity by selling it again in the market.

Figure 2. Credit and Market Risks in *Ijara* (Leasing) Contracts

Source: authors. Note: I^* could be combined with right to (re-)purchase (*thumma al-bay*); I^{**} implies "put option" to sell the asset if no payment is made due to full collateralization, but entails market risk if current/residual price is lower than spot price of asset.

Figure 3. Credit and Market Risks in *Salam* (Forward) Contracts

Source: authors.

In all exchange-based transactions, the bank incurs credit risk from nonperformance of the counterparty and/or asset impairment. Moreover, Islamic banks often carry on their balance sheets inventories of commodities and other physical assets, which pre-endow future sales-based transactions.³⁴ Consequently, market price deviations from the purchase price of the asset(s) that motivate the funding relation expose the bank to market risk in the form of potential losses (and also potential gains if the price of the asset(s) increases). This risk is often termed *commodity* or *inventory risk*, depending on the nature of the asset. Figures 1 to 3 illustrate the main features of both ordinary and special sales contracts and show the flows of assets and payments.

Equity-based instruments are equivalent to venture capital and project finance, which entail investment risks. In profit-sharing agreements (*musharakah* and *mudarabah*), the bank receives a payout in accordance with a pre-agreed disbursement ratio only if the investment project generates enough profit to repay the initial investment amount and the premium payment. Since the lender bears losses up to the total amount of investment (which determines the share capital),³⁵ equity-based contracts preclude any recourse in absence of enforceable collateral. Islamic banks may become exposed to two types of risks, depending on the accounting treatment of equity investment. If shares are held for trading purposes (that is, in the trading book of the bank) and marked-to-market, then their value is subject to the fluctuations in market price, which exposes the bank to *market risk*. Equity-based instruments held until maturity entail *equity position risk*, which is defined as the “risk arising from entering into a partnership for the purpose of undertaking or participating in a particular financing or general business activity” (IFSB, 2005a, p. 13).³⁶ According to the IFSB, the rating and the residual maturity of the specific investment position(s) determines the capital charges.

V. RISKS AND THEIR CAPITAL IMPACT WITHIN ISLAMIC BANKING

This section reviews the main risks associated with the balance sheet characteristics and financial products commonly found in Islamic banking activities. The strong asset linkage and “process-driven perspective” on profit generation have fundamental implications for the capital assessment of Islamic banks. This *entrepreneurial approach* underpinning many Islamic finance contracts and the high dependence on collateral also raises the search cost of financial intermediation and monitoring cost of counterparties (especially if repayment is

³⁴ For example, the bank may acquire and carry the asset on its balance sheet for a short period of time so that it can complete a *murabahah* contract by selling it again.

³⁵ Full loss-sharing occurs under *musharakah* contracts, whereas under *mudarabah* contracts, all losses are borne by the lender.

³⁶ Notice that this definition also applies to *sukuk* held for trading and “conventional equity” positions (that is, equity issued by firms whose operations and output follow conventional finance principles but would be eligible for investors that are bound by *shari’ah* principles). Thus, these positions are not necessarily open-ended, but can have a certain maturity date.

influenced by the access and valuation of commodity prices).³⁷ In addition, the state-contingent nature of payouts from financial transactions complicates the design and implementation of hedging strategies and investor/depositor protection schemes (especially in financial systems where conventional and *shari'ah*-compliant banking coexist).

Stress tests measure the capital impact of certain risk factors based on the sensitivity of various types of financial activities to negative shocks to economic and financial conditions. As with conventional banks, the most common risks affecting solvency conditions are *credit risk* (if a counterparty fails to perform its payment obligations), *market risk* (if market prices, for example, interest rates, foreign exchange, and stock prices, decline), and *operational risk* (see Figure 4).³⁸ However, the characteristics of these risk factors have different implications for Islamic banks across financial instruments, contractual agreements, and bank business models (IFSB, 2005b):

- *Credit risk* of asset performance in all exchange-based contracts (*murabahah*, *ijara*) in the financing/lending portfolio;
- *Market risk* of asset price fluctuations affecting the valuation of forward exchange-based contracts (*salam*, *istisna*, *bay bithaman ajil*), including inventory risk³⁹ in the investment/trading portfolio from significant commodities exposures and uncovered/parallel special sales contracts (parallel *salam*); and
- (*General*) *operational risk* if the failure of systems, internal procedures, and controls (as well as external events, such as natural disasters) lead to financial losses.

Islamic banks also face unique risks, which are particularly relevant for their business model:

- *Counterparty and project risks* from profit- and loss-sharing arrangements (*mudarabah*, *musharakah*) given the asset-based nature of contracts;
- *Indirect interest rate risk* due to competition for deposits in mixed banking systems;
- *Displaced commercial risk*, which implies a transfer of some shareholder value to unsecured depositors to fund reserves for smoothing profits from lending and investments (in case of lower-than-expected returns) and compensate for losses in excess of reserves; and⁴⁰

³⁷ For example, *murabahah* transactions are increasingly realized via the purchase and sale of agricultural commodities like cocoa, rice, cotton, and maize. However, in many countries, the market volume of transactions (and the resulting inventory) underlying these Islamic contracts outstrips the real demand, which exposes Islamic banks to considerable commodity price risk.

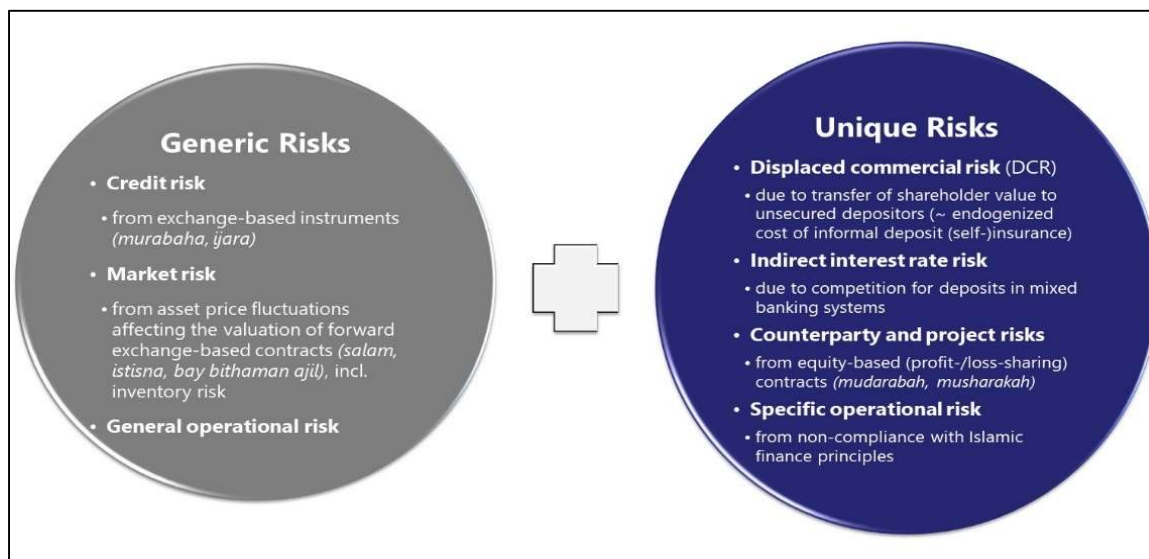
³⁸ See Greuning and Iqbal (2008) for a more detailed discussion of risk analysis in Islamic banking.

³⁹ The dependence on holding inventory of commodities as generic collateral for most financial transactions limits asset diversification.

⁴⁰ This is often referred to as rate of return risk (and indirect interest rate risk in mixed banking systems).

- *(Specific) operational risk* from either the non-compliance with Islamic finance principles or the non-recognition of *shari'ah*-compliant business activities and methods under conventional jurisprudence.

Figure 4. Generic and Unique Risks in Islamic Banking



Source: authors.

Given the limited access of Islamic banks to high-quality *shari'ah*-compliant funding over short-term horizons, any stress testing approach would need to be flexible enough to also incorporate the interaction of solvency and liquidity risks (through higher funding costs and/or deleveraging needs). Liquidity and solvency risks of individual institutions are increasingly connected during times of stress and tend to be influenced by system-wide liquidity conditions associated with the interconnectedness and network effects within the financial system. Current stress testing models either contain liquidity and solvency interactions and/or network modules to consider contagion and systemic risk from a cross-functional perspective (Jobst and others, 2017). Empirical evidence suggests that (i) the interaction between solvency and funding costs is indeed statistically significant; and (ii) it might be economically relevant, especially during periods of stress. Stress tests that do not account for the interaction between solvency and liquidity shocks substantially underestimate the risk exposure of individual banks and banking sectors (Puhr and Schmitz, 2014; Schmitz and others, 2017).⁴¹

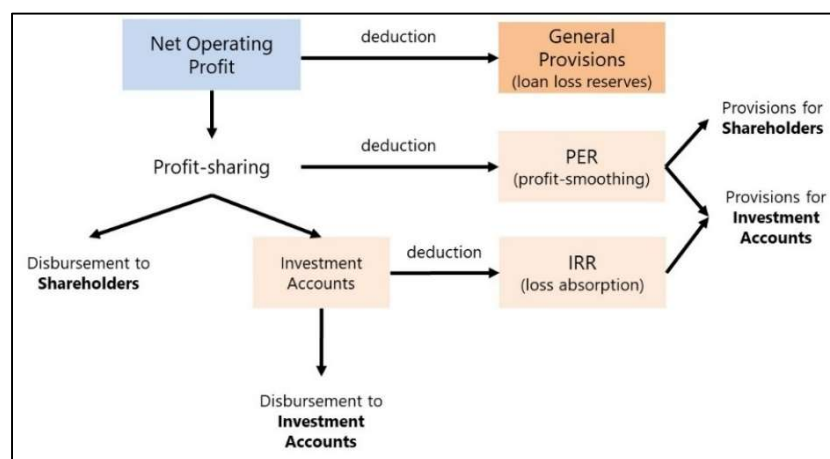
⁴¹ The liquidity stress testing work stream of the Basel Committee's *Research Task Force* (RTF) found that disregarding the interaction between funding costs and solvency can cause the impact of standalone liquidity or solvency stress tests to be underestimated by between 30 and 50 percent under standard adverse scenarios (BCBS, 2015).

A. Displaced Commercial Risk

Islamic banks endogenize the mutual cost of depositor protection through an informal and non-binding self-insurance scheme covering IA holders as unsecured creditors (investors) without (re)payment guarantees. IAs contractually bear all losses from projects (investments and lending), where the bank acts as agent or *mudarib* (مدرب),⁴² and, thus, can help mitigate losses. However, some Islamic banks with a large share of funding from IAs smooth the returns paid to depositors over time (and absorb some or all losses if necessary) due to competitive pressures.⁴³ Similarly, they might also consider absorbing liquidity risk from assets managed on behalf of IA holders, who can withdraw their funds before the contractual maturity (for instance, when investment projects yield lower-than-expected rates of return).⁴⁴ In both cases, shareholders may forgo part (or all) of their pre-agreed *mudarib* profit share to offset a profitability shock affecting IA holders' promised rate of return (as equity is subordinated to deposits) (Lukonga, 2015); this may affect a bank's capital position if some retained earnings are transferred to IA holders (see Box 1).

This mechanism is referred to as *displaced commercial risk* (DCR) and varies with the impact of investment and lending performance. DCR is not derived from Islamic finance principles but has evolved as common practice among Islamic banks to maintain stable funding in situations when adherence to the loss-sharing of IAs would suggest otherwise. However, in some countries, profit smoothing is not practiced (such as in the case of Malaysia), and, thus, DCR does not apply to any form of investment account (BNM, 2017).

Figure 5. Profit Equalization Reserve (PER) and Investment Risk Reserve (IRR)



Source: authors. Note: Depending on the country, these deductions are applied either before or after taxes.

⁴² Note that the loss-bearing capacity would be contractually limited to loss- and profit-sharing (*musharakah*) contracts.

⁴³ IAs also raise unique consumer protection issues because of inadequacies in disclosures and the asymmetric treatment of IAs as investors without shareholder rights (Lukonga, 2015).

⁴⁴ For example, consider the case of an Islamic bank that accepts IA deposits via *mudarabah* (profit-sharing) contracts and invests the funds in long-term *murabahah* and *ijara* contracts (ordinary sales with fixed return). However, the bank realizes returns that may be lower than what was anticipated when the initial investment was made. In this case, *mudarabah* investors might be inclined to withdraw their deposits.

In absence of depositor protection, DCR normally applies only to *unrestricted* IAs (UIAs) since *restricted* IAs (RIAs) are considered fully loss-absorbing (and tend to be treated as off-balance sheet items). DCR covers any *unexpected losses* that are not absorbed by UIA holders, and thus need to be fully capitalized (that is, the share of IAs assumed to be affected by DCR (consistent with the traditional concept of credit and market risk-weighting). Banks also establish two types of provisions from which to draw funds to smooth the rate of return paid to IA holders and compensate for any *expected losses*; even though these reserves are outside the concept of DCR, they have an operational impact on the quantification of DCR (see Figure 5):⁴⁵

- The *profit equalization reserve* (PER) is typically funded by the net income from *mudarabah* IAs. The bank (as agent or *mudarib*) is entitled to a pre-agreed fraction of profits from these equity-based contracts, so both IA holders and shareholders are beneficiaries of the PER. Islamic banks normally use PER to smooth the income of investors over time.⁴⁶
- The *investment risk reserve* (IRR) is solely attributable to IA holders and is funded by income after the deduction of the bank's share (that is, the *mudarib*'s share) and contribution to PER. Since the *mudarib* does not bear losses outside cases of negligence and/or misconduct, IRR is typically used to cover losses from investments financed with IAs.

⁴⁵ This way they reduce the probability of some shareholder value being transferred to IA holders during periods of underperformance. See also IFSB (2010) for a discussion on smoothing techniques for IA holders, which is complementary to the one presented in this paper.

⁴⁶ Existing IA holders hold no legal claim on either type of reserves. If an account is closed, the prorated amount of reserves becomes orphaned, and banks may donate them to charity. However, this practice requires high standards of corporate governance to ensure that the management and accumulation of these reserves is transparent.

Box 1. The Quantification of Displaced Commercial Risk

The cascading mechanism underpinning the creation of prudential reserves can also be expressed in terms of income flows and balance sheet identities of an Islamic bank. If the bank's liabilities consist only of equity, E , and unrestricted IA accounts, UIA, general loan loss provisions and PER (which are expressed as shares l and p , respectively) are retained from estimated annual net income, \tilde{r}_A (which is expressed as return from jointly funded total assets, A), so that the available return, $(1-p)(1-l)\tilde{r}_A$, for disbursement and profit-sharing between investors and shareholders

$$(1-p)(1-l)\tilde{r}_A \left\{ \begin{array}{l} \left(\frac{E}{A}\right)(1-p)(1-l)\tilde{r}_A \rightarrow PER \\ \left(\frac{UIA}{A}\right)(1-p)(1-l)\tilde{r}_A \left\{ \begin{array}{l} e\left(\frac{UIA}{A}\right)(1-p)(1-l)\tilde{r}_A \\ (1-e)\left(\frac{UIA}{A}\right)(1-p)(1-l)\tilde{r}_A \left\{ \begin{array}{l} i(1-e)\left(\frac{UIA}{A}\right)(1-p)(1-l)\tilde{r}_A \rightarrow IRR \\ (1-i)(1-e)\left(\frac{UIA}{A}\right)(1-p)(1-l)\tilde{r}_A \end{array} \right. \end{array} \right. \end{array} \right.$$

defines the amount of IRR, $i(1-e)(1-p)(1-l)\tilde{r}_A(UIA/A)$, which is retained by the Islamic bank before attributing income to UIAs, where UIA/A represents the share of profits allocated to UIAs, e is the bank's commission as *mudarib* for UIAs, and i is the proportion of returns appropriated to IRR. Capital is required to absorb *displaced commercial risk* (DCR) from unexpected losses (after accounting for reserves) when UIAs' returns are negative, $\tilde{r}_{UIA} = (1-i)(1-e)(UIA/A)(1-p)(1-l)\tilde{r}_A < 0$ and exhaust available (accumulated) reserves so that $\tilde{r}_{UIA}A > PER + IRR$.

We can determine the amount of capital required to cover unexpected losses by estimating the worst negative returns based on the historical cumulative distribution function of UIAs' returns, \tilde{r}_{UIA} , at a given level of statistical confidence, $a \in (0,1)$, over time horizon t (consistent with bank's prevailing solvency standards).¹ Let \tilde{r}_{UIA} be a sample of observations drawn from identically distributed, independent random variables $\{X_t; t = 1, 2, \dots, n\}$ following the stochastic process

$$\mathcal{F}(x) = \mu_{\tilde{r}_{UIA_t}} + z_t \sigma_{\tilde{r}_{UIA_t}} \quad z_t \sim iid(0,1), \quad (B1.1)$$

with conditional mean and standard deviation $\mu_{\tilde{r}_{UIA_t}} = E(\tilde{r}_{UIA})$ and $\sigma_{\tilde{r}_{UIA_t}}$, respectively, where $\sigma_{\tilde{r}_{UIA_t}}^2 = E(z_t^2 | \Omega_{t-1})$, and z has the conditional c.d.f. $G(z) = \Pr(z_t < z | \Omega_{t-1})$, based on the available information Ω_{t-1} at time $t-1$.

Thus, we can rewrite equation (B1.1) above as

$$VaR_{a,t} \equiv \inf(x_t | \mathcal{F}(x) \geq a) = \mu_{\tilde{r}_{UIA_t}} + \mathcal{N}(1-a) \sigma_{\tilde{r}_{UIA_t}}, \quad (B1.2)$$

which represents the point estimate of the $(1-a)$ -quantile of the probability distribution $\mathcal{F}(VaR_{a,t}) = \Pr[x_t > VaR_{a,t}] = 1-a$, where $\mathcal{F}(x) \sim \mathcal{N}[\mu_{\tilde{r}_{UIA_t}}, \sigma_{\tilde{r}_{UIA_t}}^2]$ converges to a normal distribution. The corresponding *conditional tail expectation* (CTE) (which represents a coherent risk measure of unexpected negative returns) with $\frac{1}{a} \int_0^{\infty} \mathcal{F}_t^-(x) dx = \frac{1}{1-a} \int_a^1 \mathcal{F}_t^{-1}(a) da$ is defined as

Box 1. The Quantification of Displaced Commercial Risk (continued)

$$CTE_{a,t} = \mathbb{E}[x_t | x_t \geq \mathcal{F}_t^{-1}(a) = VaR_{a,t}], \quad (B1.3)$$

based equation (B1.2), after accounting for available (accumulated) reserves, where

$$\begin{aligned} VaR_{a,t} &= -\sup \left\{ \mathcal{F}_t^{-1}(a) | \Pr \left[\left(\tilde{r}_{UIA} - \frac{PER + IRR}{A} \right) > 0 \right] \geq a \right\} \\ &= \mu_{\tilde{r}_{UIA}} + \mathcal{N}(1-a) \sigma_{\tilde{r}_{UIA}} + \frac{PER + IRR}{A}. \quad (B1.4) \end{aligned}$$

While the empirical diffusion process of returns might not necessarily converge to normality, this assumption makes it straightforward to derive point estimates of $CTE_{a,t}$ based on the equivalency between the z -scores $\phi(\Phi^{-1}(1-a))/(1-a)$ (for CTE) and $\Phi^{-1}(a)$ (for Value-at-Risk [VaR]), where $\phi(\cdot)$ and $\Phi^{-1}(\cdot)$ are the standard normal probability distribution and quantile functions.² Appendix II shows how to determine $CTE_{a,t}$ if the normality assumption is relaxed and the asymptotic tail properties are modeled using *extreme value theory* (EVT).

Multiplying the estimated value of $CTE_{a,t}$ with the amount of total assets, A , determines the unexpected losses absorbed by shareholders in the absence of any risk-sharing between the Islamic bank and UIA holders, which would imply perfect DCR (and a so-called α -parameter equal to one, which is explained in Section V). DCR declines by any amount of unexpected losses that are absorbed by UIA holders (net of provisions), so that $\alpha < 1$.

Note:

1/ We ignore cases where returns are either smoothed by PER or absorbed by IRR if they fall below a benchmark return rate but are still positive. See Toumi and others (2011) for a detailed analytical treatment of these cases.

2/ For instance, we can approximate CTE at the statistical confidence level $a = 99.7$ percent via VaR at $a = 99.9$ percent.

