

LINDA AND ENTROPY CONCENTRATION INDICES AS INSTRUMENTS OF CREDIT RISK MANAGEMENT

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Introduction. Assessing the concentration level of profitable assets in financial organizations is not a straightforward task, given the diverse and dynamic nature of these assets. Consequently, most organizations have dedicated departments that continually monitor concentration levels. The data gathered from these observations are utilized by management in making informed decisions on how to further distribute assets. However, for effective decision-making, it is crucial to accurately evaluate the concentration level, and this has led to the creation and use of several concentration coefficients since the latter half of the 20th century. Typically, a combination of these coefficients is used to evaluate the concentration level in any market. It's worth noting that the optimal concentration level for financial organizations may vary depending on the state or region due to differences in their development, strategies, and primary goals [Khandrujev, 2010, 6-13]. For example, while tourism might be a crucial sector in one country, industry may be the primary focus in a neighboring country. A clear indication of the level of economic activity in each state or country is the percentage of the respective sector's contribution to the GDP [Khan, 2016, 19-39]. According to the Central Bank of RA, the GDP components are relatively evenly distributed across sectors, with Agriculture, Wholesale and Retail Trade, Manufacturing Industry, Services, and Construction for 15.2%, 12.6%, 12.3%, 11.4%, and 7.2%, respectively [RA CBA].

Methodology. This study aims to evaluate the level of concentration in the credit portfolios of commercial banks in Armenia. We have analyzed the distribution of credit portfolios across eight commercial banks in Armenia based on different economic sectors. The primary data sources for the research were the 2018 and 2021 financial reports of these banks, which were audited by reputable international external auditing organizations. To ensure reliable results, the concentration level was assessed using three coefficients: Herfindahl-Hirschman, Linda, and Entropy. The Herfindahl-Hirschman index is one of the most common indicators for assessing the level of concentration. The Herfindahl-Hirschman index is calculated by the following formula:

$$HHI = \sum_{i=1}^n S_i^2 \quad (1)$$

where S is the share of the loan portfolio attributable to a given sector of the economy, n is the number of sectors of the economy. A credit portfolio is considered weakly con-

centrated if $HHI < 0.1$, moderate if $0.1 < HHI < 0.18$ and highly concentrated if $HHI > 0.18$. The Entropy index is another measure of concentration level, similar to the Herfindahl-Hirschman index [Hart, 1971, 73-85]. It helps to identify any deviation from the optimal level of credit portfolio concentration. However, the Entropy index calculation method eliminates potential errors that may occur when using the Herfindahl-Hirschman index. For example, the calculation of the Herfindahl-Hirschman index may lead to errors when fractions are raised to the power of two, which can be avoided by logarithmic transformation of the fractions. To calculate the Entropy index, the following method is used:

$$E = - \sum_{i=1}^n S_i \log_2 S_i \quad (2)$$

where S is the share of the loan portfolio attributable to a given sector of the economy, n is the number of sectors of the economy. The coefficient E can vary from 0 to $\log_2 n$. A high level of concentration in the loan portfolio takes place if the coefficient E tends to zero and vice versa. Linda's score is also an indicator of the level of concentration. Linda's coefficient is calculated as follows:

$$L_k = \frac{1}{k(k-1)} \sum_{i=1}^{k-1} Q_i \quad (3)$$

where Q_i is the average share of the first i sectors divided by the average share of the next $k-i$ sectors:

$$Q_i = \frac{\frac{1}{i}(s_1 + s_2 + \dots + s_i)}{\frac{1}{k-i}(s_{i+1} + s_{i+2} + \dots + s_k)} \quad (4)$$

When the loan portfolio is evenly distributed, the coefficient L_k will be equal to the number $1/K$. The core of concentrated areas can be identified by observing a sequence of decreasing and then increasing values of L_2, L_3, L_4 , and so on, starting from a particular value. The number of decreasing values determines the core of concentrated areas. If the credit portfolio is highly concentrated from the beginning, the Linda coefficient will continue to grow without limit. Another important measure is the arithmetic average of Linda coefficients for the identified core. A market is considered to be weakly concentrated if the Linda coefficient is less than 0.300, moderately concentrated if it falls between 0.300 and 0.500, and highly concentrated if it is greater than 0.500. The disparity coefficient is another analytical measure of Linda's ratio that indicates the degree of deviation of the L_k value from a perfectly balanced state, which can be expressed as follows [Linda, 1976, pp.55]:

$$Dis = k * L_k - 1 \quad (5)$$

Literature review. Concentration indices are commonly used in the financial sectors of both the US and Europe to evaluate market concentration and portfolio diver-

sification. The Hirschman Index (HHI), the Linda coefficient, and the Entropy indices are among the most frequently used indicators. The HHI, in particular, is a popular tool for measuring market concentration in both the US and Europe. Studies such as those conducted by Azar and Schmaltz [Azar, 2019] and De Groen [De Groen, 2019] have used the HHI to analyze market concentration in the US and European banking industries, respectively, and have found significant increases in concentration over time, as well as considerable variation in concentration levels across different countries. These findings suggest that high levels of market concentration may result in adverse outcomes for consumers, such as higher prices and lower quality services.

