Large Exposures: Implicit Credit Risk Concentration add-ons and the Basel Framework

Grandes exposiciones: add-ons *por concentración de riesgo de crédito implícita y el marco de Basilea*

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Abstract

The Basel large exposures standard, addressed to banks, is in the process of being implemented, and although the new rule is reducing the limit for the large credit exposures in banks, and is geared to better control the portfolio risk parameters that make a portfolio more prone to losses due to credit concentration, it is important to know the share of risk and capital implicit to this new rule. In this work, the implicit add-ons for credit risk concentration are determined through a Monte Carlo credit risk model, and the results are compared with current capital requirements. The author also analyzed the complete Basel framework to understand how the concentration risk is addressed in an integrated approach rather than with a specific capital supplement.

Keywords: *large exposures, LEX, credit risk concentration add-ons, granularity adjustment, HHI, ICAAP, CVaR.*
JEL Classification: *F38, G21, G28.*

Resumen

La regulación de Basilea sobre grandes exposiciones está en proceso de implementación y, aunque es una regulación que reduce el límite del tamaño para las exposiciones de gran tamaño en los bancos y está orientada a un mejor control de los parámetros de riesgo que ocasiona que los portafolios se inclinen más a tener pérdidas grandes por concentración de crédito, es importante conocer la porción de riesgo de crédito y capital que lleva implícita. En este trabajo se determinan, mediante una simulación Montecarlo a través de un modelo de riesgo de crédito, los add-ons *implícitos (o añadidos implícitos) debidos a la concentración de crédito, y se comparan con los requisitos actuales de capital. Al mismo tiempo, se analiza el marco completo de Basilea para entender cómo se aborda el riesgo de crédito de concentración, esto es, de forma integral, más que mediante un suplemento particular de capital.*

Palabras clave: *grandes exposiciones, LEX,* add-ons *por concentración de riesgo de crédito, ajuste de granularidad, HHI, ICAAP, CVaR.*
Clasificación JEL: *F38, G21, G28.*

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1. Introduction

A regulation on bank's large exposures was issued in 2019 by the Bank for International Standards (Basel Committee) and is being implemented by countries within the Basel Accord following local implementation schedules. In Mexico, the regulation entered into effect in October 2023. The large exposures regulation is a tool to deal with credit risk concentration, specifically "name concentration". However, questions on the effectiveness of this regulation were raised regarding the adequacy of the capital requirement. Thus, there is a need to analyze if the current capital requirement is aligned with the charge of capital implicit in this regulation regarding credit risk concentration. Due notice is given to the fact that the credit risk due to concentration accounts for an important share or capital at risk, measured through the computed add-ons.

Concentration risk arises basically from two kinds of concentration of credit risk: The so-called "name risk" referred to as the one resulting from a single counterparty or a group of connected counterparties, and the concentration in economic sectors. This work addresses the "name concentration" problem since this is the focus of the large exposures regulation.

The Basel regulation placed its initial focus on credit risk capital requirements given that it is the main component of capital for most banks. The regulatory framework included two approaches:

I. The standard model, based on agencies' external ratings, where the risk weight of a loan for corporate loans depends on the credit rating of the obligor, the risk weight of other credit transactions was fixed by the regulator according to the type of transaction and parameters like the loan-to-value ratio in the case of residential loans.

II. The internal ratings-based approach (IRB), with models developed internally by the banks and assessed and approved by the regulator. The models determined the three basic risk parameters for credit: probability of default, loss given default, and exposure at default (PD, LGD, and EAD). At the same time, the IRB had two approaches: foundation IRB and advanced IRB (FIRB and AIRB). In the foundation approach, the bank develops an internal model to estimate the probability of default but has to use the regulatory parameters for the LGD and EAD. Under this approach, banks compute the capital requirement with a closed formula that provides the comparison capital requirement used by the author in this work.

At the beginning (2000–2004) there was a proposal to include a component of the capital requirement resulting from the concentration level of the bank's portfolio. Eventually, the Basel Committee did not include this capital component, and the discussion on how to deal with credit risk concentration remained open. After years of discussion, the proposal for a different approach emerged in 2014 and concluded in 2019. This was called the large exposures approach or LEX. This work looks retrospectively and links the initial discussion with the final proposal.

2. Objective

This work seeks to determine the add-on implicit in the large exposures regulation (LEX, following the Bank for International Settlements—BIS—practice) and to assess its importance in the regulatory capital. The regulation has followed a different path from computing and assigning a specific supplement of capital due to credit risk concentration, relying more upon the complete Basel framework, as well as on current and in-process capital supplements. Therefore, it is important to quantify the risk implicit in the new LEX rule. The difference between the capital requirement without concentration, measured by the capital requirement through the Basel IRB formula, and the requirement including concentration in the credit portfolio will be the adjustment add-on—the share of risk not included in the regulatory requirement. To do so we will go from a capital requirement with only a systemic risk to a capital requirement including an idiosyncratic risk derived from the risk concentrated in a single counterparty or a group of connected counterparties. We hypothesize that the concentration credit risk has an important share of capital at risk since real-world portfolios are heavily concentrated.

3. Previous Studies on Credit Risk Concentration and add-on Computation

The problem of credit risk concentrations has been extensively addressed in the past. Works can be classified according to the problems addressed from 2000 to the present.

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3.1 Stage 1: Works Preceding the 2004 BIS Document

Assessment of the granularity approach or the ASFR framework adopted by the Basel Committee. Studies and literature collected by the BIS's Committee on Banking Supervision (BCBS) itself helped define the June 2004 *International Convergence of Capital Measurement and Capital Standards* document.

Works included in the BIS Selected Literature on Concentration Risk in Credit Portfolios—published between 2001 and 2004. (BCBS, 2005).

a) Basel II and its asymptotic single-risk-factor model foundation (3 works): Gordy (2003), Wilde (2001a), Basel Committee on Banking Supervision (2004), represents the research, presentation, and publishing of the asymptotic IRB formula that excludes all concentration risk in the capital requirement.

b) Granularity adjustment for single name concentrations (six works). They address the 2001 first BIS proposal to adjust the capital requirement for single-name concentration. Wilde (2001b) summarizes the main problem with the 2001 adjustment: "[T]he granularity adjustment as presented in Basel II is inaccurate and [so is] the belief expressed in its derivation." As we know, this adjustment was discarded.

c) VaR adjustment for sector concentration (two works).

d) Estimation of default dependence (nine works).

e) Contagion in credit portfolios (four works).

We can consider this selection of literature as an initial departing point for concentration risk as presented in the large exposures' regulation. These works were developed before the 2004 Basel document. They explain the IRB formula, and the initial proposal for adjusting such formula and show problems aside from name concentration. Works on correlation were useful to determine the correlation formula that accompanies the IRB capital formula. Apart from correlation in defaults, those works address dependence regarding sectors. Contagion, as well as concentration and dependence in economic sectors, is out of the scope of this work.

3.2 Stage 2. Works After the Publishing of the BIS Committee 2004 Convergence Document

This stage is summarized in the BIS's Committee on Banking Supervision 2006 Working Paper No. 15, *Studies on credit risk concentration* (BCBS, 2006) that addresses the main issues around credit risk concentration, some of them finally present in the BIS regulation and especially in the LEX:

a) The economic capital due to concentration and the technical difficulties in computing this capital, particularly in sector concentration.

b) The use of the Hirschman-Herfindahl Index (HHI).

c) The use of credit limits to manage concentration risk.

d) Business interconnectedness and its impact on contagion.

e) Stress that testing is a tool to identify the effect of concentration risk in capital requirements.

f) Issues around data to handle and properly address the concentration risk, including those to consolidate the total exposure.

The topics related to economic capital were particularly useful for this document; the rest helped us understand the complete Basel framework as an integrated tool.

3.3 Stage 3. Works Published Before the Final LEX Regulation was Released

The IRB Basel formula follows the Asymptotic Single Risk Factor Framework (ASRF) that assumes infinity granular portfolios, which does not consider the credit concentration that accompanies most corporate loan portfolios. Therefore, the natural attempt was to compute a granularity adjustment based on the Hirschman– Herfindahl Index, whose inverse provides the number of loans for a given level of concentration, this was done by Gordy and Lutkebohmert in 2013, as quoted by Nokkala (2022, p. 380): "The granularity adjustment of Gordy and Lutkebohmert (2013) uses portfolio exposure distribution and aligns the fully diversified IRB unexpected loss with non-diversified portfolios' corresponding unexpected loss."

Regarding the portfolio size to study concentration risk, Nokkala states the following:

> The literature on credit portfolios does give some guidance on how to construct realistic portfolios in terms of exposure distribution with a given portfolio size n. Heterogenous credit sizes are practically observed in research and Galaasen et al. (2020) presents [sic] an "80% to 20%" rule, stating that 20% of the largest credits constitute 80% of a portfolio's exposure. (Nokkala, 2022, p. 382).

In our proposal, the concentration level is the one implicit in the LEX regulation.

Martin Hibbeln published an extensive book on the matter (Hibbeln, 2010). Following different approaches, he determined add-ons using parametric models as well as Montecarlo simulations.

The BIS finally followed a comprehensive approach including different components of its regulation, but research continues extending the lines we have mentioned. One interesting line is the use of complex systems to analyze contagion risk due to credit concentration (Relim et al., 2019).