B. Credit Risk

Like their conventional peers, Islamic banks face credit risk from counterparties failing to meet their obligations in investment or lending contracts (IFSB, 2005b). Both types of asset-based contracts, ordinary sales/leases (*murabahah* and *ijara*) and special sales (*salam*, *istisna'a* and *bay bithaman ajil*), imply credit risk.⁴⁷ In ordinary sales/leases and special sales with deferred payment (*bay bithaman ajil*), the credit risk stems from the uncertainty about the timely and full repayment (which in the case of the latter is amplified by the lack of collateral due to delayed settlement). In special sales with deferred delivery (*salam* and *istisna'a*), credit risk arises from (i) the failure to deliver the specified commodities; (ii) the late delivery of the commodities; or even (iii) the defective delivery of the commodities.

⁴⁷ However, since these contracts are partially (or fully) collateralized, credit risk in Islamic finance contracts is mitigated by the collateral value after accounting for the *market liquidity risk*, which is the risk that it will not be able to sell an asset quickly (due to a deterioration of its liquidity value) without materially affecting its price.

While equity-based contracts (*mudarabah* and *musharakah*) held in the banking book expose the bank primarily to so-called *capital impairment risk*, some of these investments may also imply credit risk.

C. Market Risk

Islamic banks are especially exposed to market risk due to the prevalence of asset-based financial contracts and transactions. Market risk arises from adverse movements in asset prices that affect the valuation of on- and off-balance sheet exposures. These exposures from inventory can be particularly large for Islamic banks, which tend to hold considerable inventories of commodities to pre-endow future sales contracts or fund trading in active (secondary) markets for equity-based transactions. For instance, selling a *murabahah* or *salam* contract exposes the bank to the risk of a decline in the future market price of the underlying asset, which would reduce the expected rate of return. Islamic banks aim to mitigate market risk by minimizing inventories of commodities on their balance sheets, completing transactions swiftly (so as to avoid any lapse of time causing differences in contractual and market prices), and enlisting various hedging techniques. The expediency of execution, however, is often subject to external constraints, especially in less developed economies where it may take longer to conclude trades due to the lack of automation. Similarly, Islamic banks that are heavily engaged in financing agricultural activities could also be exposed to greater commodity and inventory risk, depending on the volatility of the price of the agricultural products involved.

Credit and market risks interact if an Islamic bank limits inventory risk from special sales. Engaging in multiple *salam* contracts exposes the bank not only to credit risk from the first *salam* contract but also to market risk from any offsetting *salam* contract. After agreeing to a *salam* contract on a particular commodity, an Islamic bank would enter into a second (parallel) *salam* contract to sell forward the commodity received under the first *salam* contract; this reduces the bank's net open position of a certain commodity and mitigates associated inventory risk. However, if the first *salam* contract fails, the bank would have to buy the commodity at the prevailing market price to meet its obligation under the parallel *salam* contract.⁴⁸ Since two *salam* contracts cannot be made contingent on each other, the bank cannot reduce the credit risk of the first contract by making the second agreement contingent on the fulfillment of the first. Thus, market risk amplifies potential losses from counterparty risk if the commodity price underlying the *salam* contract appreciates.⁴⁹

⁴⁸ Islamic banks undertaking the parallel *salam* transaction are exposed to credit risk in the event that the purchaser fails to pay for the commodity it had agreed to purchase from the Islamic bank. Nevertheless, in the event of non-delivery of the commodity by the seller under the initial *salam* contract, the Islamic bank is not discharged of its obligation to deliver the commodity to the purchaser under the parallel *salam* contract.

⁴⁹ Note that such market risk does not apply to parallel contracts on special sales with deferred payment (*bay bithaman ajil*) since commodities would have been delivered already. However, parallel *bay bithaman ajil* contracts, which involve a delayed payment by the bank to a third party and thus help them manage liquidity more efficiently, are also affected by additional credit risk. A depreciation of the asset price of the commodities increases the probability of non-payment, which could create additional funding needs at maturity.

Moreover, since the parallel *salam* does not offset the credit exposure stemming from the first *salam* (IFSB, 2005a), it does not represent a genuine hedge but purely as an asset-liability/cash flow management tool.⁵⁰

D. Operational Risk

The concept of operational risk generally relates to potential losses stemming from failed internal processes and systems as well as human error and fraud (including legal risk). For an Islamic bank, failure to comply with religious norms under *shari'ah* principles governing its activities (or to enforce *shari'ah* principles under secular courts) represents an additional legal risk, which falls within the classification of operational risk.⁵¹ Such legal risk could lead to the de-recognition of income and resultant losses. Even in jurisdictions with a conventional solvency regime, an Islamic bank would be statutorily entitled to compensate customers in cases when a particular transaction is deemed non-compliant with *shari'ah* principles. The bank may also decide to forgo some of its profits that are attributable to non-compliant activities (and reduce shareholder value). Typically, these profits are donated to charity.

VI. CAPITAL REQUIREMENT FOR ISLAMIC BANKS

The capital adequacy of Islamic banks is similar to that of conventional banks, but also accounts for the potential loss absorption by depositors. Unlike in conventional banking, the capital base of Islamic banks does not cover all unexpected losses, assuming that unsecured investors, such as IA holders, are not fully repaid if the bank becomes a gone concern. In keeping with the Basel Accord for conventional banks, the IFSB (2005a) introduced (and later refined; see IFSB [2012b]) the *Capital Standard for Islamic Financial Institutions*, which adjusts both the numerator (capital) and the denominator (risk-weighted assets) of the conventional capital adequacy ratio (CAR) to accommodate the business model of Islamic banks. This capital standard comprises a *Standard Formula* and a more elaborate *Supervisory Discretion Formula* (SDF), which differ from the capital standard defined in the Basel II/III framework for conventional banks (BCBS, 2010).

The *Standard Formula* does not explicitly recognize the potential the DCR banks face in practice (which can reduce capital), but all existing reserves are assumed to be available to absorb losses.

⁵⁰ See Jobst and Solé (2009 and 2012) for discussions on hedging possibilities within the context of Islamic finance.

⁵¹ For a detailed definition of operational risk in Islamic banking, see IFSB (2005a and 2005b).

Thus, capital adequacy ratio (CAR_{Std}) is defined as

$$CAR_{Std} = \frac{\overbrace{\text{total (book) equity}}^{\text{capital}} \{+ PER_{equity} + IRR_{RIA}\}}{OpRisk + RWA_{total} - (RWA_{RIA} + RWA_{UIA})}, \quad (1)$$

where the numerator defines the amount of eligible capital, $OpRisk$ is the capital charge for operational risk, RWA_{Total} stands for total RWAs (related to market and credit risks). The RWAs are reduced by the amount of RWAs funded by IAs (IFSB, 2013).⁵² However, operational risk losses are attributable to the bank, and thus need to be capitalized.⁵³ Eligible capital is defined as total equity, which might—in some circumstances—also include the shareholders' share of PER and (RIA's share of) IRR.⁵⁴ This definition of capital is similar to that of Tier 1 under the revised Basel Accord (BCBS, 2010), which includes disclosed reserves from after-tax retained earnings. The consideration of PER for Islamic banks is consistent with this approach (Graiss and Kulathunga, 2007).

The SDF adjusts the *Standard Formula* to account for the bank's voluntary loss absorption through DCR (beyond existing reserves), but also recognizes that *shari'ah*-compliant banking does *not* cover all investor-specific losses from investments/lending funded by UIA holders.⁵⁵ The UIA holders' share of reserves mitigating some of the DCR and any unexpected losses on investments financed by IAs (in the case of UIAs only beyond DCR) are subtracted from RWAs (IFSB, 2013; see Figure 6).⁵⁶ The eligible capital in the specification of CAR_{SDF} can also—in some circumstances—comprise the shareholders' share in the PER, PER_{equity} , and IRR attributable to IAs (after accounting for the degree of DCR affecting UIAs), IRR_{RIA} .

⁵² Where the funds are commingled, the RWAs are calculated based on their pro-rata share of the relevant assets funded by IAs, including PER and IRR, or equivalent reserves.

⁵³ Since these potential losses may be hard to measure in practice (Jobst, 2007a), the IFSB adopted the *Basic Indicator Approach* (BIA) of the Basel framework for regulatory treatment of operational risk. Under the BIA, the capital requirement for operational risk is equal to the average over the previous three years of a fixed percentage of positive annual gross income. The recommended percentage is 15 percent (IFSB, 2005a).

⁵⁴ The inclusion of reserves as part of eligible capital is not uniform across countries with substantial Islamic banking activity (and would exclude reserves to cover expected losses of UIA holders). For instance, in Bahrain, PER and IRR are included in regulatory capital as Tier 2 capital “up to a maximum amount equal to the capital charge pertaining to 30 [percent] of the risk[-]weighted assets financed by unrestricted investment account holders (Central Bank of Bahrain, 2008, Section CA-2.1).”

⁵⁵ For instance, in the case of Malaysia, the market and credit RWAs attributable to investment accounts are excluded from the capital requirement. In addition, these investment account holders are not protected by deposit insurance.

⁵⁶ Conversely, the application of DCR implies that affected IAs are explicitly excluded from the financial safety net (that is, deposit protection scheme) of the relevant jurisdiction.

Thus, the appropriate CAR is given by

$$CAR_{SDF} = \frac{\overbrace{\text{total (book) equity}}^{\text{capital}} \{+ PER_{equity} + IRR_{RIA} - \alpha(PER_{UIA} + IRR_{UIA})\}}{\underbrace{OpRisk + RWA_{total} - RWA_{RIA} - (1 - \alpha)RWA_{UIA} - \alpha \times RWA \text{ funded by reserves } (PER_{UIA} \text{ and } IRR_{UIA})}_{RWA_{PER,IRR}}}, \quad (2)$$

where $\alpha \in [0,1]$ signifies the estimated degree of DCR, that is, the amount of unexpected losses from UIAs, which need to be capitalized. In practice, the supervisory authorities have relative discretion in setting the value of α (see Table 2).⁵⁷ RWA_{RIA} and RWA_{UIA} are the RWAs funded by the two types of loss-bearing investment accounts (RIA and UIA).

Alternatively, when supervisory authorities have discretion in accounting for DCR and also for RIAs, the corresponding reserves would need to be made explicit in the capital adequacy formula by including PER_{RIA} and RWAs funded by PER_{RIA} . The deduction of RWAs would decline by αRWA_{RIA} and the diminished loss-absorbing impact of reserves on capital decreases by IRR_{RIA} and αPER_{RIA} , so that

$$CAR_{SDF} = \frac{\overbrace{\text{total (book) equity}}^{\text{capital}} \{+ PER_{equity} - \alpha(PER_{UIA} + PER_{RIA} + IRR_{UIA})\}}{\underbrace{OpRisk + RWA_{total} - RWA_{RIA} - (1 - \alpha)RWA_{UIA} - \alpha \times RWA \text{ funded by reserves } (PER_{UIA}, PER_{RIA}, \text{ and } IRR)}_{RWA_{PER,IRR}}}, \quad (3)$$

However, for the remainder of the paper, we disregard this augmented definition of capital in equations (1) and (2), so that

$$CAR_{SDF} = \frac{\overbrace{\text{total (book) equity}}^{\text{capital}}}{OpRisk + RWA_{total} - RWA_{RIA} - (1 - \alpha)RWA_{UIA} - \alpha RWA_{PER,IRR}}. \quad (4)$$

For illustrative purposes (see Figure 6), we retain the IRR available to smooth returns of UIAs for a given degree of DCR (see Box 1) so that

$$CAR_{SDF_{adj}} = \frac{\overbrace{\text{total (book) equity}}^{\text{capital}} - \alpha IRR_{UIA}}{OpRisk + RWA_{total} - RWA_{RIA} - (1 - \alpha)RWA_{UIA} - \alpha RWA_{PER,IRR}}. \quad (5)$$

⁵⁷ The IFSB (2011) issued a *Guidance Note* providing further details on how to calculate this parameter to encourage consistency in the cross-country treatment of reserves for capital adequacy purposes and used a parameter value of 30 percent as an example, which, for instance, has been chosen by the Central Bank of Bahrain (2008). See also Iqbal and Mirakhor (2006) for a discussion on the choice of the α -parameter.

The share $(1 - \alpha)$ of RWAs associated with UIAs, $(1 - \alpha)RWA_{UIA}$, is deemed unaffected by DCR (that is, it constitutes loss absorption by depositors), and, thus, is deducted from the denominator—just like RWA_{RIA} , which is often treated as an off-balance sheet item and need not be capitalized.^{58,59} Only the proportion of RWAs funded by reserves that cover expected losses incurred by UIAs, $(1 - \alpha)RWA_{PER,IRR}$, is relevant for the denominator in the calculation of capital adequacy.

Table 2. Displaced Commercial Risk—Current Regulatory Implementation and Industry Practice

(ordered by global share of Islamic banking assets)*

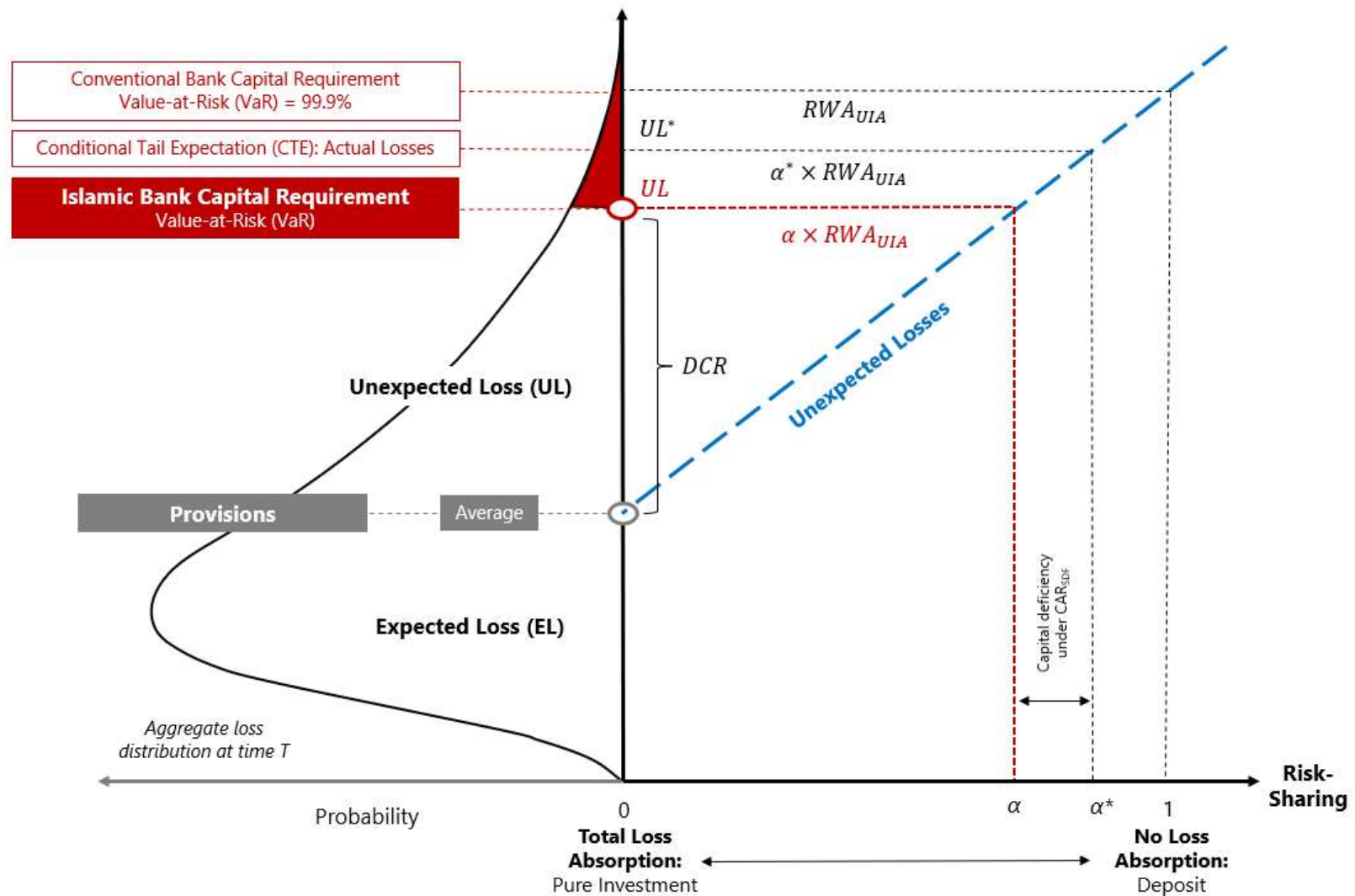
Country	Alpha-Value
Saudi-Arabia	1.00
UAE 1/	0.35
Malaysia	0.00
Kuwait	0.50
Qatar	0.35
Turkey	0.70
Indonesia	0.00
Bahrain	0.30
Sudan	0.50
Kazakhstan	0.35
<i>IFSB Example</i>	<i>0.30</i>

Sources: Adewale and Archer (2019), Farooq and Vivek (2012), IFSB (2011), and authors. Note: */ no data available for Iran and Bangladesh; 1/ Dubai.

⁵⁸ However, note that any *musharakah*-based RIAs imply profit- and loss-sharing, so a share of RIA also has a loss-absorptive capacity (which is generally not reflected in the capital assessment). For simplicity, we do not recognize this aspect of loss absorption in the denominator of CAR.

⁵⁹ So RWA_{total} includes αRWA_{UIA} and the $(1 - \alpha)$ share of RWAs funded by PER and the share of IRR available to cover UIAs, which are subject to DCR. Thus, αRWA_{UIA} represents the maximum value of DCR.

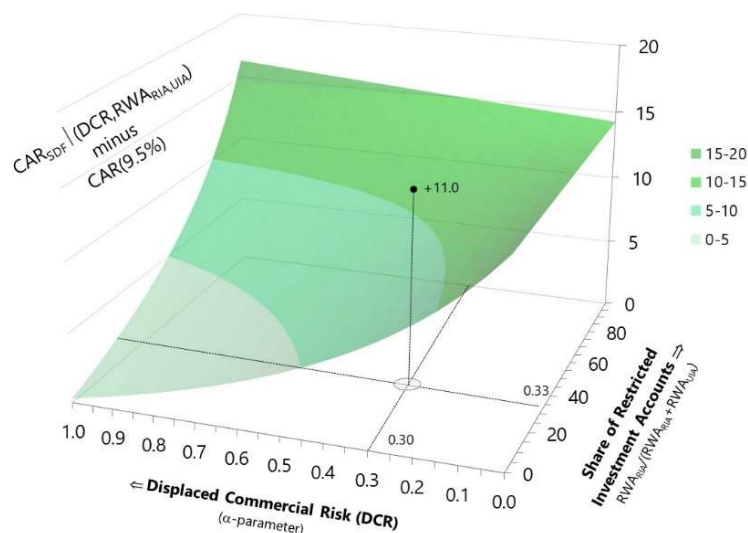
Figure 6. Loss Absorption of Unexpected Losses by Unrestricted Investment Accounts



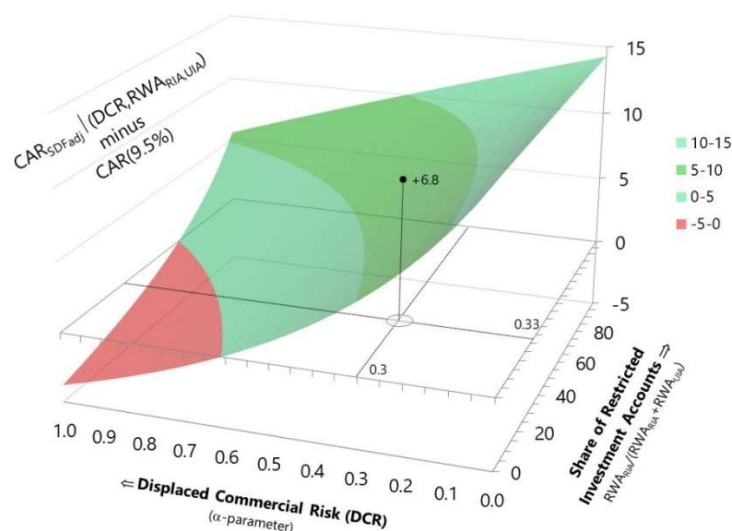
Source: authors.

Figure 7. Comparison of Conventional and Islamic Banking Capital Adequacy Formulae with Same Input Parameters
(in percent)

Deviation of CAR_{SDF} from $CAR=9.5$ percent (based on equation (4))



Deviation of CAR_{SDFadj} from $CAR=9.5$ percent (based on equation (5))



Source: authors. Note: The surface shows the difference between the conventional *capital adequacy ratio* (CAR) and the CAR using the *Supervisory Discretion Formula* (SDF) for Islamic banks, CAR_{SDF} (see equation (2) above), for the rising degree of DCR and share of investment accounts, so that $CAR_{SDF}|DCR, RWA_{UIA,RIA} - CAR$, where $CAR = 9.5\%$ represents the ratio of eligible capital and total risk-weighted assets (RWA), based on the assumptions and data in Appendix I, Table A2. The increase of reserves was implemented consistent with changes in the *alpha*-parameter, so that the numerator becomes *capital* $- \alpha IRR_{UIA}$ (without including other reserves, similar to the general specification of CAR_{SDF}). For a common assumption of DCR of 30 percent (see Table 2), $CAR_{SDF} = CAR + 6.8\%$ (all else being equal). For this illustration, equation (2) was amended to account for the accumulation of reserves in the form of IRR_{UIA} over time.