The US and European financial sectors employ concentration indices such as Linda's coefficient and the Hirschman Index (HHI) to measure market concentration and the entropy index to assess portfolio diversification. In a study of the European banking industry [Lambrecht, 2003, 425-442], Linda's coefficient was used to determine that market concentration has significantly increased over time, leading to reduced competition and consumer welfare. Additionally, the entropy index is frequently used to evaluate the performance of investment strategies in both the US and European financial sectors. De Santis [De Santis, 2019, 13-67] used the entropy index to establish that a more diversified portfolio translates to lower risk and higher returns in European stock markets.

Scientific novelty. Currently, there is a dearth of research on the implementation of concentration indices in the financial sector of Armenia. Hence, the utilization of the Hirschman Index, Linda's coefficient, and the Entropy index in analyzing the banking sector of Armenia can be deemed as a scientific breakthrough that will provide a better comprehension of the concentration of the financial market and the diversification of portfolios. Such research is crucial in facilitating evidence-based policy decisions and enhancing the efficiency of the Armenian banking industry.

Analysis. Commercial banks in the Republic of Armenia typically rely on the Herfindahl-Hirschman coefficient and the sum of CR_k of k large shares to measure concentration levels in their credit portfolios. However, the allocation of credit assets to different sectors in Armenian commercial banks differs from that of other countries. The Central Bank of the Republic of Armenia has reported that 20.8 percent of credit assets are allocated to the Trade sector, while the Agriculture sector only accounts for 9.6 percent of credit assets (as shown in Table 1) [RA CBA].

Although the Trade sector dominates the credit assets of commercial banks in the Republic of Armenia, the Herfindahl-Hirschman index suggests a moderate level of concentration at 0.11. This article aims to evaluate the concentration level and identify the core of concentrated sectors in the loan portfolio of 8 RA commercial banks using three concentration indices: the Herfindahl-Hirschman, Linda, and Entropy coefficients.

Comparisons of the concentration level between 2021 and 2018 are presented based on the credit asset allocation data in Table 4 and Table 5. Table 2 summarizes the values of the Herfindahl-Hirschman coefficient obtained using Equation 1.

Table 1. Distribution of the Loan Portfolio of Commercial Banks of the Republic of Armenia by Sectors of the Economy, AMD

Sectors	Total Amount	Share
Trade	482,364,694.00	20,876%
Construction	315,159,577.00	13,640%
Manufacturing	299,831,149.00	12,976%
Agriculture. Forestry and Fishing	222,274,662.00	9,620%
Financial and Insurance Activities	209,028,955.00	9,047%
Accommodation and Food Service Activities	173,078,681.00	7,491%
Other industries of economy	141,348,295.00	6,117%
Electricity. Gas. Steam and Air Conditioning Supply	120,781,315.00	5,227%
Mining and Quarrying	90,347,279.00	3,910%
Transportation and Storage	70,449 137.00	3,049%
Information and Communication	56,485,640.00	2,445%
Real Estate Activities	50,064,657.00	2,167%
Professional. Scientific and Technical Activities	33,141,894.00	1,434%
Arts. Entertainment. and Recreation	22,664,691.00	0,981%
Human Health and Social Work Activities	16,276,819.00	0,704%
Education	7,054,447.00	0,305%
Water Supply; Sewerage. Waste Management and Remediation Activities	236,836.00	0,010%

Table 2. Assessment of the centralization level using the Herfindahl-Hirschman index

Banks	2018		2021	
	HHI value	Concentration level	HHI value	Concentration level
Acba Bank OJSC	0,260729	high	0,231065	High
Ameriabank CJSC	0,122282	medium	0,108733	Medium
Araratbank OJSC	0,190401	high	0,193343	High
Ardshinbank CJSC	0,106112	medium	0,109387	medium
Conversebank CJSC	0,185136	high	0,182058	high
HSBC-Armenia Bank CJSC	0,254135	high	0,208476	high
Inecobank CJSC	0,293249	high	0,260283	high
IDbank CJSC	0,350675	high	0,257103	high

The summary indicators of the entropy coefficient are presented in table 3:

Table 3. Assessing the level of centralization using the entropy index

Banks	2018		2021	
	E value	log ₂ n	E value	log ₂ n
Acba Bank OJSC	2,347415	3,169925	2,466162	3,169925
Ameriabank CJSC	3,356082	3,70044	3,441305	3,70044
Araratbank OJSC	0,190401	2,807355	2,561001	2,807355
Ardshinbank CJSC	3,442027	3,807355	3,370774	3,807355
Conversebank CJSC	2,659302	3	2,669148	3
HSBC-Armenia Bank CJSC	2,448859	3,169925	2,650311	3,169925
Inecobank CJSC	2,347297	3,169925	2,418802	3,169925
IDbank CJSC	1,918108	3,321928	2,477437	3,321928

After arranging the credit portfolio in descending order, let's apply Linda's coefficient:

Table 4. Allocation of credit assets of commercial banks by economic sectors, Mill. AMD, 2021

Sectors/Banks	Acba Bank OJSC	America bank CJSC	Ararat bank OJSC	Ardshin bank CJSC	Converse bank CJSC	HSBC-Armenia CJSC	Ineco bank CJSC	IDbank CJSC
Real Estate Activities	-	22,6	25,5	-	-	-	-	-
Trade	37,1	94,0	26,3	49,5	34,0	42,9	57,2	27,0
Manufacturing	6,98	9,84	9,190	5,26	12,6	10,9	18,6	6,51
Agriculture	3,30	42,4	4,79	1,25	13,952	4,03	0,87	25,0
Electricity. Gas. Steam and Air Condit. Supply	4,45	29,2	-	35,7	3,7	8,30	1,8	4,27
Information and Communication	-	20,4	-	20,0	-	-	-	-
Mining and Quarrying	-	29,1	-	42,3	-	-	-	3,23
Tourism	-	31,2	-	20,3	-	-	3,09	2,30
Construction	20,2	48,9	13,0	42,0	22,5	5,91	9,63	5,2
Government	-	-	-	65,12	-	-	-	-
Accommodation, Food Service	38,1	37,9	11,2	28,65	-	19,3	16,2	-
Other Service Activities	-	-	-	28,5	6,83	17,5	-	1,96
Transp. and Storage	4,65	37,8	5,92	0,49	3,41	-	8,69	0,42
Financial and Insurance	4,28	9,93	-	11,8	-	2,83	-	-
Other industries	1,47	14,3	-	9,7	19,0	3,73	10,4	8,51

Table 5. Allocation of credit assets of RA commercial banks by economic sectors, Mill. AMD, 2018

Sectors/Banks	Acba Bank OJSC	Ameria bank CJSC	Ararat bank OJSC	Ardshin bank CJSC	Converse bank CJSC	HSBC Armenia CJSC	Ineco bank CJSC	ID bank CJSC
Real Estate Activities	-	12,3	-	-	-	-	-	-
Trade	27,3	102,0	23,8	37,8	35,0	37,6	62,1	21,7
Manufacturing	7,94	7,48	17,0	6,53	7,31	5,72	14,1	1,87
Agriculture	1,47	18,5	3,02	9,39	10,1	1,81	0,77	0,19
Electricity. Gas. Steam and Air Conditioning Supply	3,72	21,9	-	62,1	8,4	3,50	6,32	8,69
Information and Communication	-	20,6	-	25,1	-	-	-	-
Mining and Quarrying	-	61,8	-	39,1	-	-	-	0,53
Tourism	-	37,4	-	27,6	-	-	7,83	0,64
Construction	5,04	23,3	9,97	33,9	19,0	1,6	3,96	0,61
Government	-	-	-	11,8	-	-	-	-
Accommodation and Food Service Activities	16,7	23,6	-	21,2	-	13,9	17,4	-
Other Service Activities	-	-	10,3	31,0	10,7	14,5	-	0,13
Transportation and Storage	2,34	28,4	3,92	0,70	1,78	-	6,97	0,64
Financial and Insurance Activities	0,37	43,0	-	8,80	-	3,03	-	-
Other industries of economy	1,10	14,5	13,9	9,89	23,6	4,74	5,08	7,06