4. The Large Exposures (LEX) Regulation Components and their Implications

In this work, we will use the global regulation (Financial Stability Institute, 2022) and the specific implementation in Mexico for examples, parameters, and precise implications.

The BIS LEX framework was concluded and released by the BIS to enter into effect as of January 1st, 2023. It was implemented in Mexico in 2023 and became effective in October 2023 for systemic banks. The BIS assessed Mexico as LEX regulatory-compliant in December 2023 (BCBS, 2023, p. 7).

Main components of the Financial Stability Institute, 2022:

- The LEX regulation defines Tier 1 capital as the capital reference to determine the LEX limits. This is to ensure that banks consider only high-quality capital to absorb losses derived from high credit risk concentration.
- LEX requires banks to consolidate their credit exposures at name (single counterparty) or group of interconnected counterparties. The banks must conduct an assessment of economic interdependencies to define connectedness due to economic interdependency.

- The regulation defines a large exposure as a consolidated exposure equal to or higher than 10% of the bank's Tier 1 capital.
- Exposure limits set by LEX:
    - 25% of Tier 1 capital for any counterparty or group of interconnected counterparties.
    - 15% of Tier 1 capital for Global Systemic Important Banks (G-SIBs) and connected counterparties.
- Connections include not only control relationships among counterparties but any relevant economic interdependency (due to concentration on sales, suppliers, loans, guarantees, or another important dependency.)
- Banks monitor their LEX and report them to regulators. In case of any limit breach, the banks must remediate immediately.
- Exposures in LEX include both banking and trading books and in-balance and off-balance elements. The target is to consolidate all credit risk derived from the relation with the counterparties or group of connected counterparties. This approach differs from the previous one, which focused on loans.
- Mitigation. The LEX permits the use of mitigants used for regulatory capital computation purposes to reduce exposures—such as collaterals, guarantees, credit protections, etc.

The LEX implementation in Mexico contains all BIS components:

- LEX permits banks to conduct the assessment on counterparties or groups of interconnected counterparties only when the exposure is equal to or higher than 5% of Tier 1 capital.
- The exposure of the four main counterparties or group of interconnected counterparties must be lower than the Tier 1 capital.
- Besides de G-SIBs, Local Systemic Banks (D-SIBs) are included in the 15% of Tier 1 capital limit.

Let us rethink the LEX regulation and its implications in the management of the credit concentration risk and the metrics to manage the credit risk.

The LEX regulatory approach does not include a specific capital requirement for credit risk concentration but requires the development of a framework to manage such risk. Nonetheless, the LEX regulation's components have important implications for the parameters used to compute the capital requirement under the IRB framework. As shown in Table 1, we can align the components with the credit risk key parameters that are important to determine the capital requirement (see Table 1).

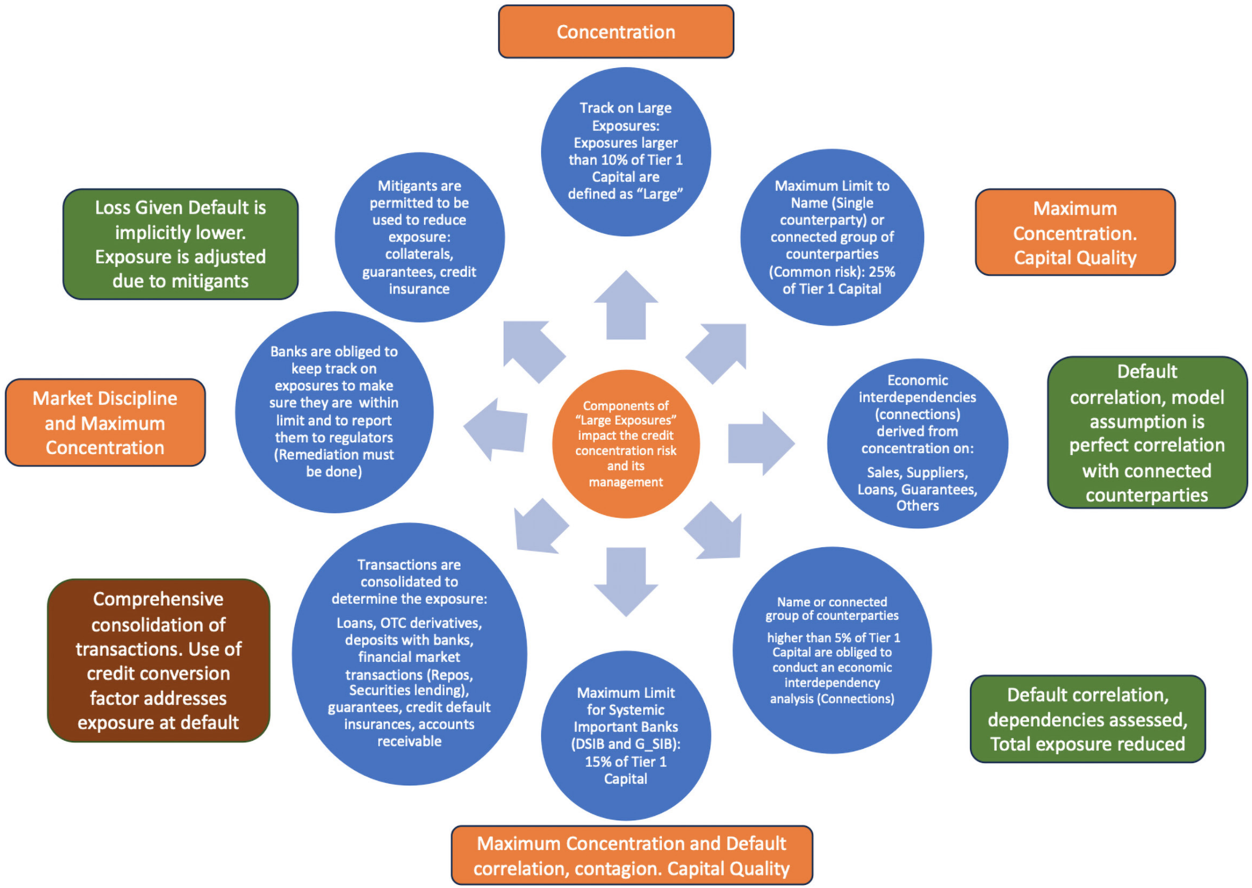
Table 1. LEX Components and Related Credit Risk Parameters

LEX Component	Related Credit Risk Parameter
Large Exposure equal to or higher than 10% of Tier 1 capital Limit of 25% of Tier 1 capital Limit of 15% of Tier 1 capital	**Concentration** vs infinite granular approach in the IRB Basel formula. Specific levels of concentration can be derived from LEX rules.
Exposures include: • Banking book (in- and off-balance) • Trading book Determination of exposure includes the use of credit conversion factors	**EAD (Exposure at Default).** Size of the exposure through consolidation of all exposures and the use of credit conversion factors.
Use of mitigants (collaterals, guarantees, credit insurance, etc.)	**LGD (Loss Diven Default)**. The use of permitted mitigants implies a lower LGD.
Economic interdependency analysis Grouping connected counterparties (Due to both control and economic interdependencies)	**Correlation**. Connected counterparties are considered by the LEX as a single exposure for concentration purposes, so a perfect correlation is assumed for connected counterparties.
Limits to G-SIBs and D-SIBs	**Systemic risk and diversification**. Limiting exposures with G-SIBs and D-SIBs forces the system to diversify the funding of banks that may have systemic impact and contagion.

Source: Prepared by the author.

In theory, all those elements provide a framework to manage the concentration risk. In Figure 1 all the elements of the framework are joined and show at the center the management of the concentration risk (see Figure 1). We can trace how every component affects the credit risk parameters, as shown in Figure 2 (see Figure 2). Our objective is to model portfolios derived from the LEX regulation and to compute the concentration component that is completely absent from the Basel IRB formula.

Figure 1. Components of Large Exposures Regulation and Effect on Risk Management and Risk Metrics Parameters



Source: Prepared by the author.

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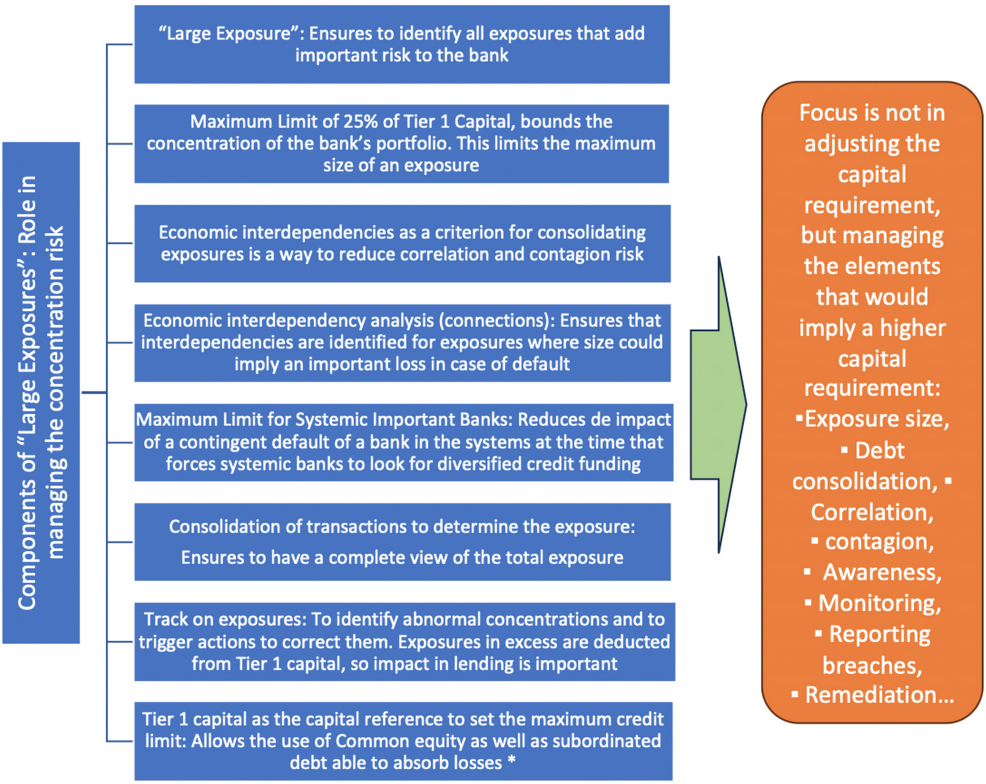
Figure 2. Components of Large Exposures Regulation and Effect on Risk Management and Risk Metrics Parameters



* In the case of Mexico, only subordinated debt convertible to capital is allowed. The law must be modified to permit the use of other absorbing losses debt to be used.