However, the predefined impact of DCR on loss absorption by UIAs in CAR_{SDF} entails conceptual challenges by commingling expected and unexpected losses. The loss-absorbing share of UIAs, $(1 - \alpha)RWA_{UIA}$, is contingent on the adequate provisioning for *expected losses* to UIAs through IRR_{UIA} and the capitalization of *unexpected losses* up to αRWA_{UIA} . If earmarked capital and reserves are insufficient to cover a higher-than-expected DCR, the lower loss absorption by UIAs would decrease CAR_{SDF} . Also, CAR is likely to decline (all else being equal) if the bank does not generate enough profits to allocate retained earnings to keep the assumed loss-absorbing share of UIAs unchanged (which is likely in an adverse situation).⁶⁰

Figure 7 compares the conventional and Islamic specification of CAR based on equations (3) and (4) using the stylized balance sheet data of an Islamic bank (see Appendix I, Table A2). The first chart shows that the capital adequacy of the Islamic bank is strictly higher under the adjusted specification of CAR due to the loss absorption by IA holders. Considering that reserves covering expected losses of UIAs are deducted from capital, CAR_{SDF} can drop below the conventional CAR if low loss absorption by IAs implies high DCR, and RWAs of Islamic banks converge to those under the conventional assessment of capital adequacy as the α -parameter increases.

Based on the analytical determination of DCR in the previous section (Section IV.A), we can evaluate whether a certain choice of the α -parameter is consistent with the actual investment risk faced by UIAs, assuming that the bank capitalizes most (but not all) unexpected losses that are not absorbed by the loss-sharing arrangement with UIAs. Given that the loss-absorbing share of RWAs funded by UIAs, $(1 - \alpha)RWA_{UIA}$, is subtracted from total RWAs in the denominator of CAR_{SDF} , an appropriate α -parameter for $\alpha RWA_{UIA} \leq UL$ would need to satisfy

$$\alpha^* \times \frac{UIA}{A} \times \underbrace{\frac{\overline{RW}_{total} \times A}{RWA_{total}}}_{RWA_{UIA}} = CTE_{a,t} \times UIA, \quad (6)$$

which simplifies to

$$\alpha^* = CTE_{a,t} / \overline{RW}_{total}, \quad (7)$$

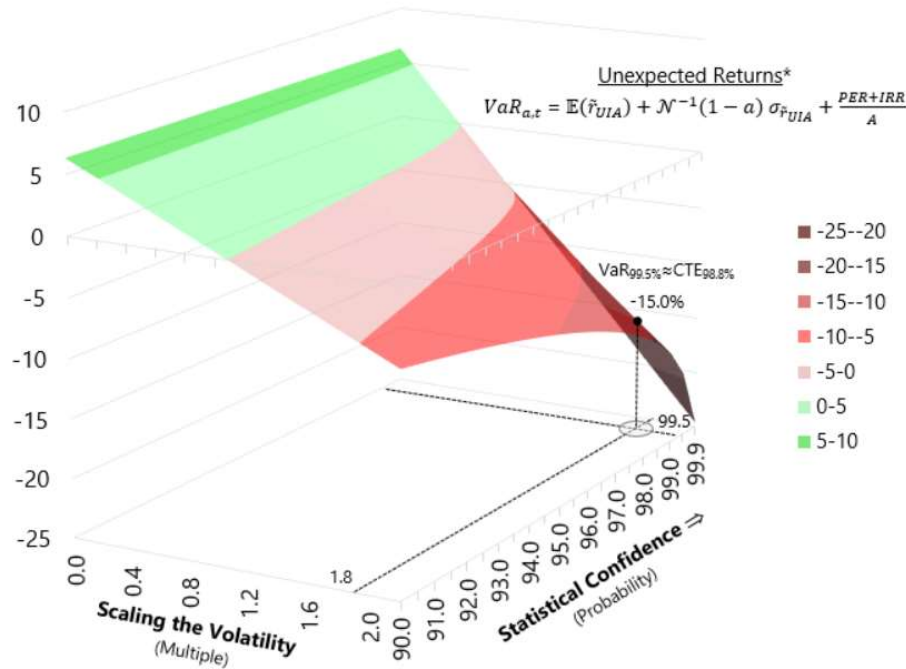
where the conditional tail expectation $CTE_{a,t}$ specifies the estimated share of UIA being lost with given level of statistical confidence, $a \in (0,1)$, over time horizon t (consistent with bank's prevailing solvency standards) (see Box 1), assuming that the average credit and market risk weights for assets funded by UIAs, $\overline{RW}_{UIA} = \overline{RW}_{total} = RWA_{total}/A$, is the

⁶⁰ In general, the consideration of loss absorption in the capital adequacy formula for Islamic banks would require that loss-absorbing IAs are excluded from deposit insurance and IA holders fully accept investment risks and are able to bear losses, which remains untested in practice.

same as the one for all other balance sheet assets, where $RWA_{total} = RWA_{credit} + RWA_{market}$.

The assumed DCR is not credible if the bank cannot absorb actual unexpected losses in addition to expected losses covered by available IRR. In case of $UL^* > UL$, unexpected losses are insufficiently capitalized (that is, the assumed capital relief from UIAs in equation (2) is too high since $\alpha^* > \alpha$,) and would require a transfer of shareholder wealth, $(\alpha^* - \alpha)RWA_{UIA}$, to compensate for higher-than-expected loss absorption by UIA holders; this also implies that the bank would need to remain profitable to fund such a transfer during times of stress.

Figure 8. Comparison of Conventional CAR and CAR_{SDF} (in percent)



Source: authors. Note: The surface shows the tail estimates of the mean-variance of the MSCI World Islamic Equity Index as a proxy for the unexpected investment returns of UIAs at different percentile levels, subject to the scaling of the volatility parameter. The index is transformed by taking the logarithmic differences of the closing daily price (in percentage) over a 10-year time period, $t = 10$, until end-2018 (with $\mu_{r_{A,t}} = 4.57\%$ and $\sigma_{r_{A,t}} = 3.34\%$), and the bank-specific assumptions $l = 0.03$ (for general loan loss reserves), $p = 0.022$ (for PER), $l = 0.03$ (for IRR), $e = 0.01$ (for bank's commission), $UIA/A = 0.4$, which are derived from Appendix I, Table A2.

We construct a simple practical example of this approach by using the historical return performance of the *MSCI World Islamic Equity Index*⁶¹ as a proxy for the investment returns of UIAs and the stylized balance sheet of an Islamic bank (see Appendix I, Table A2). The amount of unexpected loss is determined as a point estimate (see equation (B1.4) in Box 1)

⁶¹ For more information, see <https://www.msci.com/documents/10199/c0b90e16-5746-4cdc-b033-1ec7da64386e>.

for different levels of statistical confidence after accounting for the “cascading mechanism” of provisioning (PER and IRR) and the loss-mitigating effect of existing reserves. Figure 8 shows the sensitivity to $Var_{a,t}$ to the historical return volatility. Under these conditions, we find that that choice of $\alpha = 0.3$ would be insufficient since $CTE_{a,t} > \alpha \overline{RW}_{total} = 0.15$ if the historical volatility doubles to a level of statistical confidence close (but below) the prudential requirement (99.9 percent).⁶²

VII. STRESS TESTING ISLAMIC BANKS

This section provides an overview of the calibration of shocks to specific risk factors and their impact on the determination of capital adequacy of Islamic banks. In general, the capital assessment under stress should capture all material risks affecting all operations and provide a total view of capital adequacy—on an aggregated or individual basis—of legal entities and/or across groups. Compared to conventional banks, Islamic banks require a more nuanced treatment of risk factors given the specificities of risk exposures, the influence of *shari’ah* compliance on the transmission of shocks, and the impact of potential risk mitigation. Thus, this section identifies the characteristics of these risk factors and illustrates how properties of Islamic banking shape the way in which shocks can be integrated into a standard specification of risk factors underlying the capital assessment.

A. Scope of Risk Factors

Like their conventional peers, Islamic banks are vulnerable to three key transmission channels of negative shocks to their balance sheets, albeit with different implications for the profit and loss (P&L) statement and the assessment of capital adequacy:

- *Changes in pre-impairment income* from financing activities, including the capital impact of investment shortfall (which may entail DCR) due to lower-than-expected rates of return, indirect interest rate risk, and/or higher funding costs;
- *Changes in asset quality*, including valuation changes of traded securities (*mark-to-market* [MtM] and *available-for-sale* [AfS]), asset impairment charges (credit losses and other losses) of *held-to-maturity* (HtM) assets,⁶³ and operational risk losses; and

⁶² Since the volatility of returns tends to be higher after negative returns (Black, 1976) the asymmetric power ARCH (or APARCH) model defines the conditional volatility of returns as $\sigma_t^\delta = \alpha_0 + \alpha_1(|\varepsilon_{t-1}| - \gamma\varepsilon_{t-1})^\delta + \beta\sigma_{t-1}^\delta$, with $\alpha, \beta, \gamma > 0$ and $\alpha_0 \geq 0$, where $-1 < \gamma < 1$ captures the leverage effect, δ is the power, and $\varepsilon_t = \sigma_t z_t$ with z_t following a standard normal distribution.

⁶³ The exact category names may differ depending on the local accounting rules used in each jurisdiction. For instance, *International Financial Reporting Standard 9* (IFRS 9) of the *International Accounting Standards Board* (IASB) does not use this nomenclature. Roughly speaking, MtM corresponds to “held with a trading intent” (HfT), AfS corresponds to “fair value reported in other comprehensive income” (FVOCI), and HtM corresponds to “fair value through profit and loss” (FVPL) at amortized cost. However, U.S. GAAP continues using these categories (under Accounting Standard Codification [ASC] 320). In Islamic finance, AfS exposures are often called “available for lease” (AfL), which acknowledges their functional characteristics for exchange-based contracts.

- *Changes in risk intensity* resulting from higher unexpected losses (due to deteriorating asset quality) of defaultable assets and traded securities (that is, credit and market RWAs), mitigated by the positive impact of charge-offs and net lending and investment, and lower loss absorption by IAs (including changes in assumptions about DCR).

Stress tests would include (as a minimum) both credit and market risks affecting the capital adequacy of Islamic banks: (i) declining lending and investment income due to a negative shock to the realized rate of return (and indirect interest rate risk in mixed banking systems); (ii) rising impairments due to increasing credit and counterparty risks in the lending and investment portfolios; and (iii) adverse changes in asset prices affecting the valuation of exposures to market risk.⁶⁴ The impact of these risk factors is measured as the change of CAR_{SDF} according to equation (iv) under the impact of stress after accounting for net operating losses and the change in RWAs (which also affects assets funded by reserves), so that

$$\begin{aligned}
 CAR_{SDF_{stressed}} &= CAR_{SDF} \\
 &+ \frac{\text{net operating income} - \text{dividend payout}}{\text{retained earnings}} + \Delta RWA_{total} + \Delta OpRisk \\
 &= \frac{\text{capital} + \text{retained earnings}}{\left(\begin{array}{l} OpRisk + \Delta OpRisk \\ + RWA_{total} + \Delta RWA_{total} - (RWA_{RIA} + \Delta RWA_{RIA}) \\ -(1 - \alpha)(RWA_{UIA} + \Delta RWA_{UIA}) - \alpha(RWA_{PER,IRR} + \Delta RWA_{PER,IRR}) \end{array} \right)}, \quad (8)
 \end{aligned}$$

where the net operating income (after taxes) comprises the implied rate of return from financing activities and investment less (i) the net effect of asset impairments and valuation losses (that is, credit and market risks); and (ii) the impact of changes in the rates of return and funding costs (including forgone return from impaired assets). The change of RWAs, ΔRWA_{total} , reflects the net change in unexpected losses from higher market and credit risks due to the deteriorating asset quality, after accounting for the substitution effect between higher RWAs of existing impaired assets and lower RWAs of new assets (unless renewals are excluded from the stress test). Operational risk losses reduce net operating income, but primarily change the capitalization of operational risk in the denominator.

These risk transmission channels of shocks from credit and market risks, as well as changes

⁶⁴ Operational risk losses are inherently difficult to model within the context of changing macrofinancial conditions and would require a specific calibration. In most cases, operational risk losses are held constant (unless some cyclical aspects of operational risk exposure, such as internal and external fraud, are considered in more detail).

in profitability, can be modeled via so-called “satellite models” or expert judgment.⁶⁵

Satellite models define the historical sensitivity of bank performance to changes in macrofinancial conditions and commonly include a lagged term, GDP growth, rates of return, cost of capital, other macroeconomic variables, and firm-specific variables, such as leverage, loan-to-asset ratio, and the funding gap. Most satellite models are focused on changes in credit and market risks. Other risk factors, such as operational risk, require more qualitative approaches (and a discrete specification of the severity of shocks) due to a lack of sufficient empirical observations and/or difficulties estimating consistent macrofinancial scenarios. The results of stress tests and the interpretation of associated findings are heavily influenced by the scope and calibration of macrofinancial linkages and the assessment of vulnerabilities to these risks but depend on data availability/granularity.

The following section focuses on the practical implementation of these risk factors, with each considered a single-factor shock over a single time period (without the loss mitigation of net operating profits from investments and lending).

B. Displaced Commercial Risk

Analogous to the net interest income of conventional banks, the implied rate of return from lending and investments is the main determinant of the profitability of Islamic banks. However, the impact of changes in the rate of return on capital adequacy depends on the scope for DCR (that is, the extent to which reserves can be released to cover claims from investment deposits if realized profits fall below expectations and overall profitability of investments generate losses that exhaust provisions).

Three possible stress scenarios illustrate how shocks to the rate of return influence the scope for DCR:

- *Shock to asset returns.* Suppose that the bank’s rate of return from investment/lending drops below the (non-guaranteed)⁶⁶ targeted profit rate offered to depositors (that is, the realized rate of return is lower than the expected rate of return). Islamic banks have a few options available to mitigate the effect of investment shortfall on the stability of the deposit base. While this investment shortfall should be passed on to IA holders in principle, they are fully (or partially) covered by provisions (PER and IRR); if they

⁶⁵ Satellite models are essential to the stress testing framework, which includes (i) the object of analysis (structural conditions, regulatory situation); (ii) the determination of coverage (single entity or consolidated reporting); (iii) the development of a methodological framework (and analysis of data quality); (iv) considerations regarding the accounting standard and the treatment of capital resources; (v) the design of stress scenarios (single period versus multiple period, aggregate versus joint effects (after considering diversification); (vi) the definition of output measures; (vii) the validation of results; and (viii) dealing with the outcome of the stress test (Jobst and others, 2013).

⁶⁶ Financial guarantees are considered *shari’ah* compliant only if they are directly related to the funding for the completion of a service or the production of a good.

exceed provisions, shareholders tend to absorb part of this shortfall by accepting DCR to maintain the deposit base (“total accounts”). Therefore, the shortfall is given by

$$\text{investment shortfall} = (\text{actual return} - \text{exp.return}_{IA}) \times \text{total accounts}_{IA}. \quad (9)$$

- *Shock to availability of funding.* Suppose that the bank’s lending and investments generate the expected rate of return but competitors offer higher returns, which threaten to erode the bank’s deposit base. If the bank is unable to increase the returns offered to its existing IA holders, it faces the risk of depositors withdrawing their funds, so that

$$\text{investment shortfall} = \left(\frac{\text{total accounts}_{IA}}{-\text{exp.total accounts}_{IA}} \right) \times \text{actual return}_{IA}. \quad (10)$$

- *Shock to asset returns and funding.* Suppose that there is a decline in the amount of funds available in the economy—that is, a generalized tightening in liquidity conditions, which reduces the amount of cash that depositors are willing to place in IAs and increases the rate of return demanded by depositors.⁶⁷ The net effect is the deterioration of investment performance due to an increasing funding cost. The shortfall is now given by

$$\text{investment shortfall} = \left(\frac{\text{actual return}_{IA}}{-\text{revised exp.return}_{IA}} \right) \times \left(\frac{\text{exp.total accounts}_{IA}}{-\text{total accounts}_{IA}} \right). \quad (11)$$

Once the amount of investment shortfall is known, the effect on CAR after considering retained earnings can be computed as⁶⁸

$$CAR_{DCR} = \frac{\text{capital} + \left(\frac{\text{retained earnings}}{-\text{investment shortfall} (1 - \text{share covered by } PER_{equity})} \right)}{\left(\frac{\text{OpRisk} + RWA_{total} - RWA_{RIA} - (1 - \alpha)RWA_{UIA}}{-\alpha (\max(RWA_{PER,IRR} - RWA_{PER,IRR \text{ covering investment shortfall}}, 0))} \right)}, \quad (12)$$

which might involve a reduction of capital if the investment shortfall exceeds available provisions, PER_{UIA} and IRR , so that

$$RWA_{PER,IRR} - RWA_{PER,IRR \text{ covering investment shortfall}} < 0. \quad (13)$$

PER is shared between both shareholders and depositors, whereas IRR can only be used for distributions to depositors. In practice, shareholders may decide to release some of PER_{equity} . If all reserves are exhausted, any transfer of shareholder value would diminish also retained earnings if $(\alpha^* - \alpha)RWA_{UIA}$ so that

⁶⁷ This scenario can also be interpreted as a liquidity risk shock.

⁶⁸ Note that specification of retained earnings in equation (8) excludes any investment shortfall that exceeds reserves. Instead, such net investment shortfall is shown separately for illustrative purposes.

$$\begin{aligned}
& \text{investment shortfall covered by } PER_{equity} \\
& = \max \left(\frac{\text{investment shortfall} - \text{investment shortfall covered by } PER_{UIA} \text{ and } IRR}{0}, 0 \right). \quad (14)
\end{aligned}$$

C. Indirect Interest Rate Risk

Additional risks could arise from changes in general interest rates if Islamic banks operate in a mixed financial system (that is, where conventional and Islamic financial service providers operate alongside each other). Islamic banks that choose to benchmark the return on their IAs to the deposit rate offered by conventional banks incur *indirect interest rate risk*.⁶⁹ A tightening of monetary conditions and the attendant increase of prevailing (maturity-matched) interest rates (by conventional banks) could result in Islamic banks losing some of their deposits to conventional banks unless the expected return from investment matches the higher market rate. The economic effect of this scenario would be similar to that of DCR due to a shock to an Islamic bank's rate of return from investment/lending, so that

$$\text{interest rate gap} = \left(-\eta \times \frac{\text{exp. return}_{IA}}{\text{market interest rate}} \right) \times \text{total accounts}_{IA}, \quad (15)$$

whose magnitude is influenced by the degree of pass-through, η , from general interest rates to the expected returns of IAs.

If realized profits fall below expectations, Islamic banks would have to offer a higher rate of return (or raise the profit-sharing ratio) on IAs above the (non-guaranteed) targeted return by releasing reserves to maintain their deposit base. If both PER_{UIA} and IRR are not sufficient to finance the “interest rate gap” to conventional banks, shareholders may decide to release some of PER_{equity} (as in equation (14) above for investment losses). Since some IA holders may be insensitive to (small) changes in the rate of return, the elasticity of deposits is captured by the fraction ϕ of IAs that would need to be compensated by the existing reserves and/or lower dividend payouts to shareholders.⁷⁰ Thus, the interest rate gap can be expressed as

⁶⁹ Note that indirect interest rate risk refers to an *ex post* adjustment to a pre-defined rate of return and does not imply that Islamic banks are generally unable to adjust profit rates; in fact, in countries with a mixed financial system, such as Malaysia, where exchange-based funding liabilities, such as reverse *murabahah* contracts, have evolved into the dominant form of deposit funding, Islamic banks adjust their profit rate by offering new fixed deposit with a different profit rate in response to changes in monetary policy, just like their conventional peers (see Table 1).