Table 6. Estimating the level of concentration using the Linda index, 2021

Acba Bank OJSC		Ameriabank CJSC		Araratbank OJSC		Ardshinbank CJSC	
L _k	value	L _k	value	L _k	value	L _k	value
L ₂	0,51356	L ₂	0,96153	L ₂	0,51468	L ₂	0,65771
L ₃	0,53144	L ₃	0,62360	L ₃	0,55885	L ₃	0,46188
L ₄	0,75853	L ₄	0,46550	L ₄	0,46944	L ₄	0,33825
L ₅	0,83615	L ₅	0,35849	L ₅	0,41452	L ₅	0,28523
L ₆	0,77018	L ₆	0,30990	L ₆	0,41731	L ₆	0,26139
L ₇	0,68587	L ₇	0,27121	L ₇	0,40960	L ₇	0,23049
L ₈	0,65251	L ₈	0,23647			L ₈	0,22657
L ₉	0,74521	L ₉	0,22311			L ₉	0,21256

	L ₁₀	0,21122		L ₁₀	0,22682
	L ₁₁	0,21389		L ₁₁	0,23705
				L ₁₂	0,27482
				L ₁₃	0,47846
				L ₁₄	0,51013
L_{avg}		L_{avg}	L_{avg}	L_{avg}	
0,51356		0,40678	0,48937	0,33425	
Dis		Dis	Dis	Dis	
0,02		1,1122	1,0721	0,91304	
Conversebank CJSC		HSBC Armenia Bank CJSC	Inecobank CJSC	IDbank CJSC	
L_k	value	L_k	value	L_k	value
L ₂	0,75620	L ₂	1,11002	L ₂	1,53592
L ₃	0,52017	L ₃	0,68447	L ₃	0,93754
L ₄	0,44686	L ₄	0,60756	L ₄	0,79731
L ₅	0,37632	L ₅	0,55381	L ₅	0,65114
L ₆	0,39959	L ₆	0,53582	L ₆	0,54847
L ₇	0,46499	L ₇	0,54534	L ₇	0,63956
L ₈	0,47271	L ₈	0,52104	L ₈	0,74886
		L ₉	0,51780	L ₉	0,97017
				L ₁₀	3,73774
L_{avg}		L_{avg}	L_{avg}	L_{avg}	
0,52488		0,69833	0,89407	0,83843	
Dis		Dis	Dis	Dis	
1,39751		2,21492	2,29082	3,44985	

Table 7. Estimating the level of concentration using the Linda index, 2021

Acba Bank OJSC		Ameriabank CJSC		Araratbank OJSC		Ardshinbank CJSC	
L _k	value	L _k	value	L _k	value	L _k	value
L ₂	0,81568	L ₂	0,82689	L ₂	0,69996	L ₂	0,79429
L ₃	0,83104	L ₃	0,64248	L ₃	0,49921	L ₃	0,49229
L ₄	0,79877	L ₄	0,50281	L ₄	0,43077	L ₄	0,37152
L ₅	0,75004	L ₅	0,44489	L ₅	0,35348	L ₅	0,30239
L ₆	0,76707	L ₆	0,40219	L ₆	0,42387	L ₆	0,26100
L ₇	0,82092	L ₇	0,35138	L ₇	0,45610	L ₇	0,23194
L ₈	0,85684	L ₈	0,31168			L ₈	0,21568
L ₉	1,14185	L ₉	0,28048			L ₉	0,23281
		L ₁₀	0,25826			L ₁₀	0,24268
		L ₁₁	0,24966			L ₁₁	0,24167
		L ₁₂	0,24698			L ₁₂	0,23713
		L ₁₃	0,26113			L ₁₃	0,25578

L_{avg}		L_{avg}		L_{avg}		L_{avg}	
0,81568		0,4107		0,49585		0,38130	
Dis		Dis		Dis		Dis	
0,63136		1,96378		0,76741		0,72541	
Conversebank CJSC		HSBC Armenia Bank CJSC		Inecobank CJSC		IDbank CJSC	
L_k	value	L_k	value	L_k	value	L_k	value
L_2	0,73909	L_2	1,29176	L_2	1,77822	L_2	1,25300
L_3	0,52998	L_3	0,75088	L_3	1,12618	L_3	0,82091
L_4	0,52986	L_4	0,81664	L_4	1,02899	L_4	1,14835
L_5	0,45431	L_5	0,75351	L_5	0,86745	L_5	1,73355
L_6	0,40869	L_6	0,72086	L_6	0,73660	L_6	1,70685
L_7	0,37243	L_7	0,67169	L_7	0,66366	L_7	1,57708
L_8	0,52067	L_8	0,70035	L_8	0,62404	L_8	2,34486
		L_9	0,69333	L_9	0,89140	L_9	3,72240
						L_{10}	6,54394
L_{avg}		L_{avg}		L_{avg}		L_{avg}	
0,50572		1,02132		0,97502		1,03696	
Dis		Dis		Dis		Dis	
1,60698		1,25265		3,99230		1,46272	

Conclusion. After examining Table 1, it is evident that although there has been a decrease in the Herfindahl-Hirschman index in 2021 compared to 2018, there still exists a significant level of concentration in the commercial banks studied. Additionally, the Entropy results reveal a high concentration level. However, relying solely on the Herfindahl-Hirschman or Entropy index is not sufficient to manage medium or high levels of concentration. It is necessary to have a tool that can identify the core of concentration in the credit portfolio, which may not be apparent at first glance. Linda's index meets this requirement and can improve the efficiency of concentration risk management.