Source: Prepared by the author.

Before addressing the task of computing capital requirements, it is worth pointing out that the LEX regulation is not the only component of the Basel regulation dealing with handling credit risk concentration. The complete framework is important to deal with this risk, but of course, not only with this risk. The next section addresses this issue.

5. The Basel Regulation Framework and its Connection with the Concentration Risk

At the end of the day, the LEX regulation is looking to avoid impacts on the financial system derived from large losses in banks due to large exposures in loans granted and other credit exposures.

As explained in the *Large exposures standard: executive summary* (Financial Stability Institute, 2022) document, the LEX standard is part of the Basel III reform package that complements the Basel Committee on Banking Supervision's risk-based capital framework to achieve a:

- Microprudential objective of serving as a backstop to the risk-based capital regime by protecting banks from incurring large losses from the default of a single counterparty or group of connected counterparties.
- Macroprudential objective of supporting efforts to manage systemic risks by reducing the interconnectedness between systemically important banks.

It is important to highlight the following:

- The systemic focus of the standard.
- The seeking of reduction of the interconnectedness.
- To bound exposures to limit large losses.
- The risk-based capital regime.

Thus, it is not only important to study the complete framework but also to compute the impacts on capital according to the implicit risks in the LEX.

First, let's address the BIS framework's components and their connection with the credit concentration risk. For our purpose, the relevant components are as follows:

I. The Basel IRB capital requirement. It determines the capital requirement for the IRB approach. The base assumption is a capital requirement over an infinite granular portfolio where concentration is absent. For non-IRB banks, there is a standard approach. In theory, this requirement is higher than the one for the IRB. Nonetheless, current rules and the IRB capital floors implemented recently may come close to both requirements.

II. The LEX standard as previously explained.

III. Conservation capital supplement. This supplement applies to all banks and may help them face any losses, including large ones (concentration).

IV. Capital Buffer for Systemic Important Banks (G-SIBs and D-SIBs). Applies only to Systemic Banks. In Mexico it ranges from 0.6% to 2.5%, representing 6.5% of the Risk-Weighted Assets (RWAs).

V. Total Loss-Absorbing Capacity (TLAC), applies only to Systemic Banks and is the maximum between 6.5% of the RWA's and 3.75% of the adjusted assets for leverage ratio computation (Mexico rule).

VI. Internal Capital Adequacy Assessment Process (ICAAP). It is an annual regulatory exercise that seeks to assess if the total capital that the bank has is enough to absorb the losses that the bank may face under different scenarios, including those of adverse economic conditions. Banks must demonstrate capital adequacy in all scenarios; otherwise, they must present a preventive action plan. The ICAAP is linked to other Basel regulation components to fulfill the complete capital regulation: the TLAC supplement, systemic capital supplements, conservation capital supplements, liquidity requirements, contingency plans, resolution plans, etc. Since the assessment must show that the bank is fulfilling all capital supplements and requirements in any scenario.

VII. Contingency plan. This plan is a detailed document that has all ordered feasible actions that the bank can execute to bring back the bank's capital ratio to compliant levels and to ensure continuity in its operations. It is a confidential plan, updated annually.

VIII. Resolution plan: This plan is confidential and entails a detailed and ordered process in case the bank's capital ratio falls below regulatory limits without the possibility of recovery. This plan is for the financial regulatory authority to take control and execute needed actions to protect public deposits due to the bank's financial problems, for example, insolvency derived from large losses due to credit risk concentration.

Figure 3 shows the integration of the pieces into a complete framework (see Figure 3). For our purposes, we place the credit concentration risk in the center but is a complementary piece of the framework.

Figure 3. Concentration Risk and its Integration into the BIS Regulation Framework

Source: Prepared by the author.

The author presents this framework in articulated form to understand the role that every piece has in managing concentration risk.

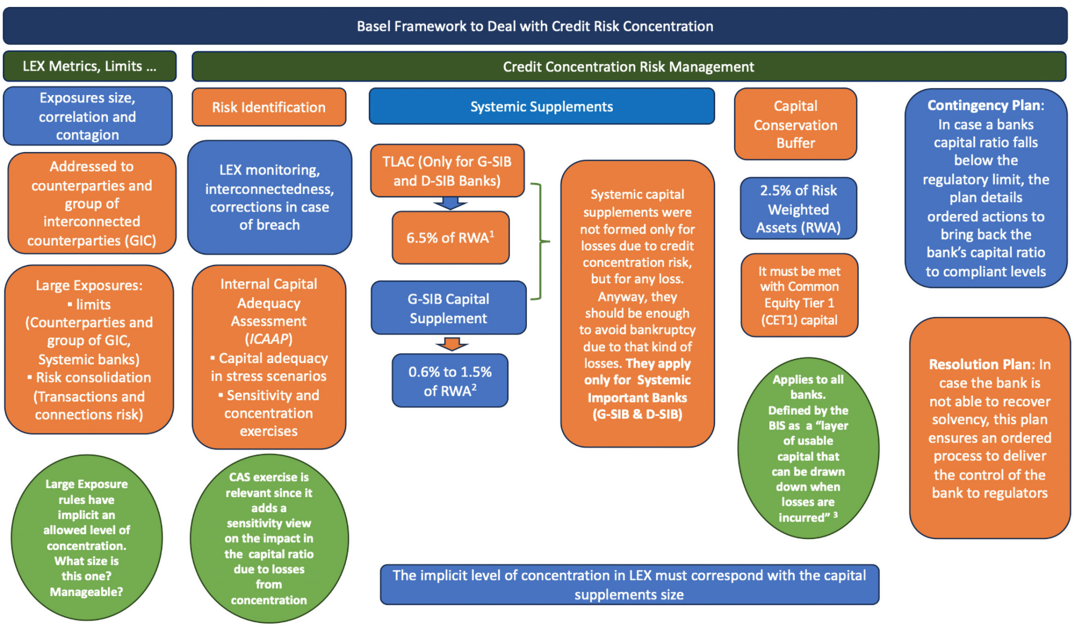
The 2008 banking crisis triggered important initiatives that will be reflected in specific regulations later. The focus of those initiatives was oriented to the resilience and stability of the financial system and of course to protect the economy, as explained by the Basel Committee on Banking Supervision:

> This consultative document presents the Basel Committee's proposals to strengthen global capital and liquidity regulations with the goal of promoting a more resilient banking sector. The objective of the Basel Committee's reform package is to improve the banking sector's ability to absorb shocks arising from financial and economic stress, whatever the source, thus reducing the risk of spillover from the financial sector to the real economy. (BCBS, 2009, p. 1).

In that sense, we must interpret the articulation of the regulation pieces explained before. The regulation addresses the main systemic components of the financial system—the important part is the system, not a specific group of banks.

Let us use Figure 4 to complete the articulation of the pieces (see Figure 4).

Figure 4. Role of the Pieces of the BIS Regulation Framework in Managing Credit Concentration Risk



[1] The rule in Mexico is a maximum between 6.5% of the risk-weighted assets or 3.75% of the risk-adjusted assets for leverage ratio computation purposes.

[2] In Mexico the supplement is assigned by the regulator to every bank designated as locally systemically important or D-SIB. The size of the supplement depends on the systemic impact of the bank.

[3] Financial Stability Institute (2019).

Source: Prepared by the author.

We can notice, on the one hand, that systemic banks have two heavy capital supplements to deal with losses: G-SIB and D-SIB losses (from 0.6% to 1.5%) and the TLAC supplement of approximately 6.5% of the bank's risk-weighted assets. On the other hand, the rest of the banks are only obliged to form the capital conservation supplement, not the TLAC supplement, as shown in Table 2 (see Table 2).

Table 2. Summary of Banks' Capital Supplements

Supplement (as % of Risk-Weighted Assets or RWAs)	Mexican banks
Capital conservation 2.5% of RWAs	All Banks
Domestic Systemic Important Banks: 0.6% to 1.5% of RWAs	Domestic Systemic Important Banks (6)
Total loss-absorbing capacity (TLAC): 6.5% of RWAs or 6.75% of risk adjusted assets used for leverage ratio computation.	Domestic Systemic Important Banks (6)

Source: Prepared by the author, based on information from several sections of CNBV (2024a).