⁷⁰ Estimating the effect of changes in conventional banks' interest rates on the depositors' base of Islamic banks is an important but underexplored research area for which longer time series than currently available are needed.

$$\text{interest rate gap} = \left(\frac{\text{exp.return}_{IA}}{-\eta \times \text{market interest rate}} \right) \times \phi \times \text{total accounts}_{IA}, \quad (16)$$

whose effect on CAR can be written as⁷¹

$$CAR_{IRR} = \frac{\text{capital} + \left(\frac{\text{retained earnings}}{-\text{interest rate gap} (1 - \text{share covered by PER}_{equity})} \right)}{\left(\frac{\text{OpRisk} + RWA_{total} - RWA_{RIA} - (1 - \alpha)RWA_{UIA}}{-\alpha \left(\max(RWA_{PER,IRR} - RWA_{PER,IRR} \text{ covering interest rate gap}, 0) \right)} \right)}, \quad (17)$$

where

$$\begin{aligned} & \text{interest rate gap covered by PER}_{equity} \\ &= \max \left(\frac{\text{interest rate gap} - \text{interest rate gap covered by PER}_{UIA} \text{ and IRR}, 0 \right). \end{aligned} \quad (18)$$

D. Credit Risk

Credit risk represents a key component of the capital assessment of Islamic banks under stress and can be specified in a way similar to that of conventional banking. Credit risk shocks affect the valuation of exchange-based contracts in the financing and lending portfolio (that is, ordinary sales [*murabahah*], special sales [*salam*, *istisna'a*, *bay bithaman aji*], and leases [*ijara*]) as well as investment exposures in the banking book (that is, direct equity exposures, investment certificates [*sukuk*], and profit- and loss-sharing contracts [*mudarabah*, *musharakah*]). Some shocks that are typically considered in stress tests are:

- a broad-based deterioration of economic conditions affecting multiple sectors,⁷² resulting in a general increase of *nonperforming asset* (NPA) balances and charge-offs;
- a negative shock to a specific economic sector affecting the asset quality of all relevant exposures; and

⁷¹ The specification of retained earnings in equation (12) excludes the interest rate gap that is not absorbed by reserves on the calculation of net operating profits after taxes and dividend payouts. Instead, the interest rate gap is shown separately for illustrative purposes.

⁷² Credit losses are typically forecast based on separate models for write-downs and write-ups specific to each sector (corporate, retail, public, and financial institutions) or even more granularly, each portfolio under these sector headings. A simpler approach could also be applied by computing net losses.

- *deterioration of already existing NPAs* by one or more “notches” in the distribution across subcategories (substandard, doubtful, and delinquent).⁷³

The first two shocks result in additional credit losses but also increase the level of *unexpected losses* (above the level of provisioned asset impairment reflected in pre-shock NPAs), which increase the estimates of RWAs. In contrast, the last shock would not increase credit losses but raise the level of required provisions due to higher *expected losses* overall. The credit risk-related losses from both lending and investment activities can be expressed as

$$\text{credit risk loss} = \Delta NPA - \text{specific provisions} + \text{foregone returns}, \quad (19)$$

which reflects the amount of asset impairments ΔNPA (net of any specific provisions for *expected losses*)⁷⁴ and the forgone return from impaired lending (due to termination, default, or arrears)⁷⁵. Higher *unexpected losses* due to deteriorating asset quality can be specified as⁷⁶

$$\begin{aligned} \Delta RWA_{\text{credit}} = & \Delta RWA_{\text{credit}_{\Delta PD}} + \Delta RWA_{\text{credit}_{\Delta \text{concentration}}} \\ & - RWA_{\text{charge-off}} - RWA_{\Delta \text{credit}}, \end{aligned} \quad (20)$$

due to a higher probability of default (PD), $\Delta RWA_{\text{credit}_{\Delta PD}}$, the change in portfolio concentration, $f(\Delta \text{Concentration}_{\text{portfolio}})$, the impact of charge-offs, $RWA_{\text{charge-off}}$, and the net change of the RWAs of credit-related exposures, $RWA_{\Delta \text{credit}}$, which captures the *substitution effect* between higher RWAs of impaired assets and lower RWAs of new investment/lending (assuming that renewals are included in the stress test in a non-static credit portfolio). However, recent developments in stress testing following the

⁷³ Credit risk shocks affecting the valuation of financial market instruments tend to be implemented via a rating class-specific widening of credit spreads based on historical calibration. These shocks assume an increase in default risk but not a general change in the rate of return impacting the valuation of all investments.

⁷⁴ The specific provisioning under IFRS 9 is based on accounting rules (“credit risk approach”) using (forward-looking) estimates of the probability of default (PD) and loss-given-default (LGD) to calculate expected losses on the book value (that is, historical [amortized] cost) of the exposure. Under the previous accounting standard (IAS 39), backward-looking PD and LGD were used to calculate incurred losses as a measure of expected losses. The credit risk parameters (PD and LGD) for the calculation of regulatory capital requirements could differ from those applied in statutory reporting (that is, financial statements) based on prevailing accounting standards.

⁷⁵ The amount of specific provisions should not include accrued returns on missed payments (unlike conventional banks’ reporting under IFRS, which allows accrual of interest income on NPAs). Accrual accounting assumes that income is recorded in the period earned rather than in the period of the cash flow; however, interest accruals can distort financial reporting due to the following issues: (i) lending income is recorded even though the borrower does not repay; (ii) NPAs increase from the accrual at the rate of uncollected repayment; and (iii) provision coverage loses meaning since there is a matching provision to accrued returns.

⁷⁶ This equation can be further refined based on the changes in the “automatic” collateralization of many *shari’ah*-compliant contracts due to the requirement of direct investor claims to the profit-generating asset/capital.

implementation of the IFRS 9 impairment model suggest a greater focus on modeling credit risk losses using an accounting approach,⁷⁷ which has also shifted the estimation of unexpected losses toward standardized approaches. Thus, equation (20) can be simplified to

$$\Delta RWA_{credit} = -RWA_{charge-offs} - RWA_{\Delta credit}, \quad (21)$$

where the RWAs of defaulted exposures, $RWA_{charge-off}$, reduce the total RWA_{credit} , which can be approximated by taking 2.5 times the average RWAs for non-defaulted exposures (accounting for the fact that risk-weights for defaulted exposures were higher prior to default). Appendix V provides a detailed specification of the nonlinear effect of changes in PDs and the impact of concentration risk on RWAs for a more comprehensive implementation of credit risk (consistent with economic capital approaches).

Implementing the above formula in an Islamic banking context is complicated by the loss absorption of IA holders, which reduces the impact of credit risk shocks on both the level of capital (through net operating income) and unexpected losses (in the form of RWAs). Since IA holders absorb some losses associated with higher credit risk under stress, the CAR formula can be written as

$$CAR_{credit} = \frac{\left(\begin{array}{c} \text{capital + retained earnings} \\ - \text{credit risk loss} \times \underbrace{\left(\frac{\bar{RWA}_{UIA} + \bar{RWA}_{RIA}}{\bar{RWA}_{total}} \right)}_{\text{share of loss borne by UIA and RIA}} \end{array} \right)}{\left(\begin{array}{c} OpRisk + \bar{RWA}_{total} - \bar{RWA}_{RIA} - (1 - \alpha)\bar{RWA}_{UIA} - \alpha\bar{RWA}_{PER,IRR} \\ + \Delta RWA_{credit} \times \underbrace{\left(\frac{\bar{RWA}_{UIA} + \bar{RWA}_{RIA}}{\bar{RWA}_{total}} \right)}_{\text{share of loss borne by UIA and RIA}} \end{array} \right)}, \quad (22)$$

assuming that all IAs (UIA and RIA) absorb credit risk-related losses in proportion to their share of total RWAs, with updated \bar{RWA}_{total} consistent with ΔRWA_{credit} , and corresponding changes in loss absorption and associated provisioning is $\bar{RWA}_{RIA} = RWA_{RIA} + \Delta RWA_{RIA}$, $\bar{RWA}_{UIA} = RWA_{UIA} + \Delta RWA_{UIA}$, and $\bar{RWA}_{PER,IRR} = RWA_{PER,IRR} + \Delta RWA_{PER,IRR}$.⁷⁸ However, the attribution of losses according to equation (20) would further depend on whether losses stem from assets funded by either UIAs or RIAs (which is ignored in this expression). If data constraints limit a sufficiently detailed analysis of loss absorption by IA holders, the conservative implementation of credit risk under stress would result in

⁷⁷ Stress testing of expected losses from credit risk that are in line with current accounting approaches are explained in Gross and others (IMF, *forthcoming*).

⁷⁸ Note that this expression could be refined by conditioning the marginal increase of RWAs for credit risk on share of RWAs for credit risk (not total RWAs) funded by investment accounts (RIA and UIA).

$$CAR_{credit} = \frac{\text{capital} + \text{retained earnings} - \text{credit risk loss}}{\left(OpRisk + \overline{RWA}_{total} - \overline{RWA}_{RIA} - (1 - \alpha)\overline{RWA}_{UIA} \right.} \quad (23)$$

$$\left. - \alpha\overline{RWA}_{PER,IRR} + \Delta RWA_{credit} \right)$$

which ignores the loss absorption by IAs, so that $\frac{\overline{RWA}_{UIA} + \overline{RWA}_{RIA}}{\overline{RWA}_{total}} \rightarrow 0$, and overstates the effective capital impact of credit risk-related losses.⁷⁹

Special sales (with delayed settlement) may involve additional credit risk. The counterparty risk of a bank increases if the asset price of a commodity (“collateral asset”) supporting a sales contract with deferred delivery (*salam* or *istisna’a*) increases until the maturity date of the contract; this applies conversely to asset price declines if the borrower’s payment to the bank is deferred (*bay bithaman ajil*). In the case of the former, for example, a negative supply shock to the agricultural sector (that is, output declines due to a drought or some other natural disaster) would increase the market price for agricultural goods if demand remained unchanged. In this situation, an agricultural *salam* contract (see Figure 2) would expose the bank to higher counterparty risk since the value of the to-be-delivered commodity (as the collateral asset) is likely to exceed the amount owed by the borrower in present value (PV) terms. The credit loss arises when the borrower fails to deliver the commodity or delivers a smaller amount than agreed in the *salam* contract *ex ante*. In a *bay bithaman ajil* contract, the depreciation of the collateral asset increases the borrower’s cost of repayment, resulting in a higher probability of default.

The credit risk losses from the borrower’s early determination or failure to fully repay a *salam* contract can be quantified as the *ex post* difference between the contractual and actual value of the commodity plus any forgone rate of return (if default occurs prior to the contractual maturity/delivery date).

$$\begin{aligned} & \text{credit risk loss}_{\text{special sales}_{\text{delayed delivery}}} = \\ & (1 + \text{foregone return})(PV(\text{collateral asset}) \\ & \quad - \text{spot value}(\text{payment of asset})), \end{aligned} \quad (24)$$

where the discount factor to derive the PV of the collateral assets, $PV(\text{collateral asset})$, represents the “implied return” of the bank.

Conversely, for a contract with deferred payment (*bay bithaman ajil*), the depreciation of the collateral asset would have the same effect, so that

⁷⁹ Therefore, the resulting impact on capital adequacy provides a lower bound (or a worst-case impact) for this particular shock.

$$\begin{aligned}
& \text{credit risk loss}_{\text{special sales delayed payment}} \\
&= (1 + \text{foregone return})(PV(\text{asset repayment}) \\
&\quad - \text{spot value}(\text{delivered asset})). \quad (25)
\end{aligned}$$

Combining both equations above for all exposures to special sales results in the net amount of credit risk-related losses under the assumption that the valuation of some contracts is influenced by the same change in asset prices so that

$$\begin{aligned}
& \text{credit risk loss}_{\text{special sales}} \\
&= \text{credit risk loss}_{\text{special sales delayed delivery}} \\
&\quad + \text{credit risk loss}_{\text{special sales delayed payment}}. \quad (26)
\end{aligned}$$

Thus, equation (23) can be augmented by equation (26) so that

$$CAR_{\text{credit}} = \frac{\left(\begin{array}{c} \text{capital} + \text{retained earnings} \\ - \text{credit risk loss} - \text{credit risk loss}_{\text{special sales}} \end{array} \right)}{\left(\begin{array}{c} OpRisk + \overline{RWA}_{\text{total}} - \overline{RWA}_{RIA} - (1 - \alpha)\overline{RWA}_{UIA} \\ - \alpha\overline{RWA}_{PER,IRR} + \Delta RWA_{\text{credit}} \end{array} \right)}. \quad (27)$$

E. Market Risk

Given the asset-based nature of Islamic banking, market risk (“inventory risk”) arises chiefly from price changes of net open positions of inventory. Islamic banks hold certain assets (for example, real estate or commodities) as collateral to different forms of exchange-based contracts, such as *murabahah*, *salam*, and *ijara* (see Table 1), which are recorded at fair value as *available-for-lease* (AfL).⁸⁰ The expected losses from these lending and investment activities are “bi-dimensional,” that is, they are defined by the probability of shortfall between the value of collateral and the total counterparty exposure. Thus, the risk that the value of the inventory owned by the bank diminishes and/or experiences greater price volatility is closely related to credit risk. If the market price declines, the bank would be forced to charge a lower sales price or adjust the lease value, unless it is willing to accept a lower degree of collateralization. Then the market-related loss is given by

$$\begin{aligned}
& \text{market risk loss}_{\text{ordinary sales}} = \\
& (1 + \text{foregone return})(\text{inventory}_{\text{nominal value}} - \text{inventory}_{\text{market value}}). \quad (28)
\end{aligned}$$

Market risk losses can also arise from the decline in the market values of profit- and loss-sharing investments held in the trading book, *market risk loss*_{trading}, such as investment

⁸⁰ This excludes equity-based transactions (*musharakah/mudarabah*), which do not involve any form of collateralization by definition.

certificates (*sukuk*), *Islamic collective investment schemes* (ICIS), and equity securities. If the change in market risk is associated with a change in price volatility, it will affect the risk-weighting of inventory assets held in the trading book, ΔRWA_{market} . Moreover, market risk exposures may involve some foreign exchange (FX) risk, which requires a different methodological treatment than in the context of conventional banking.⁸¹ There are two important differences between Islamic and conventional FX transactions: (i) under the rules of *sarf*, which govern currency exchanges consistent with Islamic finance principles, gold and silver are treated as foreign currency (and not as commodities); and (ii) the permissible use of currency derivatives in Islamic finance is restricted (Jobst, 2009; Jobst and Solé, 2012).

Special sales (see Table 1) may result in additional market risk if they occur together with a reverse transaction. Islamic banks typically take offsetting short positions through *parallel* special sales to minimize the carry cost of holding inventory as collateral (such as commodities) for contracts with deferred delivery (*salam* or *istisna'a*). In the case of a *parallel salam*, the bank receives a certain amount of cash from a third party and delivers the collateral asset upon maturity, which coincides with the delayed receipt of the collateral asset from the original sale (see Figure 3). The market risk of a *parallel salam* contract arises if the collateral asset appreciates. The bank would lose

$$\text{market risk loss}_{\text{special sales}} = FV(\text{collateral asset}_{\text{spot value}}) - \text{collateral asset}_{\text{market value}} \quad (29)$$

if the market value of the collateral asset to be delivered to the counterparty of the *parallel salam* at maturity is *higher* than the future value (FV) of the spot payment for the collateral assets the bank is due to receive under the initial *salam* contract.⁸²

Similar to the consideration of unexpected losses from credit risk, price volatility and/or changes in the composition of listed exposures (sales and profit- and loss-sharing contracts) in the trading and investment portfolios change the amount of unexpected losses from market risk (see Table 1), which is specified as

$$\Delta RWA_{market} = \underbrace{f(\Delta VaR_{portfolio})}_{\Delta RWA_{market \Delta price}} - RWA_{\Delta market}, \quad (30)$$

⁸¹ See Blaschke and others (2001) and Čihák (2007) for a detailed explanation of how to approach foreign exchange risks. See also IFSB (2005a).

⁸² This dimension of market risk is an important consideration when modeling shocks to the credit risk of special sales and establishes an important link between credit and market risk. In fact, the capital standard for Islamic banks distinguishes between single *salam* contracts and *salam* contracts with *parallel salam* contracts in setting risk weights (IFSB, 2005a).

where $f(\Delta VaR_{portfolio})$ reflects the change in the VaR and $RWA_{\Delta market}$ represents the net change in portfolio allocation affecting RWAs, based on investment and trading behavior under stress. Since most stress tests focus on standardized approaches (assuming that higher price volatility is associated with a decline in credit quality), the expression above simplifies to $\Delta RWA_{market} = -RWA_{\Delta mar}$, while the impact of valuation changes on the capital intensity is determined by predefined changes in risk weights. Appendix V explains how equation (30) can be derived based on an economic valuation approach.

Islamic banks absorb market risk losses through net operating income or, in the case of insufficiency, in its common equity. So the CAR after a shock to market risk from ordinary and parallel special sales, as well as assets in the trading portfolio, would be

$$CAR_{market} = \frac{\begin{pmatrix} \text{capital} + \text{retained earnings} \\ - \text{market risk loss}_{ordinary sales} \\ - \text{market risk loss}_{special sales} \\ - \text{market risk loss}_{trading} \end{pmatrix}}{\begin{pmatrix} OpRisk + \widetilde{RWA}_{total} - \widetilde{RWA}_{RIA} - (1 - \alpha)\widetilde{RWA}_{UIA} \\ - \alpha\widetilde{RWA}_{PER,IRR} + \Delta RWA_{market} \end{pmatrix}}, \quad (31)$$

with updated \widetilde{RWA}_{total} consistent with ΔRWA_{market} . The scope of impact can also be made conditional on the source of funding. One could assume that the total amount of *sukuk* and the ICIS portfolio were exclusively funded by UIAs (IFSB, 2015); alternatively, in the case of commingling with other sources of funding for these investments, the respective shares would need to be taken into account. The impact on the net income of Islamic banks would then depend on the degree of loss absorption by UIAs (subject to the degree of DCR).

F. Operational Risk

Operational risk of Islamic banks is explicitly recognized in the capital assessment but could encompass a wide range of activities that might be outside the scope of stress tests. The one-off nature of large operational risk events frequently eludes purely quantitative models and warrants a qualitative overlay that explains the causality of operational risk events and the sensitivity of their financial impact.⁸³ Given the pervasiveness of operational risk from *shari'ah* compliance in Islamic banking, potential areas of overlap with other sources of risk are significant, suggesting an integrated (and possibly more qualitative) stress testing approach for this risk factor.⁸⁴ Thus, shocks to operational risk are not exclusive to the failure

⁸³ Thus, shocks in stress tests are frequently informed by structural (predictive factor) models based on *key risk indicators* (KRIs) as a way of blending both quantitative and qualitative approaches that go beyond the exclusive regulatory treatment via a separate capital charge.

⁸⁴ In fact, capital adequacy for operational risk appears incidental to the importance of corporate governance paired with suitable risk management and control procedures.

to comply with *shari'ah* principles, and their impact might differ from that implied by simple quantitative approaches, such as the BIA. For the purposes of a methodological treatment consistent with the quantitative assessment of other risk factors, the impact of shocks to operational risk above the regulatory minimum, $\Delta OpRisk$, on capital adequacy under stress is defined as

$$CAR_{operational} = \frac{\text{capital} + \text{retained earnings} - \text{operational risk loss}}{\left(\begin{array}{c} OpRisk + \Delta OpRisk + \widetilde{RWA}_{total} \\ - \widetilde{RWA}_{RIA} - (1 - \alpha)\widetilde{RWA}_{UIA} \\ - \alpha\widetilde{RWA}_{PER,IRR} \end{array} \right)}. \quad (32)$$

G. Combination of Risk Factors and Organization of Risk Drivers

The aggregate impact of shocks to these risk factors should be considered without diversification benefits. Assuming that risk factors are not fully correlated, it is reasonable to account for their dependence structure and combinations of stress testing parameters in which the individual impact of each risk is lower than the risk in isolation. However, combining multiple risk factors with diversification effects tends to complicate the reliable capital assessment. Instead, the capital impacts CAR_{DCR} , CAR_{IRR} , CAR_{credit} , CAR_{market} , and $CAR_{operational}$ of the various risk factor in equations (12), (17), (27), (31) and (32) are combined so that $CAR_{SDF_{stressed}}$ in equation (8) above can be rewritten as⁸⁵

$$CAR_{SDF_{stressed}} = \frac{\left(\begin{array}{c} \text{capital} + \text{retained earnings} \\ - \text{investment shortfall} (1 - \text{share covered by } PER_{equity}) \\ - \text{interest rate gap} (1 - \text{share covered by } PER_{equity}) \\ - \text{credit risk loss} - \text{credit risk loss}_{special\ sales} \\ - \text{market risk loss}_{ordinary\ sales} - \text{market risk loss}_{special\ sales} \\ - \text{market risk loss}_{trading} - \text{operational risk loss} \end{array} \right)}{\left(\begin{array}{c} OpRisk - \Delta OpRisk + \widetilde{RWA}_{total} \\ - \widetilde{RWA}_{RIA} - (1 - \alpha)\widetilde{RWA}_{UIA} - \alpha\widetilde{RWA}_{PER,IRR} \\ - \alpha \left(\max \left(\begin{array}{c} RWA_{PER,IRR} \\ - RWA_{PER,IRR} \text{ covering investment shortfall} \\ - RWA_{PER,IRR} \text{ covering interest rate gap, 0} \end{array} \right) \right) \end{array} \right)}, \quad (33)$$

with \widetilde{RWA}_{total} consistent with ΔRWA_{credit} and ΔRWA_{market} , which simplifies to

⁸⁵ The simple aggregation of risk factor impacts would preserve the stochastic assumptions of each risk factor.

$$CAR_{Std_{stressed}} = \frac{\begin{aligned} & \text{capital} + \text{retained earnings} \\ & - (1 - \text{share covered by } PER_{equity}) \left(\begin{aligned} & \text{investment shortfall} \\ & + \text{interest rate gap} \end{aligned} \right) \\ & - \text{credit risk loss}_{total} - \text{market risk loss}_{total} - \text{operational risk loss} \end{aligned}}{OpRisk - \Delta OpRisk + \overline{RWA}_{total} - \overline{RWA}_{RIA}}, \quad (34)$$

under the standard formula (without DCR; see equation (4)), where $\text{credit risk loss}_{total} = \text{credit risk loss} - \text{credit risk loss}_{special sales}$ and $\text{market risk loss}_{total} = \text{market risk loss}_{ordinary sales} - \text{market risk loss}_{special sales} - \text{market risk loss}_{trading}$. Both equations include balance sheet dynamics related to changes in RWAs due to new lending and investment (with retained earnings reflecting the impact of changes in net profitability (after income and taxes) as well as dividend policy and the managerial capital buffer). Adapting this approach would result in a stylized output template for a multiperiod stress test to accommodate the main results, risk drivers, balance sheet information, and stress testing parameters (see Appendix I, Table A3).