While looking at Table 5, it is evident that there are no loan portfolios with low concentration in the studied banks for 2021, and medium-concentration loan portfolios are present in Ameriabank CJSC, Ardshinbank CJSC, and Araratbank OJSC. The core of concentration in the credit portfolios of these banks is made up of 10 out of 11 sectors, 5 out of 7 sectors, and 8 out of 14 sectors. These results are considered favorable when compared to the indicators of Acba Bank OJSC. The presence of medium-concentration loan portfolios in Ameriabank CJSC, Ardshinbank CJSC, and Araratbank OJSC, as well as the absence of loan portfolios with low concentration, indicates that these banks have a more diversified credit portfolio than Acba Bank OJSC. The fact that the core of concentration in the credit portfolios of these banks is spread across multiple sectors suggests that they are not heavily reliant on a single sector, reducing the risk of

losses in the event of a downturn in any one particular sector. This level of diversification can be considered favorable as it reflects a more balanced approach to lending and risk management.

In the case of Acba Bank OJSC, Linda's index shows an increase in concentration in both 2018 and 2021, indicating a dominant position in one or two sectors. Specifically, the credit portfolio of Acba Bank OJSC is heavily concentrated in Trade and Service, as well as Accommodation and Food Service Activities. The heavy concentration of Acba Bank OJSC's credit portfolio in Trade and Service, as well as Accommodation and Food Service Activities, may be due to the fact that these sectors are vital components of Armenia's economy. As a result, the bank may be focusing on providing financing to businesses operating in these sectors to support their growth and contribute to the overall development of the country's economy. Inecobank CJSC also has a high level of concentration in its loan portfolio, with 6 out of 9 sectors making up the core of concentration. Even though the majority of sectors are part of the core, there is a significant imbalance in the allocation of credit assets between them, with a substantial amount allocated to the Trade sector and a much smaller amount to the Agriculture sector. 57.2 billion AMD is allocated in the Trade sector, and only 0.8 billion AMD in the Agriculture sector. The significant imbalance in the allocation of credit assets between the Trade and Agriculture sectors may be due to several factors. One possible reason is that the Trade sector may have a higher demand for credit as it involves a wide range of businesses, including wholesalers, retailers, and distributors, which require significant capital to operate. On the other hand, the Agriculture sector may have a lower demand for credit, as it may be perceived as a riskier sector due to its vulnerability to natural disasters, weather fluctuations, and other external factors that can affect crop yields and profitability. Additionally, the lending policies and risk management strategies of the bank may also contribute to the imbalance in credit allocation between the two sectors. It is important to acknowledge that there is no single index or metric that can accurately and comprehensively measure the level of concentration in every situation. One advantage of using the entropy coefficient over the Herfindahl-Hirschman coefficient is that the logarithm of fractions used in its calculation eliminates potential errors. Another advantage of Linda's index is that it can identify the core sectors of concentration in credit portfolio, providing insight not only into the level of concentration, but also into the specific sectors where concentration is highest. A key advantage of using Linda's index is that it allows for exclusion of certain parts of the loan portfolio that do not belong to any particular sector of the economy. This is significant because all banks have such parts in their loan portfolios, and excluding them helps to calculate Linda's coefficient more accurately. Combining the three coefficients discussed in the article can lead to a more precise representation of the concentration level in the credit portfolio. This can improve the efficiency of managing concentration and credit risk.

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Linda and Entropy concentration indices as instruments of credit risk management

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In all the financial organizations of the world, the homogenous distribution of profitable assets receives a lot of attention. The most homogeneous distribution or diversification of assets according to economic sectors, regions or ratings enables organizations to control possible credit risks, thus ensuring their financial stability and business continuity. In our article, we will use two coefficients: Linda and Entropy coefficients, with the help of which we will get a more accurate estimate of the level of concentration. For these indicators, the easy calculation can be considered as an advantage, which stimulates managerial operative decision-making. Moreover, the Linda and Entropy coefficients provide a quantitative measure of the concentration of assets in a portfolio, which helps organizations determine the extent to which their portfolio is diversified. This is crucial for making informed investment decisions and managing risk effectively. Thus, financial organizations can ensure a well-diversified portfolio.