There are minimum regulatory capital requirements—including the supplements. Regulatory reporting ensures that those minimums are complied with. To assess any potential risk, banks must conduct a regulatory Internal Capital Adequacy Assessment Process (ICAAP) annually. In the manual and template to conduct such assessment, the Comisión Nacional Bancaria y de Valores (CNBV, 2023, pp. 32–33), the Mexican regulator, includes in Section 3.4.15 Sensitivity Analysis, the following: a) Simultaneous write-offs of the ten main counterparties or group of connected counterparties, (write-offs adjusted by loss given default). Sensitivity must include Public Sector Entities (PSEs such as Petróleos Mexicanos [Pemex] and Comisión Federal de Electricidad [CFE]).

The effect of this sensitivity on the regulatory capital (through the capital ratio) must be computed and disclosed to the regulator.

We need to point out several issues about this sensitivity.

The simultaneous write-off assumption is very heavy for any portfolio since a Bank that uses the maximum concentration limits, by definition, among the 10 main counterparties must include the four maximum large exposures, that in its limit would sum the 100% of the Tier 1 capital, and the next six large exposures below those four.

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That implies a perfect correlation among the ten main counterparties or group of connected counterparties regardless of sectorial connections and activity, including Public Sector Entities (PSEs).

The reader can easily guess that a loss of this size would be an important share of any bank's capital.

As an important reference to assess the relevance of concentration risk in the Mexican financial system, let us review the information presented in Table 3. This shows the vulnerabilities identified by regulators in the ICAAP for the years 2017 to 2023 (see Table 3). On average, fifteen banks showed vulnerabilities due to credit concentration. In 2022 ICAAP showed a vulnerability in sixteen banks involving 12.1% of the assets of the banking system (see notes included in Table 3). Note as well that, on average, eight banks presented capital shortfall in the ICAAP exercise.

Table 3. Vulnerabilities Identified by Mexican Regulators in the Internal Capital Adequacy Assessment Process (ICAAP) for the Years 2017–2023

		Vulnerable Banks in (ICAAP) due to:				
CESF Report as of March:	Period of the ICAAP	Loan Concentration		Capital Shortfall	Liquidiry Coverage Ratio	Depositors
2018	2017 - 2019*	19		8	8	15
2019	2018 - 2020*	15		5	3	16
2020	2019 - 2021*	12		6	3	14
2021	2020 - 2022**	12	0.4% ***	10	2	20
2022	2021 - 2023	12	0.5% ***	7	1	13
2023	2022 - 2024	16	12.1% ***	10	0	14
2024	2023 - 2025	18	0.45% ***	9	0	16
	Average	15		8	2	15

* At least one bank presented a risk of loan concentration due to sensitivity to accumulated write-offs of the ten largest counterparties that drove its capital ratio below 10.5% (minimum regulatory level).

** A least one bank presented a risk of loan concentration due to sensitivity to accumulated write-offs of the ten largest counterparties that drove its capital ratio to the minimum regulatory level.

*** Assets of vulnerable banks due to loan concentration to system total assets (percentage).

Source: Prepared by the author with information from Consejo de Estabilidad del Sistema Financiero (2018–2024).

Although the result of this sensitivity does not imply a failed (ICAAP) regulatory exercise, the bank may eventually face the question of how it would recover from a loss of this size. In such a case the action plan that the bank must outline in its contingency plan (CP) should be enough to face such losses. A bank with an important risk in this sensitivity at least will be on a watch list. Therefore, results from one exercise (ICAAP) can be linked to another (CP) straightforwardly, which is one of the benefits of the integrated framework from a regulatory point of view.

Obviously, there is an offset of the write-offs. The risk-weighted assets will also be reduced, but in any case, the net effect is important.

That risk is present in all banks, but the supplements for systemic banks are enough to cover any loss of this size. A regular (non-systemic) bank has only the capital conservation supplement of 2.5%. We will address this issue later when we compute the capital concentration add-on.

The LEX regulation is oriented to all banks including those that use the standard approach to compute their regulatory capital. For this reason, instead of including a specific capital requirement in the IRB formula, the approach is to control important parameters that have to do with the capital requirement, regardless of the bank being systemic or not, or uses the IRB or the standard approach to compute its capital requirement. The parameters are as follows:

- Total exposure consolidation.
- Limit to the size exposure, being more acid to systemic bank's exposure.
- Correlation.
- Connections and contagion.

The process that we will follow to determine the add-on is the following:

I. Assess the LEX regulation released by both the BIS and Mexico and its implications for credit portfolio concentration to design the portfolios.

II. Compute the regular capital requirement with the IRB formula approach as a comparison yardstick.

III. Determine feasible levels of concentration implicit in the LEX regulation.

IV. Compute the capital requirements through value at risk and the conditional value at risk metrics for every portfolio designed.

V. Use the Hirschman-Herfindahl Index to make portfolio size homogeneous and comparable.

VI. Using a CreditMetrics-like model, obtain the credit risk metrics (VaR and CvaR) for diverse levels of concentration through a Montecarlo simulation.

VII. Compute the concentration add-on for diverse levels of concentration.

VIII. Assess the resulting add-on regarding capital requirements and its importance.

6. Levels of Concentration Implicit in the LEX Regulation

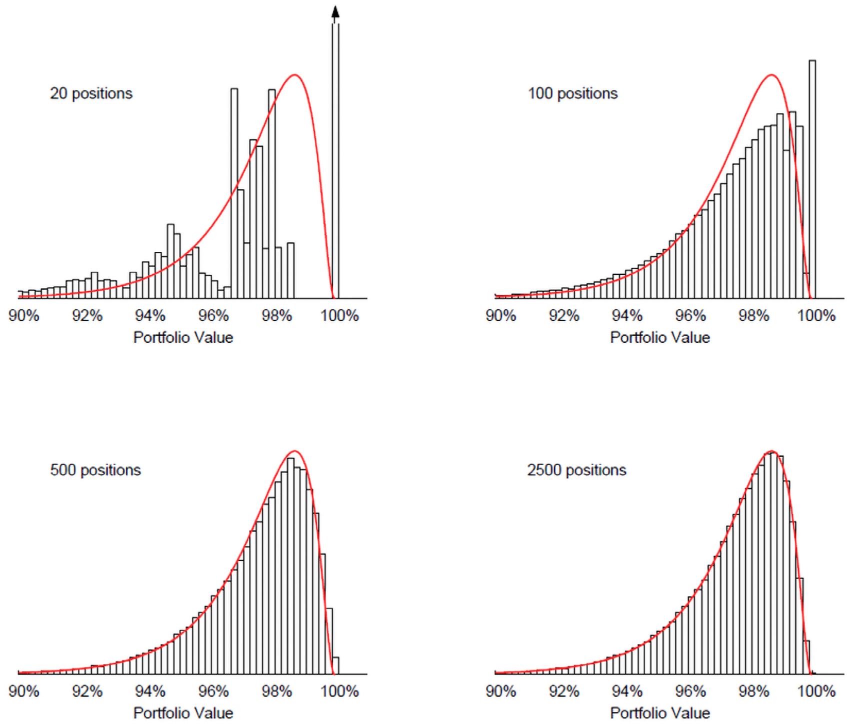
LEX regulations released by the BIS and CNBV in Mexico have implications for credit portfolio concentration, regardless of whether the bank computes the capital requirement measured with the IRB formula or determined with the standard model.

The IRB formula assumes infinite granularity in the portfolio. For practical purposes, we reduce the problem dimension based on Yi Xiao and Finger's research.

The problem we face is the same one that Yi Xiao and Finger (2002) addressed since, in both cases, we are parting from homogeneous and fine-grained portfolios. In our case, a corporate one under the Basel IRB Basel formula, that assumes infinite granularity and homogeneous risk, homogeneity and fine-grained exposures in the case of retail exposures, in both cases the dimension of the problem is reduced to analyze the problem in a more tractable size.

> Consider a portfolio with an average default probability of 5%, an average recovery rate of 50%, and an average correlation of 10%. Assuming there are 20, 100, 500, or 2500 exposures in this portfolio, each to a distinct obligor, we carry out full-blown Monte Carlo simulations with 100,000 scenarios for each case. The distribution of the portfolio is calculated from the simulation and shown as a histogram in Figure 1. With a small number of exposures in the portfolio, the distribution is rather discrete, dominated by the properties of individual positions.
>
> With more and more exposures in the portfolio, the default of a single exposure has less and less impact on the total pool, and the distribution becomes progressively smoother. The distribution eventually converges to the homogeneous and fine-grained limit shown as solid lines in Figure 1. (Yi Xiao & Finger, 2002, p. 3. Please note that the following Figure 1 is part of the quote).

Figure 1: Convergence of a loan pool to the homogeneous and fine-grained limit.



Obligor correlation $\rho = 10\%$, default probability $p = 5\%$, recovery rate $R = 50\%$. Exposure sizes are normally distributed with standard deviation equal to 1/3 of mean.

Source: Yi Xiao and Finger (2022, p.3).

On the one hand, in the quotation above note that in Xiao and Finger convergence was at 100,000 trials in a Monte Carlo simulation exercise.

On the other hand, we will use the one presented by the Committee on Banking Supervision (2006) as a reference yardstick.