The specification of these risk factors also depends on the nature, scale, and complexity of the relevant banking activities and their interaction with the design of stress scenarios and the choice of the methodological framework:

- *The selection of risk factors needs to be sufficiently flexible to accommodate the evolving nature of banks' business models and their susceptibility to certain shocks.* The calibration of risk factors is premised on how the performance of banks and the dynamics of business strategies are affected by changes in macrofinancial conditions. However, their relevance and macrofinancial sensitivity is invariably bound to change over time and influenced by the constant evolution of practices and innovations in Islamic banking (conditional on the prevailing interpretation of the legal tradition and principles of Islamic jurisprudence [*usul al-fiqh* or أصول الفقه]).
- *Additional measures can reveal a more comprehensive perspective on the full impact of different stress scenarios.* Accounting measures (for example, net income and other profitability indicators) support an enhanced understanding of the dynamics of capital buffers, as they would affect the decision to pay out dividends to shareholders or bonuses to policyholders. Changes in the loss absorption of IA holders for different scenario severities illustrate how the capital assessment during times of stress is impacted by assumptions about DCR. Also, incorporating liquidity measures could provide useful insights, especially when investment assets become more illiquid (BCBS, 2013).
- *The extension of single-period shocks to multiperiod scenarios could help identify medium- and long-term vulnerabilities.* Extending the stress test horizon and applying multiyear scenarios would also help identify medium- and long-term vulnerabilities from a gradual erosion of the solvency position, which would inform suitable remedial actions and recovery plans.

- *Secondary impacts and feedback effects emanating from a deteriorating financial position can be material in stress conditions.* For instance, the degrading of the solvency position can result in a higher cost of capital, which might drain reserves for DCR and limit the ability of Islamic banks to attract sufficient deposits. The design of stress tests tends to be sufficiently flexible to accommodate differences in banks' business models, their role in the domestic financial sector, and increasingly, their cross-border linkages with other financial institutions. Spillover effects from a general deterioration of asset prices and associated feedback effects between one or more banks under duress from the macrofinancial conditions are important considerations in a comprehensive assessment (see Appendix V).

The risk factors can be integrated into a conventional stress testing framework, such as the *IMF Workbox Solvency Tool* (Leika and others, *forthcoming*), which has been developed to conduct solvency stress tests based on current regulatory requirements and accounting standards. The tool allows stress testers to (i) project (or make assumptions about) the dynamic evolution of banks' balance sheets using balance sheet information; and (ii) assess capital adequacy under stress.⁸⁶

VIII. CONCLUSION

In this paper, we presented a simple conceptual framework for the design and implementation of top-down solvency stress testing of Islamic banks. While the general mechanics and core principles of stress testing apply universally, the distinct characteristics of Islamic banking require a differentiated treatment of several risk factors, including (i) DCR (due to some transfer of shareholder value to unsecured depositors); (ii) indirect interest rate risk (due to competition for deposits in mixed banking systems); (iii) counterparty and project risk (if a counterparty fails to perform its payment obligations); (iv) market risk from inventories of commodities and parallel special sales contracts as natural hedges; and (v) operational risk from non-compliance with Islamic finance principles. Based on existing capital standards for Islamic banks (IFSB, 2012b and 2013), we developed a general understanding of how Islamic finance principles influence the capital impact of key risk drivers under stress. Whenever possible, we applied common stress testing model(s) and technique(s) for conventional banks to integrate the formal specification of risk factors—consistent with the evolving prudential guidance from the IFSB (2012a and 2016). However, several process-oriented considerations (and the technical implementation) remained outside the conceptual scope of the paper, such as the treatment of capital resources, the design of stress scenarios, the validation of results, and dealing with the outcome of the stress tests (Jobst and others, 2013). The operationalization of this conceptual approach would require a detailed analysis of (i) the nature, scale, and complexity of the relevant banking activities as well as (ii) secondary impacts and feedback effects emanating from a deteriorating solvency

⁸⁶ Although there are some deviations (mostly related to granularity of exposures), in general, this toolkit is broadly consistent with current capital requirements and accounting standards.

in multiperiod scenarios. Ong (2014) and Ong and Jobst (2020) provide an overview of relevant stress testing methodologies, which cover these aspects and complement this paper.⁸⁷

This would also involve incorporating a cross-functional perspective of solvency and liquidity risks consistent with Islamic finance principles. Liquidity and solvency risks of individual institutions are increasingly connected during times of stress and tend to be influenced by system-wide liquidity conditions associated with the interconnectedness and network effects within the financial system. Moreover, understanding the structural implications of differences in business models, behavioral characteristics under stress, and the interaction between solvency and liquidity conditions are fundamental to the application of this approach for financial stability analysis and macroprudential surveillance. This places more emphasis on qualitative analysis, such as the reputational risk of individual firms, the competitive environment, and existing risk controls that influence the gross impact of risks.

⁸⁷ See also Adrian and others (2020) for review of current IMF stress testing approaches.

REFERENCES

- AAOIFI, 1999. Financial Accounting Standard No. 11 (*Provisions and Reserves*) (Manama/Bahrain: Accounting and Auditing Organization of Islamic Financial Institutions), available at <http://www.aaofi.com/en/standards-and-definitions/shari%E2%80%99a-standards/accounting-standards.html>.
- Adewale, Abideen Adeyemi, and Simon Archer, 2019. “Risk Sharing in Islamic Banking,” IFSB Working Paper Series (WP-10/05/2019), Technical and Research Department, May (Kuala Lumpur: Islamic Financial Services Board), available at <https://www.ifsb.org/download.php?id=5160&lang=English&pg=/index.php>.
- Adrian, Tobias, James Morsink and Liliana Schumacher, 2020. “Stress Testing at the IMF,” Departmental Paper No. 20/04, February (Washington, D.C., International Monetary Fund), available at <https://www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2020/01/31/Stress-Testing-at-the-IMF-48825>.
- Ahmad, Kurshid, 2000. “Islamic Finance and Banking: The Challenge of the 21st Century,” *Review of Islamic Economic Studies*, Vol. 9, 57–82.
- Ahmad Ibn Taymiyyah, Taqi ad-Din, 1949. *Nazariyat al Aqd* (Cairo: Matbaa al Sunnah al-Muhammadiyah).
- Al-Buhuti Ibn Yunus, Mansur, 2003. *Kashshaf Al-qina` `an Matn al-Iqna`* (Riyad: Dar `Alam al-Kutub).
- Al-Shawkani Ibn Ali, Muhammad, 1985. *Kitab al-Sayl A-jarrar Al-mutadaffiq `ala Hada'iq Al-azhar* (Beirut: Dar al-Kutub al-`Ilmiyah), 23.
- Al-Suwailem, Sami, 1999-2000. “Towards an Objective Measure of Gharar in Exchange,” *Islamic Economic Studies*, Vol. 7, Nos. 1 and 2, October–April, 66f.
- Artzner, Philippe, Freddy Delbaen, Jean-Marc Eber, and David Heath, 1999. “Coherent Measures of Risk,” *Mathematical Finance*, Vol. 9, No. 3, 203–28.
- Basel Committee on Banking Supervision (BCBS), 2005. “An Explanatory Note on the Basel II IRB Risk Weight Functions,” July (Basel: Bank for International Settlements), available at <http://www.bis.org/bcbs/irbriskweight.pdf>.
- _____, 2009. “Principles for Sound Stress Testing Practices and Supervision,” BCBS Publication No. 155, May (Basel: Bank for International Settlements), available at <http://www.bis.org/publ/bcbs155.htm>.
- _____, 2010. “Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems,” BCBS Publication No. 189, December (Basel: Bank for International Settlements), available at <http://www.bis.org/publ/bcbs189.htm>.

- _____, 2012. “Peer Review of Supervisory Authorities’ Implementation of Stress Testing Principles,” BCBS Publication No. 218, April (Basel: Bank for International Settlements), available at <http://www.bis.org/publ/bcbs218.htm>.
- _____, 2015. “Making Supervisory Stress Tests More Macroprudential: Considering Liquidity and Solvency Interactions and Systemic Risk,” Working Paper No. 29, November (Basel: Bank for International Settlements), available at <https://www.bis.org/bcbs/publ/wp29.htm>.
- _____, 2018. “Stress Testing Principles,” Guidelines, BIS Paper No. 450, October (Basel: Bank for International Settlements), available at <https://www.bis.org/bcbs/publ/d450.htm>.
- _____, 2019. “Minimum Capital Requirements for Market Risk,” BIS Paper No. 457, January (Basel: Bank for International Settlements), available at <https://www.bis.org/bcbs/publ/d457.htm>.
- Black, Fischer, 1976. “Studies of Stock Price Volatility Changes,” in: American Statistical Association (ed.) *Proceedings of the 1976 Meeting of the Business and Economic Statistics Section* (Washington, D.C.: American Statistical Association), 177–81.
- Blaschke, Winfrid, Matthew T. Jones, Giovanni Majnoni, and Soldedad Martinez Peira, 2001. “Stress Testing of Financial Systems: An Overview of Issues, Methodologies, and FSAP Experiences,” IMF Working Paper No. 01/88 (Washington, D.C.: International Monetary Fund).
- BNM, 2010. “Shariah Resolutions in Islamic Finance,” October (Kuala Lumpur: Bank Negara Malaysia), available at https://www.bnm.gov.my/microsite/fs/sac/shariah_resolutions_2nd_edition_EN.pdf.
- _____, 2017. “Investment Account,” October (Kuala Lumpur: Bank Negara Malaysia), available at <https://www.bnm.gov.my/index.php?ch=57&pg=137&ac=84&bb=file>.
- Chattha, Jamshaid A., 2020. “The COVID-19 Pandemic: Supervisory Implications and Priorities for Islamic Banking,” Toronto Centre Notes, May (Toronto: Toronto Centre), available at <https://res.torontocentre.org/guidedocs/COVID19%20and%20Islamic%20Finance%20FINAL.pdf>.
- Chavez-Demoulin, Valérie, and Paul Embrechts, 2004. “Smooth Extremal Models in Finance and Insurance,” *Journal of Risk and Insurance*, Vol. 71, No. 2, 183–99.
- Cheng, Linyin, and Amir AghaKouchak, 2014. “Nonstationary Precipitation Intensity-Duration-Frequency Curves for Infrastructure Design in a Changing Climate,” *Scientific Reports*, Vol. 4, No. 7093.

- Cheng, Linyin, Amir AghaKouchak, Eric Gilleland, and Richard W. Katz, 2014. “Non-Stationary Extreme Value Analysis in a Changing Climate,” *Climate Change*, November, Vol. 127, No. 2, 353–69.
- Central Bank of Bahrain, 2008. *Rulebook—Islamic Banks*. Vol. 2, January (Manama/Bahrain: Central Bank of Bahrain).
- Čihák, Martin, 2007. “Introduction to Applied Stress Testing,” IMF Working Paper No. 07/59 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2007/wp0759.pdf>.
- Coles, Stuart, 2001. *An Introduction to Statistical Modelling of Extreme Values* (Heidelberg: Springer Verlag).
- Committee on the Global Financial System (CGFS), 2000. “Stress Testing by Large Financial Institutions: Current Practice and Aggregation Issues,” CGFS Publications No. 14, April (Basel: Bank for International Settlements), available at <http://www.bis.org/publ/cgfs14.pdf>.
- El-Hawary, Dahlia, Wafik Grais, and Zamir Iqbal, 2004. “Regulating Islamic Financial Institutions: The Nature of the Regulated,” World Bank Policy Research Working Paper 3227, March (Washington, D.C.: World Bank), available at <http://dx.doi.org/10.1596/1813-9450-3227>.
- Ernst & Young, 2015. “World Islamic Banking Competitiveness Report 2016,” *Banking in Emerging Markets* (London: Ernst & Young Global Limited), available at [http://www.ey.com/Publication/vwLUAssets/ey-world-islamic-banking-competitiveness-report-2016/\\$FILE/ey-world-islamic-banking-competitiveness-report-2016.pdf](http://www.ey.com/Publication/vwLUAssets/ey-world-islamic-banking-competitiveness-report-2016/$FILE/ey-world-islamic-banking-competitiveness-report-2016.pdf).
- Errico, Luca, and Mitra Farrahbaksh, 1998. “Islamic Banking: Issues in Prudential Regulation and Supervision,” IMF Working Paper No. 98/30 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/wp9830.pdf>.
- Espinosa-Vega, Marco A., and Juan Solé, 2011. “Cross-border Financial Surveillance: A Network Perspective,” *Journal of Financial Economic Policy*, Vol. 3, No. 33, 182–205.
- Farooq, Mohammad Omar, and Sowmya Vivek, 2012. “Displaced Commercial Risk and the Value of Alpha for Islamic Banks in Bahrain/GCC,” Working Paper, July 1 (Manama: Bahrain Institute of Banking & Finance), available at <https://ssrn.com/abstract=2318974>.

- Financial Stability Board, 2019. “Global Monitoring Report on Non-bank Financial Intermediation 2018,” February 4 (Basel: Bank for International Settlements), available at <https://www.fsb.org/2019/02/global-monitoring-report-on-non-bank-financial-intermediation-2018/>.
- Fisher, Ronald A., and Leonard H.C. Tippet, 1928. “Limiting Forms of the Frequency Distribution of the Largest or Smallest Member of a Sample,” *Proceedings of the Cambridge Philosophical Society*, Vol. 24, No. 2, 180–90.
- Gnedenko, Boris V., 1943. “Sur la Distribution Limite du Terme Maximum d’Une Série Aléatoire,” *Annals of Mathematics*, Vol. 44, No. 3, 423–53.
- Grais, Wafik, and Anoma Kulathunga, 2007. “Capital Structure and Risk in Islamic Financial Services,” in Archer, Simon, and Rifaat Ahmed Abdul Karim (eds.) *Islamic Finance: The Regulatory Challenge* (Singapore: John Wiley & Sons (Asia) Pte Ltd).
- Greuning, Hennie Van, and Zamir Iqbal, 2008. *Risk Analysis for Islamic Banks* (Washington, D.C.: World Bank).
- Gross, Marco, Dimitrios Laliotis, Mindaugas Leika, and Pavel Lukyantsau, *forthcoming*. “Expected Credit Loss Modeling from a Macro-Financial System and Stress Testing Perspective,” IMF Working Paper (Washington, D.C.: International Monetary Fund).
- Hammad, Nazih, 2007. “Compensation for an Obligation to Sell Currency in the Future: Currency Hedging,” *Chicago Journal of International Law*, Vol. 7, No. 2, 521–36.
- Hesse, Heiko, Ferhan Salman, and Christian Schmieder, 2014. “How to Capture Macro-Financial Spillover Effects in Stress Tests?” IMF Working Paper No. 14/103 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2014/wp14103.pdf>.
- Imam, Patrick A., and Kangni Kpodar, 2015. “Is Islamic Banking Good for Growth?” IMF Working Paper No. 15/81 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2015/wp1581.pdf>.
- International Monetary Fund (IMF), 2012. “Macrofinancial Stress Testing: Principles and Practices,” IMF Policy Paper, Monetary and Capital Markets Department, August 22 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/np/pp/eng/2012/082212.pdf>.
- _____, 2015. “Islamic Finance: Meeting Global Aspirations,” IMF Survey Magazine: In the News, November 9 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/survey/so/2015/NEW110915A.htm>.
- _____, 2020a. “Global Financial Stability Overview: Markets in the Time of COVID-19,” Global Financial Stability Report, Chapter 1, April (Washington, D.C.: International

- Monetary Fund), available at <https://www.imf.org/en/Publications/GFSR/Issues/2020/04/14/global-financial-stability-report-april-2020>.
- _____, 2020b, “Assessing Stress from Oil Price Shocks,” Special Series on COVID-19, Monetary and Capital Markets Department, April 29 (Washington, D.C., International Monetary Fund), available at <https://www.imf.org/~media/Files/Publications/covid19-special-notes/en-special-series-on-covid-19-assessing-stress-from-oil-price-shocks.ashx?la=en>.
- _____, 2020c, “Banking Sector Regulatory and Supervisory Response to Deal with Coronavirus Impact (with Q and A),” Special Series on COVID-19, Monetary and Capital Markets Department, May 13 (Washington, D.C., International Monetary Fund), available at <https://www.imf.org/~media/Files/Publications/covid19-special-notes/en-special-series-on-covid19banking-sector-regulatory-and-supervisory-response-to-deal-with-coronavir.ashx?la=en>.
- Iqbal, Zamir, and Hiroshi Tsubota, 2006, “Emerging Islamic Capital Markets,” *Islamic Finance Review*, Euromoney Handbook (London: Euromoney Institutional Investor PLC).
- _____, and Abbas Mirakhor, 2006. *An Introduction to Islamic Finance—Theory and Practice* (Hoboken, NJ: John Wiley & Sons, Inc.).
- Islamic Financial Services Board (IFSB), 2005a. “Capital Adequacy Standard for Institutions (Other than Insurance Institutions) Offering Only Islamic Financial Services,” December (Kuala Lumpur: Islamic Financial Services Board), available at <http://www.ifsb.org/standard/ifsb2.pdf>.
- _____, 2005b. “Guiding Principles for Risk Management for Institutions Offering Only Islamic Financial Services,” December (Kuala Lumpur: Islamic Financial Services Board), available at <http://www.ifsb.org/standard/ifsb1.pdf>.
- _____, 2010. “Guidance Note on the Practice of Smoothing the Profits Payout to Investment Account Holders,” December (Kuala Lumpur: Islamic Financial Services Board), available at http://www.ifsb.org/standard/eng_GN-3_Guidance_Note_on_the_Practice_of_Smoothing.pdf.
- _____, 2011. “Guidance Note in Connection with the IFSB Capital Adequacy Standard: The Determination of Alpha in the Capital Adequacy Ratio for Institutions (Other than Insurance Institutions) Offering Only Islamic Financial Services,” March (Kuala Lumpur: Islamic Financial Services Board), available at <http://www.ifsb.org/standard/eng-GN-4%20Guidance%20Note.pdf>.
- _____, 2012a. “IFSB-13: Guiding Principles on Stress Testing for Institutions Offering only Islamic Financial Services (Excluding Islamic Insurance Institutions and Islamic

- Collective Investment Schemes),” March (Kuala Lumpur: Islamic Financial Services Board), available at [http://www.ifsb.org/standard/eng_IFSB13%20Guiding%20Principles%20on%20Stress%20Testing%20_\(Mar2012\).pdf](http://www.ifsb.org/standard/eng_IFSB13%20Guiding%20Principles%20on%20Stress%20Testing%20_(Mar2012).pdf).
- _____, 2012b. “Revised Capital Adequacy Standard for Institutions Offering Islamic Financial Services,” Exposure Draft No. 15, November (Kuala Lumpur: Islamic Financial Services Board), available at [http://ifsb.org/docs/IFSB%20ED-15%20Revised%20Capital%20Adequacy%20Final%20\(01-11-2012\).pdf](http://ifsb.org/docs/IFSB%20ED-15%20Revised%20Capital%20Adequacy%20Final%20(01-11-2012).pdf).
- _____, 2013. “IFSB-15: Revised Capital Adequacy Standard for Institutions (Excluding Islamic Insurance Institutions and Islamic Collective Investment Schemes),” December (Kuala Lumpur: Islamic Financial Services Board), available at [http://www.ifsb.org/standard/2014-01-28_eng_IFSB15%20Revised%20Capital%20Adequacy_\(Jan%202014\).pdf](http://www.ifsb.org/standard/2014-01-28_eng_IFSB15%20Revised%20Capital%20Adequacy_(Jan%202014).pdf).
- _____, 2016. “Technical Note on Stress Testing for Financial Institutions Offering Islamic Financial Services (IIFS),” Technical Note No. 2 (TN-2), December (Kuala Lumpur: Islamic Financial Services Board), available at <https://www.ifsb.org/download.php?id=4378&lang=English&pg=/published.php>.
- _____, 2017. “Technical Note on Stress Testing for Financial Institutions Offering Islamic Financial Services (IIFS)—User Guide,” Technical Note No. 2, June (Kuala Lumpur: Islamic Financial Services Board), available at <https://www.ifsb.org/download.php?id=4385&lang=English&pg=/published.php>.
- _____, 2018. “Islamic Financial Services Industry Stability Report,” June (Kuala Lumpur: Islamic Financial Services Board), available at <https://www.ifsb.org/download.php?id=4811&lang=English&pg=/index.php>.
- ISRA, 2010. *ISRA Compendium for Islamic Financial Terms: Arabic-English* (Kuala Lumpur/Malaysia International Shari’ah Research Academy for Islamic Finance).
- Jobst, Andreas A., 2007a. “The Economics of Islamic Finance and Securitization,” *Journal of Structured Finance*, Vol. 13, No. 1, Spring, 1–22. Also published as IMF Working Paper No. 07/117, May, available at <http://www.imf.org/external/pubs/ft/wp/2007/wp07117.pdf>.
- _____, 2007b. “Operational Risk—The Sting is Still in the Tail But the Poison Depends on the Dose,” *Journal of Operational Risk*, Vol. 2, No. 2, 1–56.
- _____, 2009. “Islamic Derivatives,” *International Journal of Monetary Economics and Finance*, Vol. 2, Nos. 3 and 4, 254–60.