> Credit concentration is sometimes known as lack of granularity. This section discusses how to extend the ASRF model to incorporate the effect of granularity.
>
> To fix ideas, consider how economic capital (credit VaR) varies over a sequence of loan portfolios with the following structure: they all contain a number of exposures

> to similar credits which are all of the same size with the exception of one that is ten times that size. Table 1 depicts the tail of the simulated loss distribution for seven such portfolios of different sizes ranging from 10 to 3000 credits. As the number of credits increases the importance in the portfolio of the single large exposure declines and the economic capital converges to the one corresponding to the infinitely granular case (BCBS, 2006, p. 9).

The following Table 4 (Table 1 of the BCBS, 2006, p. 9, and Table 4 in this text) appears on page 9 of the BCBS document (see Table 4).

Table 4. Scenarios Present in BSI's Basel Committee on Banking Supervision (BSCS, 2006) Working Paper 15

Table 1

A stylised example of the effect of granularity on portfolio risk

Number of loans	**10**	**50**	**100**	**500**	**1,000**	**2,000**	**3,000**
VaR(95%)	.0526	.0508	.0459	.0393	.0386	.0378	.0389
VaR(99%)	.5263	.1695	.1009	.0786	.0773	.0762	.0758
VaR(99.9%)	.5263	.1864	.1284	.0982	.0971	.0950	.0947

Note: Credit VaR at the specified level of confidence expressed as a fraction of total portfolio exposure. The calculations assume PD=1% and asset correlation of 20%.

Source: BCBS (2006, p. 9).

With this information, we can infer a simple add-on, if we know the increase in concentration, assuming that the 3000 exposures portfolio mimics the granular portfolio case. For instance, at a 99.9% level of confidence passing from three thousand loans to one hundred implies an add-on of 3.37% using the VaR risk metric.

In this same document, the following question is asked: "How important is the effect of name concentration on economic capital?" (BCBS, 2006, p. 9) The answer is important for our purposes:

- For large credit portfolios of over 4000 exposures, the effect is 1.5% to 4%.
- For smaller portfolios (with 1000 to 4000 loans) the effect ranges from 4% to 8%.

The 3000 exposures portfolio size is similar to the one proposed by Xiao and Finger (2002).

In our exercise, we assumed that we had a portfolio of 3000 granular exposures (same size and risk), and we derived alternative concentrated portfolios as follows, according to the main sizes found in Basel Committee on Banking Supervision (2006):

I. A portfolio of 3000 exposures but including the four allowed largest exposures (each one representing 25% of the Tier 1 capital, assuming a capitalization of 10.5% of the portfolio), the rest of the exposures remain the same size.

II. A portfolio of 2000 exposures but including the four allowed largest exposures (each one representing 25% of the Tier 1 capital, assuming a capitalization of 10.5% of the portfolio), the rest of the exposures remain the same size.

III. Portfolios of 1000, 500, 100, and 50 exposures were built in the same way: four allowed the largest exposures (each one of 25% of the Tier 1 capital, assuming a capitalization of 10.5% of the portfolio) the rest of the exposures remain the same size. As we reduce the number of loans, the money size of each exposure grows (since the rest of the portfolio, apart from the four main exposures, is divided into a lower number of loans), increasing the concentration effect.

The monetary amount of the portfolio and loans was selected as follows:

- Portfolio of loans $ 3347.00
- Regulatory capital $ 351.40 (10.5% of portfolio loans, as Tier 1 capital)
- Size of each of the four permitted large exposures: $ 87.9.

If we were to consider the Tier 1 capital of systemic banks, the level of concentration would be higher, but we can calculate the add-on with a rule we can derive from our results.

We also worked on the 3000-size portfolio with equal-size exposures in Table 5 (see Table 5).

Table 5. Concentration Effect Assuming Scenarios Derived from the Large Exposure Regulation

Original Number of Loans	3,000		2,000		1,000		500		100		50	
	LOANS	HHI	LOANS	HHI	LOANS	HHI	LOANS	HHI	LOANS	HHI	LOANS	HHI
4 Maximums (25% each)	331	0.00302	317	0.00316	281	0.00356	229	0.00437	90	0.01110	50	0.02017
4 Maximums + 1 SIB (15%)	307	0.00326	295	0.00339	264	0.00378	219	0.00457	90	0.01114	50	0.02018
4 Maximums + 2 SIB (15% each)	286	0.00350	276	0.00363	250	0.00400	210	0.00476	89	0.01118	50	0.02020
4 Maximums + 3 SIB (15% each)	267	0.00374	259	0.00386	237	0.00422	202	0.00496	89	0.01123	49	0.02021
4 Maximums + 3 SIB + 10 Large Loans (10% each)	209	0.00479	205	0.00488	194	0.00516	174	0.00575	89	0.01125	47	0.02132

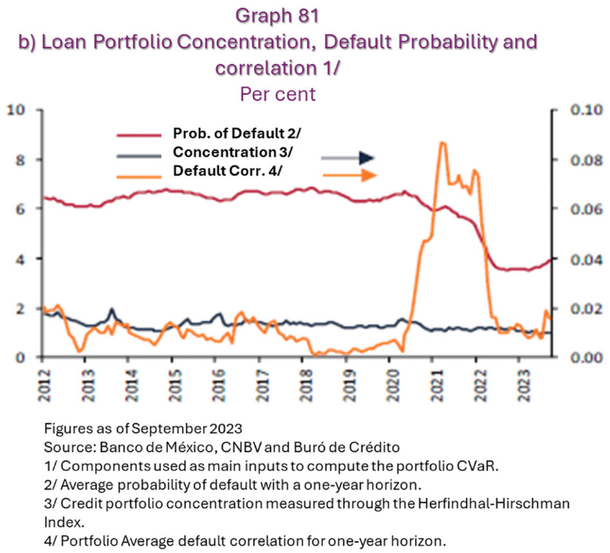
Source: Prepared by the author.

In the first line, we will compute the add-ons for all scenarios, and based on the results, we will infer the rest of the cases.

In the BCBS's framework, we find the following reference regarding the "Maximum permissible concentration under EU large exposures rules. Such calculations give estimates of 13% to 21% higher portfolio value-at-risk for this highly concentrated portfolio versus a perfectly granular one that is comparable in all other dimensions." (BCBS, 2004). Also, note 8 states the following: "Directive 93/6/EEC of 15 March 1993. An estimate of the HHI for such a portfolio would be about 0.0156"; following the HHI inverse rule (Márquez Diaz-Canedo, 2003, pp. 198-199) that number would be around 64 loans, so that estimate falls within our scenarios.

According to the Banco de México (the Mexican Central Bank) in its second semester report of 2023 on financial stability (Banco de México, 2023) the concentration (measured by the Herfindahl-Hirschman Index HHI) of Mexican banks ranged from 0.01 to 0.02 during the 2012–2023 period (see Graph 1). This is a significant level of concentration. Using the metric 1/HHI, we find that it is equivalent to portfolios with a number of loans between 50 and 100. As stated before, those numbers are consistent with the scenarios designed for this work.

Graph 1. Banco de México Graph on Loan Portfolio Concentration, Default Probability, and Correlation



Source: Banco de México (2023, p. 67).

Thus, for our purposes, the relevant HHI and associated loan portfolios are between 100 and 50 loans.

The parameters and other assumptions for our exercise are the following:

- Portfolio correlation: 20%.
- 1-year probability of default: 1%.
- Loss Given Default: 100%.
- Simulations by scenario: 500,000 (Recall that Xiao and Finger [2002] used 100,000 simulations, Martin Hibbeln 3,000,000, and other authors 400,000). The Montecarlo Simulation is a methodology capable of providing very accurate results for specific levels of concentration, as is our case. Nonetheless, the computation time burden is enormous.

The model used is a CreditMetrics-like model developed by the author. The Cholesky decomposition is used to obtain credit-correlated default scenarios. The original methodology is disclosed in JP Morgan and Reuters (1996).

The metrics to be used to compute the add-on are the Value at Risk of the portfolios and The Conditional Value at Risk (VaR and CVaR). Nonetheless, although we will compare the results from both, CvaR will be the final chosen metric to compute the add-on. We know from Artzner et al (1999) that VaR fails as a coherent measure of risk, specifically in the subadditivity property at high levels of confidence, as is the case in our research. The CVaR has become the dominant risk metric for many standards.

7. Capital Requirements and VaR Using the Basel IRB Formula

As a comparison yardstick, we computed the capital requirement using the Basel IRB formula. Is important to point out that this formula considers no concentration at all, which is why there is a need to compute the add-on resulting from passing to the real world, where concentration is an important risk factor to be considered.

The capital requirement for a loan under the selected assumptions is computed with the Basel IRB formula as follows.

Capital requirement:

$$(K) = \left[LGD * N\left[(1-R)^{-0.5} * G(PD) + \left(\frac{R}{1-R}\right)^{0.5} * G(0.999)\right] - PD * LGD\right] * (1-1.5*b)^{-1} * (1+(M-2.5)*b) \quad \text{(Equation 1)}$$

Where the correlation is:

$$(R) = 0.12 * \frac{1-e^{-50*PD}}{1-e^{-50}} + 0.24 * \frac{1-(1-e^{-50*PD})}{1-e^{-50}} \quad \text{(Equation 2)}$$

Maturity adjustment:

$$(b) = \left(0.11852 - 0.05478 * Ln(PD)\right)^2 \quad \text{(Equation 3)}$$

Ln = natural logarithm

N(x) = standard normal cumulative distribution function

G(x) = standard normal inverse cumulative distribution function

Source: BCBS (2004, para. 272).

Notice that the confidence level of this requirement is 99.9%. To align the formula with our exercise, we fix the term as one year.

The reference capital requirement using this formula and our assumptions is 13.03%.

8. Results Computing the VaR and CVaR of Portfolios with Different Concentration Levels

8.1 Introduction to Formulas and Calculations

Simulation algorithm:

- We obtain a vector of n independent, identical standard normal distributed random variables N(0,1); where n represents the size of the portfolio or portfolio replica. Let us call this vector Z.
- Since we are using a single correlation value of 20% for all elements in the portfolio, we part from an N x N size correlation matrix with a value of 1 in the diagonal and 0.2 value in all the rest elements of the matrix. The correlation matrix is C.

- We obtain the Cholesky decomposition of the correlation matrix (inferior triangular) and design this result as the M Matrix. To do so we used the algorithm described in JP Morgan and Reuters (1996, p.254, Appendix E): "Routines to simulate correlated normal random variables", and section E.2, "Applying the Cholesky decomposition." Following this algorithm, beginning from the correlation matrix C, and considering that we have standard normal random variables where the standard deviation is equal to 1, then C is equal, in terms of M, to:

$$C = M^T * M \qquad \text{Equation 4}$$

Let *i* and *j* index be the row and the column of an N x N matrix.

The diagonal elements of M are computed with:

$$a_{ii} = \left(s_{ii} - \sum_{k=1}^{n-1} a_{ik}^2 \right)^{1/2} \qquad \text{Equation 5}$$

s_{ii} represents any element in the diagonal of C.

The rest of the elements of M are computed with:

$$a_{ij} = \frac{1}{a_{ii}} \left(s_{ij} - \sum_{k=1}^{n-1} a_{ik} a_{jk} \right)^{1/2} \qquad \text{Equation 6}$$

s_{ij} represents any element out of the diagonal of C.

j=i+1, i+2,...,N

- Once having M, we obtained correlated vectors (Z_c) of the normal distributed random variables by applying the following formula.

$$\boldsymbol{Z_c} = (\boldsymbol{M} * \boldsymbol{Z^T})^T \qquad \text{Equation 7}$$

- Every random variable represents a loan. We decide if a loan is paid or defaulted if the random variable is equal to or lower than the fix threshold of -2.3263, since we set the probability of default of the exercise at 1%.

- If the loan is paid, its value is equal to the original exposure, if the loan is defaulted, the value of the loan is equal to:

$$Loan = Expsoure * (1\text{-}LGD) \qquad \text{Equation 8}$$

- In every trial we obtained loans paid and loans defaulted, the sum of all values gives the value of the portfolio in that trial.
- We repeated that process 500,000 times, recording every result.

8.2 Computing the Risk Metrics

Risk metrics have evolved over time. The first risk metric used was exclusively volatility (standard deviation). Value at risk (VaR) was set as a new risk metric standard paradigm in the 1990's. Artzner et al (1999) pointed out that the value at risk was not a coherent metric of risk, given that it does not fulfill the subadditivity property that ensures that the risk in a portfolio is lower than considering every element of the portfolio in a separated way and adding the individual risks. This happens especially in credit portfolios with a very low probability of default and which compute the VaR using elevated levels of confidence.

According to Venegas (2008, p. 694):

> The value at risk of X at a level (of confidence) of 1-q denoted by – VaR, is defined as the worst value of the portfolio, in a given period, [t,T], for a confidence interval of (1-q)100%. In a more accurate way:

$$\mathbb{P}_\theta\left\{-VaR_{1-q}^{X} \leq X\right\} = 1 - q \qquad \text{Equation 9}$$

Since we are using a Montecarlo method to compute the VaR, we will use this alternate expression presented by Venegas (2008, p. 694):

$$VaR_{1-q}^{X} = -Inf\{X \in \mathbb{R} | \mathbb{P}_\theta\{X > x\} \leq 1 - q\} \qquad \text{Equation 10}$$

In our work we computed the value of the portfolio for every one of the 500,000 scenarios and obtained first the average value of the portfolio. In the credit risk the total loss is divided into two components: the average loss is called expected loss and this constitutes the provision for credit losses (credit allowance). Losses that go far from the average losses to the VaR are equal to the economic capital or capital requirements at the confidence level that the VaR was computed. Using losses with positive sign we have:

$$Capital = VaR_{1-q}^{X} - Expected\ Loss \qquad \text{Equation 11}$$

To find the VaR of the portfolio:

1. All scenarios are arranged from worst to best portfolio values.
2. To find the VaR at a confidence level of 99.9%, for 500,000 scenarios we compute 500000*(1-99.9%) = 500. Therefore, to find the VaR, the value of the portfolio in the 500 scenario will be the value at risk.
3. To obtain the capital requirement we subtract the expected loss from the value, this is called the "unexpected loss."

The conditional VaR (CVaR), in turn, is a metric that fulfills all properties of the coherent risk framework, including sub-additivity. This metric works with the losses once we have overpassed the value at risk loss—it is computed as the average of all losses exceeding the Value at Risk and includes all losses conditional to exceed the value at risk. Venegas (2008, p. 706) defines CvaR as follows:

$$\mathcal{E}_{1-q}^{X} = VaR_{1-q}^{X} - E\left[X + VaR_{1-q}^{X} | VaR_{q}^{X} + X < 0\right] \qquad \text{Equation 12}$$

To obtain the CVaR we will compute the average of losses that are higher than the VaR, that is straightforward since we already have ordered the complete set of simulated losses, we have to include in the computation of the average all excluded scenarios from the VaR computation.

Next, we compute the Capital requirement through the CvaR as follows:

$$\boldsymbol{Capital = \mathcal{E}_{1-q}^{X} - Expected\ Loss} \qquad \text{Equation 13}$$

8.3 Portfolio Composition

To assess the effect of credit concentration in the portfolios we designed the following portfolios. Concentration in a portfolio increases as the number of loans (exposures) decreases.

1) Portfolio A 3000 has all exposures of the same size. In our exercise, this case is the most similar to an IRB granular portfolio.

2) Portfolio B 3000 has four exposures with an individual limit of 25% of Tier 1 Capital. The rest are exposures of the same size. This portfolio includes in a granular portfolio the effect of the maximum credit limit to a counterparty or group of

connected counterparties: 25%. We assume that four counterparties or groups of connected counterparties use this limit, so the limit of 100% of Tier 1 capital allocated in four counterparties or groups of connected counterparties is reached.

3) The rest of the portfolios (with sizes of 2000, 1000, 500, 100, 50, 40) have four exposures with an individual limit of 25% of Tier 1 Capital. The rest exposures are homogeneous in size. This follows the same logic of Portfolio B 3000.

Once we defined the portfolio size and composition, we executed the simulation process and computed the risk metrics. The results were as presented in Table 6 (see Table 6).

Table 6. Results of VaR and CVaR for Built Portfolios

	Value at Risk				Conditional Value at Risk			
	VaR Confidence Level				CVaR Confidence Level			
Portfolio Size	99.90%	99.50%	99.00%	95.00%	99.71%	98.56%	97.10%	85.40%
3,000 Equal	13.60%	8.53%	6.57%	2.80%	13.59%	8.53%	6.59%	2.86%
3,000 Portfolio	13.90%	8.88%	6.91%	3.06%	13.90%	8.87%	6.91%	3.06%
2,000 Portfolio	14.14%	8.95%	6.98%	3.04%	14.01%	8.93%	6.94%	3.07%
1,000 Portfolio	14.28%	8.98%	6.93%	3.05%	14.13%	8.93%	6.93%	3.07%
500 Portfolio	14.34%	9.02%	7.00%	3.07%	14.19%	9.01%	7.01%	3.12%
100 Portfolio	14.85%	10.01%	7.40%	3.66%	15.08%	9.87%	7.30%	3.58%
50 Portfolio	16.51%	10.67%	8.72%	3.56%	16.60%	10.70%	8.67%	3.57%
40 Portfolio	16.68%	11.43%	8.95%	3.97%	17.42%	11.26%	9.05%	3.71%

Source: Prepared by the author.

Recall that our comparison reference value is the VaR implicit in the IRB formula capital requirement—that is, 13.03%.

When a metric changes from VaR to CvaR, it is good practice to select the latter's confidence level to replicate the risk of the VaR. One example is to use 97.25% for CVaR and 99.9% for VaR, as shown in Graph 2 (see Graph 2). In this work, we determined the CVaR confidence level as 99.71% to align both metrics, as in Graph 3 (see Graph 3). Other works identify a confidence level of 99.72%.

Graph 2. Value at Risk for Every Portfolio at a 99.9% Confidence Level

Source: Prepared by the author.

Graph 3. Conditional Value at Risk for Every Portfolio at 99.71% Confidence Level

Source: Prepared by the author.