- _____, 2012. “Risk Management of Islamic Finance Instruments,” in: Scott Moeller (ed.) *Finance Essentials: The Practitioners’ Guide* (London: Bloomsbury Publishing), 48–52.
- _____, 2013a. “Reflect on Islamic Finance But Do Not See It As a Panacea,” *Financial Times*, Comment, November (London: Financial Times), available at <http://www.ft.com/intl/cms/s/0/de4113c6-4180-11e3-b064-00144feabdc0.html?siteedition=intl#axzz30OgvHYqp>.
- _____, 2013b. “Guidelines for the Bottom-Up Solvency Stress Test—Banking,” in: International Monetary Fund, “Belgium: Technical Note on Stress Testing the Banking and Insurance Sectors,” IMF Country Report No. 13/137, May 24 (Washington, D.C.: International Monetary Fund).
- _____, 2013c. “Derivatives in Islamic Finance: There is No Right Way to Do the Wrong Thing—Opportunities for Investors,” *Journal of Investing*, Vol. 22, No. 1, 7–21.
- _____, Peter Kunzel, Paul Mills, and Amadou Sy, 2007. “Shari’ah-Compliant Securities—Islamic Finance Expanding Rapidly,” *IMF Survey Magazine*, September 19 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/survey/so/2007/res0919b.htm>.
- _____, and Dale F. Gray, 2013., “Systemic Contingent Claims Analysis (Systemic CCA)—Estimating Market-Implied Systemic Risk,” IMF Working Paper No. 13/54 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2013/wp1354.pdf>.
- _____, Li Lian Ong, and Christian Schmieder, 2013. “A Framework for Macroprudential Bank Solvency Stress Testing: Application to S-25 and Other G-20 Country FSAPs,” IMF Working Paper No. 13/68 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2013/wp1368.pdf>.
- _____, Li Lian Ong, and Christian Schmieder, 2017. “Macroprudential Liquidity Stress Testing in FSAPs for Systemically Important Financial Systems,” IMF Working Paper No. 17/102 (Washington, D.C.: International Monetary Fund), available at <https://www.imf.org/~media/Files/Publications/WP/2017/wp17102.ashx>.
- _____, Peter Kunzel, Paul Mills, and Amadou Sy, 2008. “Islamic Bond Issuance—What Sovereign Debt Managers Need to Know,” *International Journal of Islamic & Middle East Finance and Management*, Vol. 1, No. 4, 330–44. Also published as IMF Policy Discussion Paper No. 08/03, available at <http://www.imf.org/external/pubs/ft/pdp/2008/pdp03.pdf>.
- _____, and Juan Solé, 2009. “The Governance of Derivatives in Islamic Finance,” *Journal of International Business Law and Regulation*, Vol. 24, No. 11, 556–65.

- _____, and Juan Solé, 2012. “Operative Principles of Islamic Derivatives.” IMF Working Paper No. 12/63 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2012/wp1263.pdf>.
- _____, Nobuyasu Sugimoto, and Timo Broszeit, 2014. “Macroprudential Solvency Stress Testing of the Insurance Sector,” IMF Working Paper No. 14/133, July 22 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2014/wp14133.pdf>.
- _____, and Anke Weber, 2016. “Profitability and Balance Sheet Repair of Italian Banks,” IMF Working Paper No. 16/175, August 19 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/cat/longres.aspx?sk=44195.0>.
- Kammer, Alfred, Mohamed Norat, Marco Piñón, Ananthakrishnan Prasad, Christopher Towe, and Zeine Zeidane, 2015. “Islamic Finance: Opportunities, Challenges, and Policy Options,” IMF Staff Discussion Note No. 15/05, April 6 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/sdn/2015/sdn1505.pdf>.
- Lagarde, Christine, 2015. “Unlocking the Promise of Islamic Finance,” Keynote Speech at Conference on *Islamic Finance: Meeting Global Aspirations*, November 11 (Kuwait City, Kuwait), available at <http://www.imf.org/external/np/speeches/2015/111115.htm>.
- Leika, Mindaugas, Liliana Schumacher, and Laura Valderrama, *forthcoming*. “Workbox 2020: The IMF Solvency Stress Testing Tool,” IMF Working Paper (Washington, D.C.: International Monetary Fund).
- Lopez Mejia, Alejandro, Suliman Aljabrin, Rachid Awad, Mohamed Norat, and Inwon Song, 2014. “Regulation and Supervision of Islamic Banks,” IMF Working Paper No. 14/219 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2014/wp14219.pdf>.
- Lukonga, Inutu, 2015. “Seven Questions on Islamic Finance,” *IMF Research Bulletin*, Vol. 16, No. 2 (Washington, D.C.: International Monetary Fund), 6–9.
- Merton, Robert C., 1973. “Theory of Rational Option Pricing,” *Bell Journal of Economics and Management Science*, Vol. 4 (spring), 141–83.
- _____, 1974. “On the Pricing of Corporate Debt: The Risk Structure of Interest Rates,” *Journal of Finance*, Vol. 29, May, 449–70.
- Ong, Li Lian, Rodolfo Maino, and Nombulelo Duma, 2010. “Into the Great Unknown: Stress Testing with Weak Data,” IMF Working Paper No. 10/282 (Washington, D.C.:

- International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2010/wp10282.pdf>.
- Ong, Li Lian, 2014. *A Guide to IMF Stress Testing—Methods and Models* (Washington, D.C.: International Monetary Fund).
- Ong, Li Lian, and Andreas A. Jobst, 2020. *A Guide to IMF Stress Testing—Principles, Concepts and Frameworks* (Washington, D.C.: International Monetary Fund).
- Puhr, Claus, and Stefan W. Schmitz, 2014. “A View from the Top—The Interaction Between Solvency and Liquidity Stress,” *Journal of Risk Management in Financial Institutions*, Vol. 7, No. 4, 38–51.
- Ruggiero, Peter, Paul Komar, and Jonathan Allan, 2010. “Increasing Wave Heights and Extreme Value Projections: The Wave Climate of the U.S. Pacific Northwest,” *Coastal Engineering*, Vol. 57, No. 5, 539–52.
- Sairally, Beebee Salma, Marjan Muhammad, and Madaa Munjid Mustafa, 2013. “Instruments for Meeting Capital Adequacy Requirements of Additional Tier 1 and Tier 2 under Basel III: A Shari’ah Perspective,” mimeo, Paper Proceeding of the 5th Islamic Economics System Conference (iECONS 2013), “Sustainable Development through the Islamic Economics System,” Universiti Sains Islam Malaysia, Faculty Economics and Muamalat (Kuala Lumpur, Malaysia), September 4–5.
- Schmieder, Christian, Claus Puhr, and Maher Hasan, 2011. “Second Generation Applied Stress Testing—Solvency Module,” IMF Working Paper No. 11/83 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2011/wp1183.pdf>.
- Schmitz, Stefan W., Michael Sigmund, and Laura Valderrama, 2017. “Bank Solvency and Funding Cost: New Data and New Results,” IMF Working Paper No. 17/116, May (Washington, D.C.: International Monetary Fund), available at <https://www.imf.org/en/Publications/WP/Issues/2017/05/15/Bank-Solvency-and-Funding-Cost-New-Data-and-New-Results-44914>.
- Solé, Juan, 2008. “Introducing Islamic Banks into Conventional Banking Systems,” *Journal of Islamic Economics, Banking and Finance*, Vol. 4, No. 2. Also published as IMF Working Paper 07/175 (Washington, D.C.: International Monetary Fund).
- Song, Inwon, and Carel Oosthuizen, 2014. “Islamic Banking Regulation and Supervision: Survey Results and Challenges,” IMF Working Paper No. 14/220 (Washington, D.C.: International Monetary Fund), available at <http://www.imf.org/external/pubs/ft/wp/2014/wp14220.pdf>.
- Subhani, Azeemuddin, 2011. “Wither Islamic Finance? ‘... Allah Permitteth Bay’ and Forbiddeth Riba ...’,” *New Horizon*, No. 178 (January–March), 15–8.

- Toumi, Kaouthar, Jean-Laurent Viviani, and Lotfi Belkacem, 2011. “Actual Risk Sharing Measurement in Islamic Banks,” *Critical Studies on Corporate Responsibility, Governance and Sustainability*, Vol. 2, 325–47.
- Uberoi, Priya, 2010. “An Introduction to Islamic Derivatives,” Practice Note, Practice Law Company, March 25, available at <http://us.practicallaw.com/8-501-6191>.
- Vogel, Frank E., and Samuel L. Hayes III, 1998. *Islamic Law and Finance: Religion, Risk and Return* (The Hague and Boston: Kluwer Law International).
- World Bank Group/Islamic Development Bank Group, 2017. “The Islamic Banking Sector,” *Global Report on Islamic Finance* (“Islamic Finance—A Catalyst for Shared Prosperity?”), Chapter 3, February 20 (Washington, D.C.: World Bank Group/Islamic Development Bank Group), 47–67.

APPENDIX I. ADDITIONAL TABLES

Table A1. Glossary of Islamic Finance Terms for Banking

Term	Explanation
<i>bay mu'ajal</i> or <i>bay bithaman ajil</i> (predelivery, deferred payment) مراجحه	The seller can sell a product on the basis of a deferred payment, in installments or in a lump sum. The price of the product is agreed upon between the buyer and the seller at the time of the sale and cannot include any charges for deferring payment. In a BBA contract, the lender is not compelled to disclose the profit margin.
<i>ijārah</i> (or <i>ijārah</i>) (lease, lease purchase) إِجَارَة	A party leases a particular product for a specific sum and a specific time period. In the case of a lease purchase, each payment includes a portion that goes toward the final purchase and transfer of ownership of the product. The contract commences with a promise to lease that is binding on the part of the potential lessee prior to entering the contract. An <i>ijara muntahia bittamleek</i> (or <i>ijara wa iqtina</i>) contract offers the lessee the option to own the asset at the end of the lease period either by purchase of the asset through a token consideration or payment of the market value, or by means of a gift contract.
Investment risk reserve (IRR)	Reserves (after disbursement of the <i>mudarib</i> 's share), which are used to cover (some or all) losses of investment account (IA) holders.
<i>istisna</i> (or <i>istisna'a</i>) (deferred payment and delivery) اِسْتِصْنَاع	Agreement to sell to a customer a non-existent asset, which is to be manufactured or built according to the buyer's specifications and is to be delivered on a specified future date at a predetermined selling price. A manufacturer (contractor) agrees to produce (build) and to deliver a certain good (or premise) at a given price on a given date in the future. The price does not have to be paid in advance (in contrast to <i>bay salam</i>). It may be paid in installments or part may be paid in advance with the balance to be paid later on, based on the preferences of the parties. A parallel <i>istisna</i> is a second <i>istisna</i> contract where a third party will be manufacturing for the bank an asset that corresponds to the properties of the asset underlying the first <i>istisna</i> contract.
<i>mudaraba</i> (or <i>mudarabah</i>) (trust-based contract) ضرب	Contract between the capital provider and a skilled entrepreneur whereby the capital provider contributes capital to an enterprise or activity that is managed by the entrepreneur as the <i>mudarib</i> . Profits are shared in accordance with the terms of the <i>mudarabah</i> agreement while losses are borne solely by the capital provider unless the losses are due to the <i>mudarib</i> 's misconduct, negligence, or breach of contracted terms.
<i>murābaḥa</i> (or <i>murābaḥah</i>) (mark-up/cost-plus sale) مُرَابَحَة	Sales contract whereby the bank sells to a client at an agreed profit margin plus cost (selling price) a specified asset (which may have been purchased and acquired based on a binding or non-binding promise of purchase, for instance, in the case of a purchase order).

Table A1 (concluded). Glossary of Islamic Finance Terms for Banking

<p><i>mushāraka</i> (or <i>mushārakah</i>) (equity participation or “sweat capital finance”) مُشَارَكَة</p>	<p>The bank enters into an equity partnership agreement with one or more partners to jointly finance an investment project. Profits (and losses) are shared in accordance with the terms of the <i>musharakah</i> agreement while losses are shared in proportion to each partner’s capital share. Diminishing <i>musharakah</i> is a form of partnership in which one of the partners promises to buy the equity share of the other partner gradually until the title to the equity is completely transferred to the buying partner. The “buying and selling” is independent of the partnership contract and should not be stipulated in the partnership contract since the buying partner is only allowed to give a promise to buy. It is also not permitted that one contract be entered into as a condition for concluding the other.</p>
<p>Profit equalization reserve (PER)</p>	<p>Reserve funded by <i>mudarabah</i> income (after disbursement of the <i>mudarib</i>’s share), which are used to cover (some or all) losses of investment account holders and smooth earnings of shareholders.</p>
<p><i>qard hasan</i> (benevolent loans) قَرْضُ حَسَن</p>	<p>Non-interest-bearing loan intended to allow the borrower to use the loaned funds for a period with the understanding that the same amount of the loaned funds would be repaid at the end of the period. Banks are allowed to charge borrowers a service fee to cover the administrative expenses of handling the loan. The fee should not be related to the loan amount or maturity.</p>
<p>Restricted investment accounts (RIA)</p>	<p>Investment account holders authorize the bank to invest their funds based on <i>mudarabah/mushāraka</i> (profit- and loss-sharing) or <i>wakalah</i> (agency) contracts with certain restrictions as to where, how, and for what purpose these funds are to be invested.</p>
<p><i>salam</i> (prepayment, deferred delivery) سَلَام</p>	<p>The buyer pays the seller the full negotiated purchase price of a commodity that the seller promises to deliver at a future date (prepayment). A parallel <i>salam</i> contract with a third party stipulates that the buyer acquires the same commodity specified in the first <i>salam</i> contract.</p>
<p><i>sukuk</i> (investment certificates) صُكُوك</p>	<p>These certificates confer ownership in an undivided part of an underlying asset where the holder assumes all rights and obligations to such asset.</p>
<p><i>tawarruq</i> (or reverse <i>murabahah</i>)</p>	<p>Tawarruq defines the purchase of a commodity in the possession and owned by the seller on a deferred basis, which the buyer resells to a third party (other than the original seller) to acquire cash (<i>al-wariq</i>).</p>
<p>Unrestricted investment accounts (UIA)</p>	<p>Investment account holders authorize the bank to invest their funds based on <i>mudarabah/mushāraka</i> (profit- and loss-sharing) or <i>wakalah</i> (agency) contracts without any restriction. The bank can commingle these funds with their own funds and invest them in a pooled portfolio.</p>
<p><i>wakalah</i> (agency) وَكَالَة</p>	<p>In a <i>wakalah</i> contract, the principal (<i>muwakkel</i>) appoints an agent (<i>wakil</i>) to undertake transactions on his/her behalf in non-binding contract for a fixed fee, similar to a power of attorney agreement in conventional legal terms. Services under <i>wakalah</i> include all exchange-based and profit- and loss-sharing contracts.</p>

Sources: authors, Errico and Farrahbaksh (1998), El-Hawary and others (2004), IFSB (2005a and 2005b), and ISRA (2010).

**Table A2. Stylized Balance Sheet of an Islamic Bank
(with internally consistent values, in monetary units)**

ASSETS		Amount	LIABILITIES		Amount
(1) Cash and cash equivalents		30	(7) Demand deposits: checking accounts (<i>qardh hasan</i>)		250
(2) Interbank deposits (short-term <i>murabaha</i>)		20	(8) Investment accounts (<i>mudarabah/musharakah/wakala</i>)		600
(3) Accounts receivable		912	(9) Restricted investment accounts (RIA)		200
(4) Financing and lending		832	(10) Unrestricted investment accounts (UIA)		400
<i>of which: exchange-based contracts</i>		632	(11) Funding liabilities (exchange-based and profit- and loss-sharing contracts)		50
<i>of which: ordinary sales (murabahah)</i>		432	Exchange-based contracts (<i>murabaha, salam/istisna</i>)		25
<i>of which: special sales (salam/istisna/bay bithaman ajil) 1/</i>		100	Profit- and loss-sharing contracts (e.g., <i>sukuk</i>)		25
<i>of which: leases (ijara)</i>		100	(12) Reserves		52
<i>of which: profit- and loss-sharing contracts (musharakah/mudarabah)</i>		200	(13) Profit equalization reserves (PER)		22
(5) Investment and trading		80	(14) <i>of which: attributable to UIA (PER_{UIA}) 2/</i>		20
<i>of which: inventory (commodities)</i>		30	(15) <i>of which: attributable to Equity (PER_{Equity})</i>		2
<i>of which: profit- and loss-sharing contracts</i>		50	(16) Investment risk reserve (IRR) 2/		30
(6) Fixed assets		38	(17) <i>of which: attributable to UIA (IRR_{UIA})</i>		20
			(18) <i>of which: attributable to RIA (IRR_{RIA})</i>		10
			(19) Capital (equity): long-term syndicated <i>musharaka/mudarabah</i>		48
Total		1,000			1,000

Memo items

Risk-weighted assets (RWAs)		Explanation
(20) Total RWAs	481	sum of risk-weighted assets (RWAs) for credit risk, market risk and operational risk
(21) RWAs for credit and market risks	456	calculated as the sum of: product of (34) and (35) and product of (5) and (35)
(22) <i>of which: funded by investment accounts</i>	304	calculated as sum of (23) and (24)
(23) <i>of which: funded by RIA</i>	101	share of RIA in investment/lending (credit RWAs) same as share of RIA in total funding: (36)*(21)
(24) <i>of which: funded by UIA</i>	203	share of UIA in investment/lending (credit RWAs) same as share of UIA in total funding: (37)*(21)
(25) <i>of which: funded by reserves</i>	26	sum of (26)-(29), invested at the same risk as RIA and UIA (general funds)
(26) <i>of which: funded by PER_{UIA}</i>	10	reported amount in (14) times avg. riskiness of credit risk-sensitive assets in (35)
(27) <i>of which: funded by PER_{Equity}</i>	1	reported amount in (15) times avg. riskiness of credit risk-sensitive assets in (35)
(28) <i>of which: funded by IRR_{UIA}</i>	5	reported amount in (17) times avg. riskiness of credit risk-sensitive assets in (35)
(29) <i>of which: funded by IRR_{RIA}</i>	10	reported amount in (18) times avg. riskiness of credit risk-sensitive assets in (35)
(30) RWAs for operational risk	25	calculated as the product of (31) and (32)
Other assumptions		
(31) Expected losses for operational risk	2.0	—
(32) Conversion factor (inverted minimum CAR)	12.5	implies assumed minimum CAR of 8% of risk-weighted assets (RWAs)
(33) Supervisory discretion of DCR (<i>a-parameter</i>) 3/	0.3	determines the amount of credit and market RWA subject to DCR
(34) Amount of credit-sensitive assets	832	only items in lending portfolio (4)
(35) Riskiness of assets (average risk weighting) (<i>in percent of assets</i>)	50.0	for both lending and investment exposures (credit and market risk) in (4) and (5)
(36) Share of RIA (<i>in percent of total liabilities</i>)	22.2	amount of RIA (9) relative to sum of sum of (7), (8), and (11) (excl. reserves)
(37) Share of UIA (<i>in percent of total liabilities</i>)	44.4	amount of UIA (10) relative to sum of sum of (7), (8), and (11) (excl. reserves)

Source: authors. Note: An electronic version of this table is available as MS Excel® workbook ("Datafile_Balance_Sheet_and_Output_Template") which is published together with this working paper. 1/ trade financing; 2/ "special sales" are contracts with delayed settlement in the form of *salam* and *istisna'a* (delayed delivery) or *bay bithaman ajil* (delayed payment); 3/ assumption of 5 percent reserve coverage for UIA and RIA (see (17) and (18)); 4/ supervisory authorities may apply supervisory discretion to account for DCR also to RIAs; this would then change PER in (16) to include PER_{RIA} (and a corresponding change of RWAs funded by reserves in (26) to include RWAs funded by PER_{RIA}).