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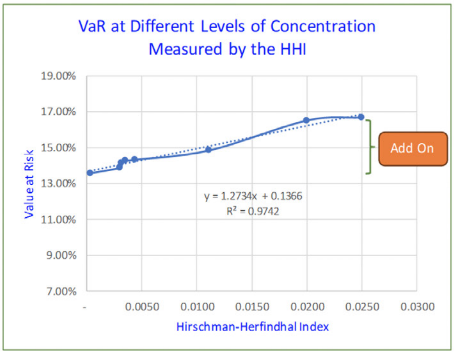
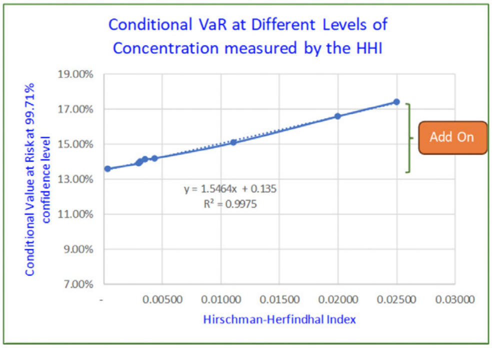
9. Computing the Concentration add-on and Assessment of Results

We obtained the add-ons by comparing the risk metric with a given level of concentration minus the capital requirement with the IRB formula. Not all banks are IRB, but the idea is to get a comparison parameter, and this is a sound one.

Graph 4 shows the resulting VaR and CVaR. It is easy to notice that the CVaR metric is much more stable. This has to do with its coherence, and so we used it to determine the add-one (see Graph 4).

Graph 4. Concentration add-on with VaR and CVaR





Source: Prepared by the author.

Despite the size of the simulations, it is advisable to correct any deviation coming from the method used and the slow convergence that we noted. For this reason, we obtained a fitted add-on from a linear regression between the HHI and the obtained add-on. Results are shown in Tables 7 and 8 and Graph 5 (see Table 7, Table 8 and Graph 5).

Table 7. Fitted Concentration add-on with the VaR Metric

Portfolio Size	1/HHI	HHI	Obtained VaR	Fitted VaR	VaR Add On
3,000 Equal	3,000	0.00033	13.60%	13.76%	0.73%
3,000 Portfolio	331	0.00302	13.90%	14.11%	1.08%
2,000 Portfolio	317	0.00316	14.14%	14.13%	1.10%
1,000 Portfolio	281	0.00356	14.28%	14.18%	1.15%
500 Portfolio	229	0.00437	14.34%	14.29%	1.26%
100 Portfolio	90	0.01111	14.85%	15.16%	2.13%
50 Portfolio	50	0.02000	16.51%	16.31%	3.28%
40 Portfolio	40	0.02500	16.68%	16.96%	3.93%

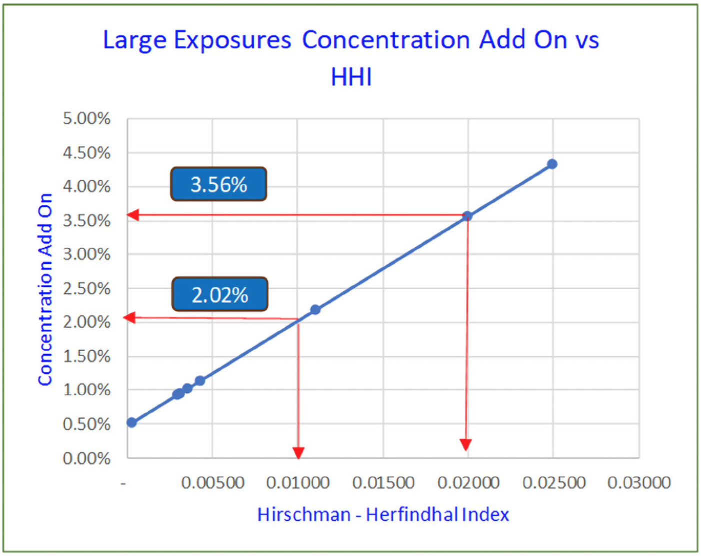
Source: Prepared by the author.

Table 8. Fitted Concentration add-on with the CVaR Metric

Portfolio Size	1/HHI	HHI	Obtained CVaR	Fitted CVaR	CVaR Add On
3,000 Equal	3,000	0.00033	13.59%	13.55%	0.52%
3,000 Portfolio	331	0.00302	13.90%	13.97%	0.94%
2,000 Portfolio	317	0.00316	14.01%	13.99%	0.96%
1,000 Portfolio	281	0.00356	14.13%	14.05%	1.02%
500 Portfolio	229	0.00437	14.19%	14.18%	1.15%
100 Portfolio	90	0.01111	15.08%	15.22%	2.19%
50 Portfolio	50	0.02000	16.60%	16.59%	3.56%
40 Portfolio	40	0.02500	17.42%	17.37%	4.34%

Source: Prepared by the author.

Graph 5. Fitted Concentration add-on with CVaR



Source: Prepared by the author.

As expected, there is a linear relation between the HHI and the add-on. If we use this relation to obtain the add-on for concentrations of 0.01 and 0.02 (the range of concentrations for the Mexican Bank system as of December 2023) we find add-ons of 2.02% and 3.56%, as shown in the previous graph.

The results are similar to those in other works. We have mentioned the Basel Committee on Banking Supervision (2004) and the EU large exposure rules quoted in that paper.

- Large Exposures of more than 4000 are 1.5% to 4%.
- Smaller portfolios (1000 to 4000 Loans) range from 4% to 8%.

One extensive study on concentration is Hibbeln (2010). This author uses several approaches to compute the add-on. He estimated the add-ons with the following results (see Table 9).

Table 9. Estimated add-ons from Hibbeln (2010)

	Add On	
HHI	HQMC	LQMC
0.010	1.56%	1.82%
0.020	2.93%	3.64%

HQMC: High-Quality Montecarlo (3 million simulations)

LQMC: Low Quality Montecarlo

Source: Estimated by the author based on Figure 4.3. Granularity add-on for heterogeneous portfolios, in Hibbeln (2010).

The resulting add-ons for the scenarios initially proposed are presented in Table 10 (see Table 10). Recall that the add-on for a completely grained portfolio of 3000 loans is 0.52. In the next case, it passes from a granular to a concentrated portfolio having the four maximum exposures permitted by the LEX regulation—the add-on is 0.94% for the first 3000-size portfolio scenario, and 1.21% for the last.

The add-on changes little for portfolio sizes of 2000 and 1000, but for sizes of 100 and 50 (with HHI equal to 0.01 and 0.02), in our relevant area, the add-on increases considerably: ranging from 2.19% to 2.21% for the former and 3.59% to 3.77% for the latter.

Table 10. Add-ons for the Proposed Scenarios

Original Number of Loans	3,000			2,000			1,000		
Scenario	LOANS	HHI	Add On	LOANS	HHI	Add On	LOANS	HHI	Add On
4 Maximums (25% each)	331	0.0030	0.94%	317	0.0032	0.96%	281	0.0036	1.02%
4 Maximums + 1 SIB (15%)	307	0.0033	0.97%	295	0.0034	0.99%	264	0.0038	1.05%
4 Maximums + 2 SIB (15% each)	286	0.0035	1.01%	276	0.0036	1.03%	250	0.0040	1.09%
4 Maximums + 3 SIB (15% each)	267	0.0037	1.05%	259	0.0039	1.07%	237	0.0042	1.12%
4 Maximums + 3 SIB + 10 Large Loans (10% each)	209	0.0048	1.21%	205	0.0049	1.22%	194	0.0052	1.27%
Original Number of Loans	500			100			50		
Scenario	LOANS	HHI	Add On	LOANS	HHI	Add On	LOANS	HHI	Add On
4 Maximums (25% each)	229	0.0044	1.15%	90	0.0111	2.19%	50	0.0202	3.59%
4 Maximums + 1 SIB (15%)	219	0.0046	1.18%	90	0.0111	2.19%	50	0.0202	3.59%
4 Maximums + 2 SIB (15% each)	210	0.0048	1.21%	89	0.0112	2.20%	50	0.0202	3.59%
4 Maximums + 3 SIB (15% each)	202	0.0050	1.24%	89	0.0112	2.21%	49	0.0202	3.60%
4 Maximums + 3 SIB + 10 Large Loans (10% each)	174	0.0057	1.36%	89	0.0112	2.21%	47	0.0213	3.77%

Source: Prepared by the author.

It is also important to note that "vertically" the increase of the add-on from the best (only 4 maximum large exposures permitted) to the worst scenario (4 maximum LE + 3 D-SIB Exposures +10 Loans larger Than 10% of Tier 1 capital) is moderated (see Table 10, and for complementary support, see Table 11). Therefore, we conclude that the main contribution to concentration is by one of the four largest loans.

"Horizontally" the average increase of the add-on is 2.59%, so the most critical component is the implicit reduction in the number of loans according to the inverse of the HHI. We can take as a concise result of this work the one in Table 10 for concentration levels of HHI= 0.01 and HHI=0.02, which is an add-on ranging from 2.2% to 3.6% in higher concentrations, as in Table 10 (see Table 10).

So, in summary, the vertical behavior (increasing base concentration) is the key driver. Adding more concentration to base scenario does not contribute heavily to capital requirement, as shown in Table 11 (See Table 11).

Table 11. Horizontal View: Increase in add-ons from "Best" to "Worst" Concentration Scenarios

Potfolio Size	3,000	2,000	1,000	500	100	50
Increase in Add On From scenario 1 to 5	0.27%	0.27%	0.25%	0.21%	0.02%	0.18%

Source: Prepared by the author.

Please note that the add-on is 4.34% for a forty-loan equivalent portfolio size, and concentration escalates the capital requirement heavily.

Assigned to a specific supplement of capital or not, the conclusion is that credit portfolio concentration implicit in LEX accounts for an important share of the capital at risk. In perspective, it is important to know how important that number is. Consider the following for some Mexican banks: In Table 12 we can see that the amount of required capital due to concentration in LEX regulation is especially important, accounting for more than 50% of the total TLAC supplement, and on average, it represents more than 20% of the regulatory capital (see Table 12).

Table 12. Capital Share Due to Concentration According to the LEX

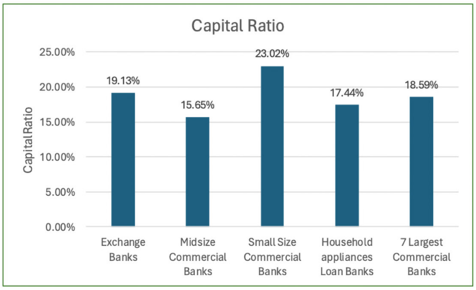
	Banamex	Banorte	BBVA México	HSBC	Santander	Scotiabank
Capital due to concentration (LEX)	28,298	33,905	70,331	20,050	32,329	17,084
% of Regulatory Capital	19%	17%	20%	23%	20%	23%
IRB Bank		x	x	x	x	

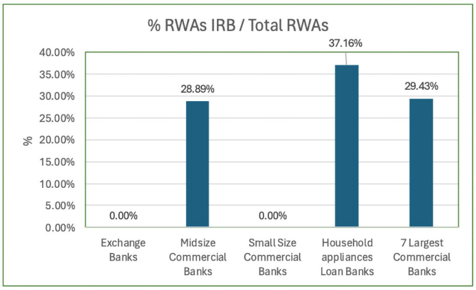
Source: Prepared by the author.

We explained before that there is not a specific capital requirement for concentration, but the pieces of the whole regulatory framework work together to handle the concentration risk. We also explained that systemic banks have two additional capital buffers apart from the capital conservation supplement and that the last one is a supplement for all banks.

It is true that capitalization ratios are, in general, higher than minimum regulatory ones, but it is important to know the marginal contribution of risk components to total risk and to capital at risk. In Graph 6 we can find the total capital ratio and by type of bank, compare such data with the one in Table 13, which shows the capital requirement for Mexican systemic banks, meaning that those have higher requirements. Recall that for the rest of the banks, the minimum ratio is 10.5% (see Graph 6 and Table 13).

Graph 6. Mexico, Total Capital Ratio by Type of Bank as of December 2023





Source: Prepared by the author with data from CNBV (2024b).

Table 13. Mexico Systemic Banks: Minimum Total Capital Ratio and Supplements as of December 2023

Capital Ratio & Suplements / Bank	Banamex	Banorte	BBVA México	HSBC	Santander	Scotiabank
Minimum Total Capital Ratio	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%
Capital Conservation Supplement	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%
D-SIB Supplement	1.20%	0.90%	1.50%	0.60%	1.20%	0.60%
Capital requirement without TLAC supplement	11.70%	11.40%	12.00%	11.10%	11.70%	11.10%
Capital requirement with 50% of TLAC supplement*	**14.95%**	**14.65%**	**15.25%**	**14.35%**	**14.95%**	**14.35%**
Total Capital Ratio as of December 2023	**18.82%**	**20.72%**	**18.27%**	**15.78%**	**17.54%**	**15.82%**
Ratio excess as od December 2023	**3.87%**	**6.07%**	**3.02%**	**1.43%**	**2.59%**	**1.47%**
Capital requirement with TLAC supplement fully formed	22.07%	23.97%	21.52%	19.03%	20.79%	19.07%

*Starting in December 2022, the TLAC supplement is being formed by one-fourth of the total requirement every year. Banks must complete this supplement by December 2025.

The author uses the 6.5% of the RWA in this table as a reference since some banks are using the 3.75% of the adjusted assets for the Leverage Ratio (LR) computation.

Source: Prepared by the author with data from CNBV (2024c).

What is capitalization like in the world? In Graph 7 we can notice that world capitalization levels are much higher than 10.5%. Only three countries have ratios lower than 12% and only one with an average capital ratio of 6%. In red labels, we have the ratios of other selected countries: the United States 16.3%; Mexico 17.7%, and Switzerland 19.7% (see Graph 7, in next page). Consider the minimum concentration component that we have computed and keep in mind that those ratios must support several types of losses including concentration implicit in LEX.

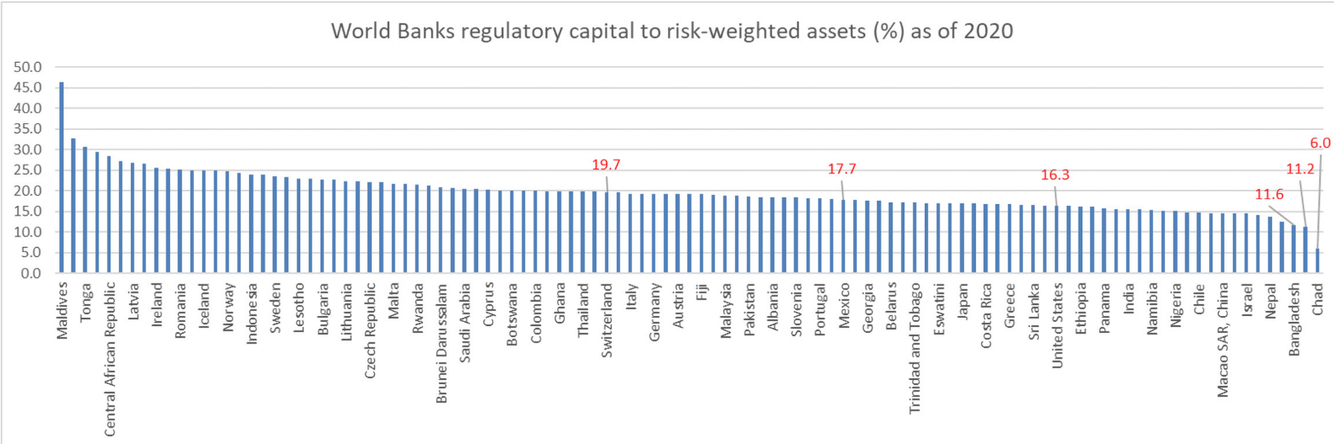
10. Conclusions

We have explained that the regulation did not follow the approach of computing a specific granularity adjustment for the bank's capital requirement due to the credit concentration risk. However, a holistic approach through the complete regulatory framework, including the LEX regulation, is a way to limit the concentration risk, and account for consolidated exposures, including not only all those with credit risk but also adding the exposures of all connected counterparties. At the same time, this approach addresses correlation and contagion and is supported by other pieces of the Basel regulation. Nonetheless, the LEX has an implicit minimum concentration and, therefore, a share of capital at risk. We have computed the add-ons and demonstrated that such a share is important. Since there is not a specific capital supplement for concentration, the existing supplements must be enough to absorb any loss, including the losses eventually coming from the concentration risk. We have also pointed out that the whole focus of the Basel regulation is systemic. Finally, we showed that although capital levels are aligned with the add-on, those levels must face any kind of loss. Losses implicit in the LEX due to concentration are particularly important and account for more than half of the TLAC supplement (6.5% of RWAs). This confirms the relevance of the size of the add-on.

The BIS implemented the LEX regulation to address the concentration risk, but once banks adopt the new regulation completely, the residual risk will remain relevant.

In Table 3, the author presents a summary of data from seven years of ICAAP in Mexico (2017-2023) showing that, on average, an important number of banks (15) present a vulnerability due to credit risk concentration. At least in one year, this involves an important share of the total system assets. LEX regulation started in Q4 2023 in Mexico.

Graph 7. World Banks' Regulatory Capital as of 2020



Disclaimer of data provider: Deposit takers' capital adequacy is a ratio of total regulatory capital to their assets held, weighted according to the risk of those assets.

Source: World Bank (n.d.).

If credit concentration would materialize, the results of this work show that for non-systemic banks, the capital conservation supplement would not be enough (3.6% vs 2.5%). For systemic banks this implies that the add-on represents 55% of the complete TLAC supplement (3.6% vs 6.5%) still in the formation process. A current offset for this risk is the levels of capital shown by Mexican banks. Nonetheless, the stress test scenarios in the ICAAP show vulnerabilities due to credit concentration, meaning that under stress conditions, situations may change considerably.

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José Juan Chávez obtained the following degrees: a Bachelor's in Economics from the School of Economics at the Universidad Nacional Autónoma de México (UNAM), a Master's in Finance, and a PhD in Financial Sciences at the Instituto Tecnológico de Monterrey (ITESM; EGADE Business School). He has been a professor at the ITESM, where he has taught courses at the undergraduate and graduate levels—both master's and PhD—for over 15 years, especially in risk management, corporate finance, and credit financing. Chávez has wide experience in the financial sector in Mexico. He worked for 34 years in Grupo Financiero Scotiabank Inverlat (GFSI) in corporate credit financing, credit policy, and credit analysis, credit risk modelling and management, and liquidity risk management. He successfully led the Basel Accord implementation in GFSI for ten years, and for the last eight years has worked in optimizing regulatory and economic capital with excellent results. He was head of the Risk Committee of the AMIB (Mexican Brokerage Houses and Investment Funds Association) from late 2020 to early 2024, where he led the group that determined the collateral haircuts for repo and securities lending markets, applying state-of-the-art market risk and credit risk standards. Currently, he is devoted to research and education activities.

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