**Table A3. Output Template of Multiperiod Stress Test for an Islamic Bank—
Main Results and Risk Drivers**

[Bank Name]			before test (end-[year])	Y1 [year]	Y2 [year]	Y3 [year]	Y4 [year]	Y5 [year]
Reporting basis [select] 1/	solo	combined	consolidated					
Macro scenario [select]	baseline	adverse scenario 1	adverse scenario 2					
Main Results	Failed stress test? (1 = yes, 0 = no)	Total Capital		0	0	0	0	0
		Tier 1		0	0	0	0	0
		Common Equity Tier 1		0	0	0	0	0
	Capital needs to recapitalize banks (In [currency] millions)	Total Capital		0	0	0	0	0
		Tier 1		0	0	0	0	0
		Common Equity Tier 1		0	0	0	0	0
Hurdle Rate Assumption	Capital needs to recapitalize banks (relative to total assets) In percent	Total Capital		0	0	0	0	0
		Tier 1		0	0	0	0	0
		Common Equity Tier 1		0	0	0	0	0
				0	0	0	0	0
Hurdle Rate Assumption	Hurdle Rate Total Capital (with conservation buffer)			10.5%	10.5%	10.5%	10.5%	10.5%
	Hurdle Rate Tier 1 Capital (with conservation buffer)			6.0%	6.0%	6.0%	6.0%	6.0%
	Hurdle Rate Common Equity Tier 1 Capital (with conservation buffer)			4.5%	4.5%	4.5%	4.5%	4.5%
Risk Drivers	A. Operating profit (before losses/impairments and taxes): (1)+(2)-(3)		20	20	20	20	20	20
	(1) Gross income from lending/investment due to change in rate of return (less foregone income from defaults)		30	30	30	30	30	30
	(2) Other income		4	4	4	4	4	4
	(3) Total expenses: (a)+(b)+(c)+(d)		12	12	12	12	12	12
	(a) of which: funding costs (deposits, investment accounts, and certificates)		2	2	2	2	2	2
	(b) of which: investment shortfall		2	2	2	2	2	2
	less: covered by PER and IRR _{UIA}		1	1	1	1	1	1
	(c) of which: interest rate gap		2	2	2	2	2	2
	less: covered by PER and IRR _{UIA}		1	1	1	1	1	1
	(d) of which: operating expenses		6	6	6	6	6	6
	B. Losses from impairments and defaults: (1)+(2)+(3)		10	10	10	10	10	10
	(1) of which: credit risk-related losses/net impairments from lending		6	6	6	6	6	6
	of which: due to special sales		1	1	1	1	1	1
	(2) of which: market risk-related losses (incl. impact of valuation haircuts)		2	2	2	2	2	2
	of which: valuation of investments/inventory		1	1	1	1	1	1
	of which: due to special sales		1	1	1	1	1	1
	of which: FX shock		1	1	1	1	1	1
	(3) of which: operational risk-related losses		2	2	2	2	2	2
	Net profit (after dividends paid and tax, if applicable)		6	6	6	6	6	6
Risk Drivers (Change) (In percent of RWAs)	Change in operating profit (before losses/impairments and taxes)		0	0	0	0	0	0
	of which: gross income from lending/investment due to change in rate of return		0	0	0	0	0	0
	of which: other income		0	0	0	0	0	0
	of which: funding costs (deposits, investment accounts, and certificates)		2	0	0	0	0	0
	of which: investment shortfall		0	0	0	0	0	0
	of which: covered by PER and IRR _{UIA}		0	0	0	0	0	0
	of which: interest rate gap		0	0	0	0	0	0
	of which: covered by PER and IRR _{UIA}		0	0	0	0	0	0
	of which: operating expenses		0	0	0	0	0	0
	Change in losses from default and impairments		0	0	0	0	0	0
	of which: credit risk-related losses/net impairments from lending		0	0	0	0	0	0
	of which: due to special sales		0	0	0	0	0	0
	of which: market risk-related losses (incl. impact of valuation haircuts)		0	0	0	0	0	0
	of which: valuation of investments/inventory		0	0	0	0	0	0
	of which: due to special sales		0	0	0	0	0	0
	of which: FX shock		0	0	0	0	0	0
	of which: operational risk-related losses		0	0	0	0	0	0
	Change in net profit (after dividends paid and tax, if applicable)		0	0	0	0	0	0

Sources: Jobst (2013b) and authors. Note: An electronic version of this table is available as MS Excel® workbook

("Datafile_Balance_Sheet_and_Output_Template") which is published together with this working paper. PER_{UIA}=profit equalization reserve for unrestricted investment accounts (UIA) and IRR=investment risk reserve. The values in the prepopulated cells are for illustration purposes only (but consistent with all the balance sheet items shown in Table A2). 1/ The reporting basis can be either "solo" (legal entity level), "combined" (domestic operations and foreign branches), or "consolidated" (all group-wide activities, irrespective of jurisdiction and legal status (branches/subsidiaries)).

Table A3 (concluded). Output Template of Multiperiod Stress Test for an Islamic Bank—Balance Sheet Information and Stress Test Parameters

Balance Sheet Information	Total capital adequacy ratio, <i>In percent</i>	18.1%	18.2%	18.2%	18.2%	18.2%	18.2%
	Tier 1 capital ratio, <i>In percent</i>	15.1%	15.2%	15.2%	15.2%	15.2%	15.2%
	Common Tier 1 ratio, <i>In percent</i>	12.1%	12.1%	12.1%	12.1%	12.1%	12.1%
	Total eligible capital	87	87	87	87	87	87
	Total capital (in '000)	87	87	87	87	87	87
	of which: Tier 1 capital (in '000)	73	73	73	73	73	73
	of which: common capital (in '000)	58	58	58	58	58	58
	Total risk-weighted assets (RWAs) (1)+(2)-(3)	481	478	478	478	478	478
	(1) of which: operational risk	25	25	25	25	25	25
	(2) of which: credit and market risk	456	456	456	456	456	456
	(a) less: funded by restricted investment accounts (RIA)	92	92	92	92	92	92
	(b) less: funded by unrestricted investment accounts (UIA) * (1-α)	129	129	129	129	129	129
	(c) less: funded by (PER _{UIA} , PER _{Equity} , and IRR _{UIA}) * α	4	4	4	4	4	4
	(3) less: RWAs of charge-offs	3	3	3	3	3	3
	Profit-sharing investment accounts (PSIA)	600	600	600	600	600	600
	of which: unrestricted accounts (UIA)	400	400	400	400	400	400
	Reserves	42	42	42	42	42	42
	of which: profit equalization reserves (PER)	22	22	22	22	22	22
	of which: for unrestricted investment accounts (PER _{UIA})	20	20	20	20	20	20
	of which: investment risk reserve (IRR)	20	20	20	20	20	20
	of which: for unrestricted investment accounts (IRR _{UIA})	13	13	13	13	13	13
	Equity: long-term syndicated murabaha/musharaka	58	58	58	58	58	58
Stress test parameters (<i>In percent</i>)	Leverage (capital/assets)	36.2%	36.4%	36.4%	36.4%	36.4%	36.4%
	Return on total regulatory capital	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%
	Dividend yield (dividend paid/equity)	11.5%	11.5%	11.5%	11.5%	11.5%	11.5%
	Assumptions						
	Percentage of profits retained	70.0%	70.0%	70.0%	70.0%	70.0%	70.0%
	Tax rate	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
	Supervisory discretion of DCR: ratio of accounts affected (α)	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%
	Indirect interest rate risk: ratio of accounts affected (β)	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
	Indirect interest rate risk: pass-through (γ)	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%
	Expected return for investment accounts (IA)	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
	Market interest rate (maturity-matched to investment accounts (IA))	1.0%	1.0%	2.0%	2.5%	3.0%	3.5%
	Credit risk						
	PD or NPA ratio (EAD-weighted average)	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
	LGD (EAD-weighted average)	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
	Asset correlation (EAD-weighted average) 2/	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
	Concentration ratio (HHI index) of EAD-weighted portfolio	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
	Credit growth	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%

Sources: Jobst (2013b) and authors. Note: An electronic version of this table is available as MS Excel® workbook

("Datafile_Balance_Sheet_and_Output_Template.xlsx") which is published together with this working paper.

EAD=exposure at default, LGD=loss-given-default, PD=probability of default, NPA=nonperforming asset ratio, DCR=displaced commercial risk, PER_{UIA}=profit equalization reserve for unrestricted investment accounts (UIA), IRR= investment risk reserve. The values in the prepopulated cells are for illustration purposes only (but consistent with Table A2). 1/ The reporting basis can be either "solo" (legal entity level), "combined" (domestic operations and foreign branches), or "consolidated" (all group-wide activities, irrespective of jurisdiction and legal status (branches/subsidiaries)); 2/ The average PDs for the portfolio should be used to derive the asset correlation from the Basel II formula (by exposure types), which is then averaged across exposure types, weighted by EAD. The portfolio average PD includes both defaulted and non-defaulted exposures.

APPENDIX II. MODELING UNEXPECTED LOSSES USING THE EXTREME VALUE THEORY

Relaxing the normality assumption of the distribution of investment returns in order to estimate unexpected losses requires estimating the tail risk. There are two practical approaches for determining the asymptotic behavior of investment returns under the extreme value theory (EVT): (i) the empirical calibration of the generalized extreme value (GEV) distribution and (ii) estimating the generalized Pareto distribution (GPD) as a subset of GEV based on exceedances.

A. Empirical Calibration Using the Generalized Extreme Value Distribution

We assume that the asymptotic tail behavior of a historical series of observations $\{x_t; t = 1, 2, \dots, n\}$ with distribution function $\mathcal{F}_t(x) = \Pr(X_t \leq x)$ and $x \in \mathbb{R}$ comprises a sequence of normalized extremes (maxima or minima) drawn from a sample of independent and identically distributed (i.i.d.) random variables based on the empirical observations specified in equation (B1.1.) in Box 1; they converge to a GEV distribution as limiting law of their asymptotic tail behavior (reflecting the diminishing likelihood of even larger extremes as the level of statistical confidence approaches certainty).

The Fisher-Tippett-Gnedenko theorem (Fisher and Tippett, 1928; Gnedenko, 1943) defines the attribution of a given distribution of normalized maxima (or minima) to be of an extremal type. If the vector-valued i.i.d. random series

$$\mathcal{X}_t = x_1, x_2, \dots, x_n,$$

we can define the sample maxima $\mathcal{Y}_x = \max(x_1, x_2, \dots, x_n)$ with ascending order statistics $x_t^{n,1} \leq \dots \leq x_t^{n,n}$ over n -number of observations.

The distribution of normalized extremes satisfies the conditions of the GEV distribution if there exists a choice of normalizing constants $\alpha_x^n > 0$ and $\beta_x^n > 0$, such that the probability of each ordered n -sequence of normalized sample maxima $(\mathcal{Y}_x - \alpha_x^n)/\beta_x^n > 0$ converges to the non-degenerate limit distribution $G_{\mathcal{Y}_x}(\cdot)$ as $n \rightarrow \infty$,⁸⁸ so that

$$\lim_{n \rightarrow \infty} \Pr((\mathcal{Y}_x - \alpha_x^n)/\beta_x^n \leq x) \rightarrow G_{\mathcal{Y}_x}(\cdot).$$

If the normalized extremes only roughly follow GEV, they are considered to fall within the *maximum domain of attraction* (MDA) of $G_{\mathcal{Y}_x}(\cdot)$. In this case, their distribution conforms to

⁸⁸ The upper tails of most (conventional) limit distributions (weakly) converge to this parametric specification of asymptotic behavior, irrespective of the original distribution of observed maxima (unlike parametric VaR models).

one of three distinct types of extremal behavior as limiting distributions (which are expressed below in their general form without specific notation):⁸⁹

$$EV0: G_0(x) = \exp(-\exp(-x)) \quad \text{if } x \geq 0, \xi = 0$$

$$EV1: G_1(x) = \exp(-x^{-1/\xi}) \quad \text{if } x \in [\mu - \sigma/\xi, \infty[, \xi > 0$$

$$EV2: G_2(x) = \exp(-(-x)^{-1/\xi}) \quad \text{if } x \in]-\infty, \mu - \sigma/\xi], \xi < 0.$$

If $\xi > 0$, GEV falls within the class of *Fréchet* (EV1) distributions, which feature regularly varying tails, including fat-tailed distributions, such as *Stable Paretian* distributions. $\xi < 0$ indicates (negative) *Weibull* (EV2)-type distributions, that is, distributions without a tail but a finite end-point (for example, uniform or beta distributions). In the case of $\xi \rightarrow 0$, GEV approaches a *Gumbel* (EV0) distribution, which encapsulates thin-tailed distributions,⁹⁰ for which all moments exist.

The cumulative distribution functions in the above equations are combined into a *unified* parametric specification of the GEV c.d.f., which for y_x is defined as

$$G_{y_x}(x) = \begin{cases} \exp\left(-\left(1 + \frac{\xi(x-\mu)}{\sigma}\right)^{-1/\xi}\right) & \text{if } 1 + \frac{\xi(x-\mu)}{\sigma} \geq 0, \\ \exp\left(-\exp\left(-\frac{\xi(x-\mu)}{\sigma}\right)\right) & \text{if } x \in \mathbb{R}, \xi = 0 \end{cases}, \quad (A2.1)$$

with the index for the test horizon dropped from this notation for simplicity. Differencing equation (8) above as $G'_{y_x}(x) = \frac{d}{dx} G_{y_x}(x)$ yields the probability density function

$$g_{y_x}(x) = \frac{1}{\sigma} \left(1 + \frac{\xi(x-\mu)}{\sigma}\right)^{-1/\xi-1} \exp\left(-\left(1 + \frac{\xi(x-\mu)}{\sigma}\right)^{-1/\xi}_+\right), \quad (A2.2)$$

where the scale, location, and shape parameters are estimated as $\hat{\mu} > 0$, $\hat{\sigma} > 0$, and $\hat{\xi}$, respectively. The scale parameter represents the annualized volatility of returns. The shape parameter is determined by the type of sub-model (EV0, EV1, or EV2). The moments are estimated concurrently by means of the *linear combinations of ratios of spacings* (LRS) method, which determines how quickly the probability of extreme observations converges to zero, using the historical spread dynamics over a chosen estimation horizon (Coles, 2001; Jobst, 2007b). The associated maximum likelihood (ML) estimator is evaluated numerically

⁸⁹ See Embrechts, Klüppelberg, and Mikosch (1997), Coles (2001), Vandewalle, Beirlant, and Hubert (2004), as well as Théron and Ribereau (2012) for additional information on the definition of EVT.

⁹⁰ For instance, normal, log-normal, gamma, and exponential distributions.

by using an iteration procedure (for example, over a rolling window of a constant number of observations with periodic updating) to maximize the likelihood $\prod_{t=1}^n g_{y_x}(x_t|\theta)$ over all three parameters $\theta = (\hat{\mu}, \hat{\sigma}, \hat{\xi})$ simultaneously.⁹¹

Given the expectation

$$\int_0^\infty \frac{x}{\hat{\sigma}} \left(1 + \frac{\hat{\xi}(x - \hat{\mu})}{\hat{\sigma}}\right)^{-1/\hat{\xi}-1} \exp\left(-\left(1 + \frac{\hat{\xi}(x - \hat{\mu})}{\hat{\sigma}}\right)^{-1/\hat{\xi}}\right) dx =$$

$$\left(\hat{\mu} + \frac{\hat{\sigma}}{1 - \hat{\xi}}\right) \left(-\left(1 + \frac{\hat{\xi}(x - \hat{\mu})}{\hat{\sigma}}\right)^{-1/\hat{\xi}}\right)$$

based on the cumulative distribution function in equation (A2.1) above, we obtain the CTE (or conditional VaR) as probability-weighted residual density beyond a pre-specified “severity threshold” defined by $VaR_{a,t}$ with the statistical significance defined by the parameter a .

Thus, equation (B1.2) in Box 1 can be rewritten as

$$CTE_{a,t} = \mathbb{E}[x_t | x_t \geq G_{y_x}^{-1}(a) = VaR_{a,t}] = \mu_{\tilde{r}_{UIA_t}} + \mathbb{E}[z_t | z_t \leq G_{y_x}(1 - a)] \sigma_{\tilde{r}_{UIA}}, \quad (A2.3)$$

with quantile function

$$G_{y_x}^{-1}(a) = \hat{\mu} + \frac{\hat{\sigma}}{\hat{\xi}} \left((-\ln(a))^{-\hat{\xi}} - 1 \right)$$

and

$$VaR_{a,t} = \sup \left(G_{y_x}^{-1}(\cdot) \mid \Pr(x > G_{y_x}^{-1}(\cdot)) \geq a \right). \quad (A2.4)$$

Equation (A2.3) is specified by the general definition of CTE (Artzner and others, 1999) as

$$CTE_{a,t} = \frac{\int_{VaR_{a,t}}^\infty (1 - G_{y_x}(x)) dx}{1 - G_{y_x}(VaR_{a,t})} = \frac{1}{1-a} \int_a^1 VaR_{a,t} da. \quad (A2.5)$$

⁹¹ Note that the maximum likelihood estimator fails for $\xi \leq -1$ since the likelihood function does not have a global maximum in this case. However, a local maximum close to the initial value can be attained.

B. Estimating the Generalized Pareto Distribution Using the Peaks Over Threshold Approach

Alternatively, the *Peaks over Threshold Approach* (POT) can be applied to approximate asymptotic tail behavior of all observations that exceed a pre-determined, sufficiently high threshold value.

We extract these extremes from the return distribution (see equation (B1.1) in Box 1) by taking the largest observations (exceedances) over threshold u , which is defined as $x_t > u$ for any $t = 1, 2, \dots, n$. Given the right endpoint of $x_0 = \sup\{x \in \mathbb{R}: \mathcal{F}_t(x) < 1\} \leq \infty$, the c.d.f. of excesses $y_t = x_t - u$ is given by

$$\mathcal{F}_t(y; u) = \Pr[x_t - u < y_t | x_t > u]$$

for $0 \leq x_t \leq x_0 - u$, which can be written as

$$\mathcal{F}_t(y; u) = \frac{\mathcal{F}_t(x) - \mathcal{F}_t(u)}{1 - \mathcal{F}_t(u)} \quad (\text{A2.6})$$

and approximated by the *generalized Pareto distribution* (GPD), whose c.d.f. is defined as

$$H_u(x) = \begin{cases} 1 - \left(1 + \frac{\hat{\xi}(x-u)}{\hat{\sigma}}\right)^{-1/\hat{\xi}} & \text{if } 1 + \frac{\hat{\xi}(x-u)}{\hat{\sigma}} \geq 0 \\ 1 - \exp\left(-\frac{\hat{\xi}(x-u)}{\hat{\sigma}}\right) & \text{if } x, u \in \mathbb{R}, \hat{\xi} = 0 \end{cases}, \quad (\text{A2.7})$$

with quantile function

$$H_u^{-1}(a) = \frac{\hat{\sigma}}{\hat{\xi}(x-u)} \left((1-a)^{-\hat{\xi}} - 1 \right), \quad (\text{A2.8})$$

where the scale and shape parameters are estimated as $\hat{\sigma} > 0$ and $\hat{\xi}$, respectively. We can rearrange equation (A2.6) above as⁹²

$$\mathcal{F}_t(x) = \left(1 - \mathcal{F}_t(u)\right) \mathcal{F}_t(y; u) + \mathcal{F}_t(u) \quad (\text{A2.8})$$

and replace $\mathcal{F}_t(y; u)$ with $H_u(x)$ and $\mathcal{F}_t(u)$ with its empirical estimator $n - n_u/n$ so that the c.d.f. consistent with GPD becomes

$$\mathcal{F}_{GPD,t}(x) = 1 - \frac{n_u}{n} \left(1 + \frac{\hat{\xi}y}{\hat{\sigma}}\right)^{-1/\hat{\xi}} \quad (\text{A2.9})$$

⁹² Note that the specification of the GEV and GPD probability distributions assumes stationarity; however, in practice, extreme observations often violate the stationarity assumption. If the stochastic process of asset returns is non-stationary, the estimated parameters are time-dependent. See Cheng and AghaKouchak (2014), Cheng and others (2014), Ruggiero and others (2010), and Chavez-Demoulin and Embrechts (2004) for alternative approaches to deal with non-stationarity in extreme observations.

if $\hat{\xi} \neq 0$, with the total number n of observations and the number n_u of exceedances above the threshold u . The corresponding point estimate of $\mathcal{F}_t(u) < a$ for $u = x_t - y_t$ can be derived from the corresponding quantile function

$$\mathcal{F}_{GPD,t}^{-1}(a) = u + \frac{\hat{\sigma}}{\hat{\xi}} \left(\frac{n_u}{n} (1-a)^{-\hat{\xi}} - 1 \right). \quad (\text{A2.10})$$

Thus, we can rewrite equation (B1.3) in Box 1 in terms of the quantile corresponding to the threshold choice so that

$$\mathbb{E}[z_t | z_t \leq \mathcal{F}_{GPD,t}^{-1}(1-a)] = \mathcal{F}_{GPD,t}^{-1}(1-a) + \mathbb{E}[z_t - \mathcal{F}_{GPD,t}^{-1}(1-a) | z_t \leq \mathcal{F}_{GPD,t}^{-1}(1-a)]. \quad (\text{A2.11})$$

Since the second term on the right is the average of the *mean excess function* (MEF)

$$e(u) = \mathbb{E}[X - u | X > u] = \frac{\sigma + \xi u}{1 - \xi} \quad (\text{A2.12})$$

over threshold quantile $\mathcal{F}_t^{GPD}(1-a)$, which is linear in threshold u for $0 < \xi < 1$ and $\sigma + u\xi > 0$, we can write

$$\mathbb{E}[z_t - \mathcal{F}_{GPD,t}^{-1}(1-a) | z_t \leq \mathcal{F}_{GPD,t}^{-1}(1-a)] = \frac{\sigma + \xi [\mathcal{F}_{GPD,t}^{-1}(1-a) - u]}{1 - \xi}. \quad (\text{A2.13})$$

Plugging equation (A2.13) into equation (A2.11) results in

$$\begin{aligned} \mathbb{E}[z_t | z_t \leq \mathcal{F}_{GPD,t}^{-1}(1-a)] &= \mathcal{F}_{GPD,t}^{-1}(1-a) + \frac{\sigma + \xi [\mathcal{F}_{GPD,t}^{-1}(1-a) - u]}{1 - \xi} \\ &= \frac{\mathcal{F}_{GPD,t}^{-1}(1-a) + \sigma - \xi u}{1 - \xi}. \end{aligned} \quad (\text{A2.14})$$

Replacing equation (A2.11) of CTE above and equation (B1.3) in Box 1 with the expression above (equation (A2.14)), we have

$$CTE_{a,t} = \mathbb{E}[x_t | x_t \geq \mathcal{F}_t^{-1}(a) = VaR_{a,t}] = \mu_{\tilde{r}_{UIA_t}} + \left[\frac{\mathcal{F}_t^{GPD}(1-a) + \sigma - \xi u}{1 - \xi} \right] \sigma_{\tilde{r}_{UIA}}. \quad (\text{A2.15})$$

APPENDIX III. MODELING DISPLACED COMMERCIAL RISK VIA CONTINGENT CLAIMS ANALYSIS

Displaced commercial risk (DCR) represents the share of unexpected losses that are not absorbed by holders of unrestricted investment accounts (IA) during times of stress (see Box 1). These liabilities are subject to the risk-sharing principle of *shari'ah*-compliant contracts and normally bear any shortfall in expected returns (or losses). Reserves (PER and IRR; see Figure 5) help mitigate the run-off risk by converting the equity-like claim of IA depositors, in whole or in part, into a quasi-secured credit claim. Despite the stability-enhancing characteristics of these reserves, transferring some shareholder wealth to unsecured creditors raises the bank's default risk. In the firm value model, such as the *Black-Scholes-Merton* (BSM) approach, this conversion amounts to adding the outstanding amount of IAs subject to DCR to the amount of existing payment obligations, which raises the default threshold.

Contingent claims analysis (CCA) could determine a market-based estimate of DCR. CCA generalizes the BSM approach for the assessment of credit risk (Jobst and Gray, 2013), and helps estimate the fair value of reserves required to cover DCR as the marginal impact of a higher default threshold on the bank's default risk over a pre-defined risk horizon. In CCA, this change of default risk would amount to higher market-implied expected losses of the bank due to a larger amount of outstanding liabilities relative to available assets using a risk-adjusted valuation of the balance sheet.

In general, CCA quantifies default risk based on the assumption that owners of equity in leveraged firms hold a call option on the firm value after outstanding liabilities have been paid off.⁹³ The asset value is assumed to follow a random, continuous process and can be either above or below the amount required for the repayment of funding over a specified period of time. This capital structure-based valuation approach of state-contingent contracts implies default if a firm's asset value is insufficient to replay non-equity investors (including depositors) at maturity, which constitutes the bankruptcy level ("default threshold" or "distress barrier") in present value terms. Conversely, if the value of assets exceeds that of liabilities (that is, the "distance to default" is positive), the call option held by equity holders on firm value has intrinsic value (in addition to its time value until the maturity of debt).

The impact of DCR on expected losses can be valued as an implicit put option. The default risk is viewed if it were a put option written on the amount of outstanding liabilities, where the default barrier represents the "strike price," with the value and volatility of assets determined by changes in the equity and equity options prices of the bank (or close approximations using various statistical techniques for non-listed banks, which are suggested

⁹³ It is based on three principles: (1) the values of liabilities are derived from assets; (2) assets follow a stochastic process; and (3) liabilities have different priorities (senior and junior claims).

in IMF, 2014). Since the repayment of all funds is considered “risky,” the probabilistic estimate of the default risk can be expressed as a put option on asset performance. The value of the put option value reflects the expected loss of the bank, that is, the probability and the degree to which the future asset value of the bank falls below the “default barrier.” It increases the higher the probability of the asset value falling below the default barrier over a predefined horizon. Such probability is influenced by changes in the level and the volatility of the implied asset value reflected in the bank’s equity and equity option prices, conditional on its capital structure, the maturity term of total payments to investors, and the leverage of the bank. The risk-adjusted return compensates for the expected losses investors accept in funding the bank (that is, the expected return on investment promised to IA holders).

The present value of market-implied expected losses can be priced as a (European) put option

$$\mathbb{E}_t(L_{t+\tau}) = \mathcal{P}_E(A, B, \tau, t) = \Phi(-x_-)B_{\tau,t}e^{-r\tau} - \Phi(-x_+)\tilde{A}_t$$

if the change of the bank’s implied asset value over time, \tilde{A}_t , is modeled as a geometric Brownian motion, where $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution, the present value $D = B_{\tau,t}e^{-r\tau}$ of outstanding payment obligations B is the strike price on the asset value, asset volatility is defined as

$$\sigma_{\tilde{A}} = \frac{E_t\sigma_E}{\tilde{A}_t\mathcal{N}(x_+)} = \left(1 - \frac{\mathcal{N}(-x_-)B_{\tau,t}e^{-r\tau}}{\tilde{A}_t\mathcal{N}(x_+)}\right)\sigma_E$$

over time horizon $T - \tau$, with (observable) equity volatility, σ_E , market capitalization, E_t , the risk-free rate of return, r , subject to the sensitivity

$$x_{\pm} = \frac{1}{\sigma_{\tilde{A}}\sqrt{\tau}} \left[\ln \frac{\tilde{A}_t}{B_{\tau,t}} + \left(r \pm \frac{\sigma_{\tilde{A}}^2}{2} \right) \tau \right]$$

of the option price to changes in the relation between the implied asset value and all outstanding payment obligations after adjusting for asset volatility.

Thus, the (market-implied) estimate of the implicit transfer of shareholder wealth to UIA holders to cover DCR can be written as

$$\Delta\mathcal{P}_E = \mathcal{P}_{EDCR}(A, B, DCR, \tau, t) - \mathcal{P}_E(A, B, \tau, t),$$

which represents the impact of the non-mitigated impact of DCR on the (market-implied) expected losses of an Islamic bank,⁹⁴ where

⁹⁴ Note that this approach uses market prices to endogenize the risk-weighting of assets in the market-based assessment of solvency risk, and thus the impact of DCR on the scope of loss-absorption through the liabilities funding assets that experience a negative valuation shock (that is, losses from projects [investments and lending] undertaken by the bank).

$$\mathcal{P}_{EDCR}(A, B, DCR, \tau, t) = \Phi(-x_{DCR-})(B_{\tau,t} + DCR_{\tau,t})e^{-r\tau} - \Phi(-x_{DCR+})\tilde{A}_t,$$

$$x_{DCR\pm} = \frac{1}{\sigma_{\tilde{A}}\sqrt{\tau}} \left[\ln \frac{\tilde{A}_t}{B_{\tau,t} + DCR_{\tau,t}} + \left(r \pm \frac{\sigma_{\tilde{A}}^2}{2} \right) \tau \right],$$

and

$$DCR_{\tau,t} = \alpha^* \times RWA_{UIA} RW_{UIA} \frac{UIA}{A},^{95}$$

based on the estimated unexpected losses according to the methodology in Box 1.

APPENDIX IV. THE PROCESS-DRIVEN PERSPECTIVE OF PROFITS IN ISLAMIC FINANCE

The prohibition of interest-based forms of income under Islamic finance principles is inherently linked to the *shari'ah* concept of wealth (*mal*).⁹⁶ The lawfulness of a transaction hinges on the commercial value of any obligation arising from the underlying contractual agreement. If an obligation is considered to have commercial value, it can be sold in exchange for another item of known value in return for fair compensation commensurate to the consumption of wealth. In this regard, two aspects are typically considered: (i) the nature of wealth and the defining elements of value in the Islamic legal tradition (*al-fiqh*); and (ii) the degree to which such value is realized in a transaction.⁹⁷

Thus, the combination of the following three elements of wealth⁹⁸ would make a transaction contractually valid (*sahih*) and permissible from a *shari'ah* perspective:⁹⁹

- *The presence of an intended “usufruct”* (that is, meaningful use). The meaningful use in the spirit of *usufruct* is defined as a proper objective in term of attracting a specific benefit or repelling detriment;

⁹⁵ Note that the uncertainty around DCR could also affect the implied asset volatility, $\sigma_{\tilde{A}}$, which is kept constant for simplicity.

⁹⁶ See Kammer and others (2015) for a conjunctural perspective on Islamic finance.

⁹⁷ The assessment of whether a transaction is permissible tends to follow *shari'ah* rulings (*ijtihad*) aimed at determining its “effective cause” (*illah*) based on analogous reasoning (*qiyas*). However, this purely legal perspective based on historical precedent could result in a very restrictive legal interpretation of *shari'ah* principles, suggesting a greater focus on the original objective and intent of Islamic contracts (*maquasid al-shari'ah*) based on economic rationale (*hikmah*).

⁹⁸ More specifically, a legal definition of wealth is stated in Al-Buhuti (2003) as “whatever has a legitimate *usufruct* for other than a needs-related interest or a [life-saving] essential,” which excludes whatever is without use or has illegitimate use as well as permitted use in exceptional circumstances or for specifically defined purposes.

⁹⁹ As further aspects of the concept of wealth creation, *shari'ah* also prohibits betting and gambling (*maisir*) as unethical (or socially detrimental and sinful) activity (*haram*) in contracts with a remote probability of positive payoffs to the investor (“game of chance”) and preventable contractual uncertainty (*gharar*).

- *The commercial value of “usufruct.”* If the object of a transaction is accorded value from a legal perspective, if it has generally acknowledged monetary value based on the commercial practice or current custom (*al-‘urf*), this implies that the absence of wealth in the past bears no relevance to the current interpretation of wealth if customs as to the creation of value have changed over time; and
- *The lawfulness of “usufruct.”* While the permissibility of any *usufruct* related to a contract requires the support of a legal (or scriptural) confirmation of its lawfulness, a similar prerequisite related to financial exchanges is neither sought after nor stipulated (Hammad, 2007).¹⁰⁰ Thus, the lawfulness of a contract—as a result of a financial transaction defined by the exchange of value for certainty about the value of a reference asset—depends on the underlying intent regarding its purpose and final use by the beneficiary rather than the general permissibility of the usufruct itself.

¹⁰⁰ Ahmad (1949) states that lawfulness is precedent in all financial contracts and transactions unless there is clear a prohibition. This is further clarified by Al-Shawkani (1984), who stated that “anything to which a lawful usufruct may be attributed may lawfully be sold. However, anything which has no usufruct to begin with (or which has an unlawful usufruct) may not be lawfully sold. This is because the means to the unlawful is itself unlawful.”

APPENDIX V. COMPREHENSIVE REPRESENTATION OF CREDIT AND MARKET RISKS IN STRESS TESTING

The deterioration of a bank's asset quality (due to either broad-based deterioration of economic conditions or a negative shock to a specific economic sector) results in a general increase of *nonperforming asset* (NPA) balances (and potentially higher specific provisions and charge-offs) and higher unexpected losses (which tends to be reflected in a higher capital intensity of credit-sensitive assets). While the realization of credit losses (and associated changes in expected losses) is relatively straightforward to measure and project, the change in capital intensity of unexpected losses, which can be expressed as

$$\underbrace{f(\Delta PD_{portfolio})}_{\Delta RWA_{credit\Delta PD}} + \underbrace{f(\Delta HHI_{portfolio})}_{\Delta RWA_{credit\Delta concentration}}, \quad (A5.1)$$

requires a detailed understanding of the sensitivity of credit RWAs to changes in default risk and portfolio concentration based on the historical credit performance and the composition of the bank's credit portfolio.¹⁰¹

The following (additive) increase of risk weights can be considered using general assumptions about the sensitivity of RWAs under stress conditions:

- The *nonlinear effect of changes in PDs on RWAs*, $f(\Delta PD_{portfolio})$, is determined by fixing the asset correlations to the lowest level of the PDs (that is, a level corresponding to an “AAA/Aaa”-rating) and the loss-given-default (LGD) to 45 percent.¹⁰² Thus, the marginal increase of RWAs (in percent) for an increase of PDs (in percent) can be calculated for each portfolio as (Jobst, 2013):

$$\Delta RWA_{credit\Delta PD} = 0.12 \times \Delta PD_{portfolio}^2 - 0.049 \times \Delta PD_{portfolio} + 0.006, \quad (A5.2)$$

where the change in unexpected losses should be consistent with the change in loan loss provisions. The RWAs of total lending for a given level of PD (in percent) can be derived from

$$RWA = K \times 12.5 \times EAD, \quad (A5.3)$$

¹⁰¹ This equation can be further refined based on the changes in the “automatic” collateralization of many *shari'ah*-compliant contracts due to the requirement of direct investor claims to the profit-generating asset/capital.

¹⁰² Since the impact of LGDs on RWAs is linear, the elasticity of unexpected losses leading to changes in RWAs can be extracted from the Basel II IRB formula for corporate loans.

where

$$K = LGD \times \left[\Phi \left(\frac{\sqrt{1/1-R} \times \Phi^{-1}(PD)}{\sqrt{R/1-R} \times \Phi^{-1}(0.999)} \right) - PD \right] \quad (A5.4)$$

and

$$R = AVC \times \left(0.12 \times \frac{1-e^{-50PD}}{1-e^{-50}} + 0.24 \times \left(1 - \frac{1-e^{-50PD}}{1-e^{-50}} \right) \right) \quad (A5.5)$$

using the credit risk assessment for mortgage loans¹⁰³ under the Basel III framework (BCBS, 2005). $\Phi(\cdot)$ and $\Phi^{-1}(\cdot)$ denote the standard normal and the inverse standard normal cumulative distribution functions; EAD is the exposure at default; AVC is the asset value correlation (and takes the value $AVC = 1.25$ if the company is a large regulated financial institution [total asset equal or greater to US\$100 billion] or an unregulated financial institution regardless of size, else $AVC = 1$). The estimate of forward-looking (expected loss) provisioning based on aligning loan loss provisions (relative to operating income) to the RWA-implied PD is $(0.00092 \times RWA^2 - 0.06 \times RWA + 1.662) \times (LGD/100)$ (Jobst and Weber, 2016).

- The *impact of concentration risk on RWAs*, $f(\Delta Concentration_{portfolio})$, is calculated as the percentage increase of RWAs (in percent),

$$\Delta RWA_{credit_{\Delta concentration}} = 100 + (0.02 + 12.6 \times HHI), \quad (A5.6)$$

at portfolio level (HHI =Herfindahl-Hirschman concentration measure) for the average exposure-weighted default probability $PD_{portfolio} = 0.4\%$. For each 0.4 percentage point increase ($PD_{portfolio} > 0.4\%$), the value of ΔRWA_{credit} above increases by $1 + (PD_{portfolio}/0.4\% - 1) \times 0.1$; for instance, a very large portfolio with a low degree of concentration ($HHI \leq 0.0006$) and an EAD-weighted $PD_{portfolio} = 0.8\%$ would be expected to experience an increase of RWAs by 3.0 percent due to the impact of concentration risk on unexpected losses.

Similar to the consideration of unexpected losses from credit risk, higher price volatility and/or changes in the composition of listed exposures (sales and profit- and loss-sharing contracts) in the trading and investment portfolios (which are classified as MtM [or “held with a trading intent {HfT}”] and AfS [or “Fair Value Reported in Other Comprehensive Income {FVOCI}”] under the revised IFRS) change the unexpected losses from market risk, so that

¹⁰³ Due to the frequent absence of granular data on the maturity profile of lending contracts, this simplified approach was chosen (with loss of generality).

$$\Delta RWA_{market} = \underbrace{f(\Delta VaR_{portfolio})}_{\Delta RWA_{marke \Delta price}} - RWA_{\Delta market}. \quad (A5.7)$$

The expression above reflects the change in the sum of VaR, stressed VaR, and incremental risk charges using short-term price changes over a 10-day period, $f(\Delta VaR_{portfolio})$ (consistent with the regulatory definition of market risk (BCBS, 2015)) and the net change in portfolio allocation affecting RWAs, $RWA_{\Delta market}$, based on investment and trading behavior under stress.

APPENDIX VI. THE EVOLVING NATURE OF STRESS TESTING

The effective implementation of stress testing approaches requires a framework that is relevant and adequate amid an evolving and complex international financial system. Greater data availability, enhanced statutory reporting, and supervisory coordination have also helped broaden the scope of macrofinancial linkages and their integration into more consistent scenarios, covering a wider range of non-bank financial institutions and markets. The IMF staff has made significant efforts to close important gaps that were highlighted by the global financial crisis to ensure that FSAP stress tests are fit for purpose and encompass the following four essential domains:¹⁰⁴

- *Dynamic approach.* A more dynamic approach considers changes in institutional behavior that can affect the capital impact of adverse macrofinancial scenarios. For instance, banks could react to stress situations by ringfencing liquidity, balance sheet adjustments (through asset sales and/or lower credit growth), raising capital, or withholding dividends;
- *Spillover effects.* The interconnectedness within financial systems (such as interbank markets) and the interactions of financial institutions with non-financial entities (through common exposures, such as the housing market), both within and across national boundaries, can result in knock-on effects related to financial contagion and amplify initial shocks system wide;
- *Cross-functional perspective of solvency and liquidity risks.* Liquidity and solvency risks of individual institutions are increasingly connected during times of stress and tend to be influenced by system-wide liquidity conditions associated with the interconnectedness and network effects within the financial system.¹⁰⁵
- *Feedback loop with real economy.* The two-way interaction between the real economy and financial activities, and related feedback effects generated by banks' reaction function to stress requires a dynamic specification of transmission channels (including the consistent and comparable design of macrofinancial scenarios, which could be enriched with insights into the adjustment process of economic agents to price and output shocks from full (or partial) equilibrium macroeconomic models).

¹⁰⁴ Dees and others (2017) present the models supporting the EU-wide stress testing exercises as part of an overall framework that covers a similar set of principles and concepts governing the key dimensions of macroprudential stress testing.

¹⁰⁵ The assumed origin of the stress is usually an adverse shock to the credit portfolios of banks, which affects the risk drivers (PDs, LGDs) and/or asset values. These first-round shocks reduce the capital ratio. If capital becomes a binding constraint, liquidity risk emerges in various forms in most models. A declining capital ratio can lead to higher funding costs, charged by lenders as a reflection of higher counterparty risk. Liquidity risk can also follow from feedback effects arising from various transmission channels. Some models assume that funding rollover stops in response to higher counterparty risk and defaults in the network of exposures.