A Comparative Analysis of Early Warning Systems for Systemic Risk Across Economies

Author: Sem Brummelaar
University of Twente
P.O. Box 217, 7500AE Enschede
The Netherlands

ABSTRACT

This research examines how Early Warning Systems for detecting systemic risk differ across different economies. The study focuses on four central banks: the Federal Reserve (United States), the European Central Bank (Euro Area), the South African Reserve Bank (South Africa), and the People's Bank of China (China). The aim of this research is to assess whether and how central banks of different economies measure and monitor systemic risk using Early Warning Systems.

In this study, the qualitative and quantitative risk factors and variables from the Early Warning Systems are analyzed. By comparing the risk factors from both a quantitative and qualitative perspective, differences and similarities between the Early Warning Systems used by the central banks were identified. The results show that all four central banks use similar base risk factors and variables. Furthermore, no clear differences were found between the categories Advanced Economies and Emerging and Developing Economies.

In conclusion, differences are apparent in the Early Warning Systems used by the Federal Reserve, the European Central Bank, the South African Reserve Bank, and the People's Bank of China. However, all four central banks use mostly similar risk factors and variables for detecting and monitoring systemic risk using their Early Warning Systems. This implies a more standardized Early Warning System can be used, which makes comparing systemic risk across regions easier.

Graduation Committee members:
Wouter Heeswijk
Marcos Machado

During the preparation of this work, the author(s) used no artificial intelligence tools.

Keywords
Systemic Risk; Financial Stability; Early Warning Systems; Central Banks; Advanced Economies; Emerging and Developing Economies

1. INTRODUCTION

The banking industry is a critical part of the economy, as its influence on the economy and economic growth is unprecedented. Especially globalization, innovation and deregulation have contributed to making banking the cornerstone of the economy (Song & Chen, 2025). However, we see that because of this influence, the industry is also known for causing economic downturns. These economic downturns and crises are seen throughout history, with notably the 2008 financial crisis as a perfect example of how the banking industry can send an entire economy into a recession (Murphy, 2008). The reason the banking industry was at the heart of this crisis was because of high levels of systemic risk (Bullard et al., 2009). This is the risk related to the financial system collapsing due to the interdependence of banks and financial institutions (Ali Namaki, 2023). Early Warning systems (EWS) are used by regulators, governments, financial institutions, and central banks. These institutions use these EWS to detect increased levels of systemic risk and take action to prevent crises such as the 2008 financial crisis.

In the financial world, systemic risk is a concept that has been described and defined by many different researchers. However, because of the many different factors and potential origins of systemic risk, and the difficulties in detecting it, there is still disagreement about a clearly defined, and widely accepted definition (Wever et al., 2022). Namaki et al. (2023) stated that "Systemic risk is the risk of an entire financial system collapsing due to links and dependencies among financial institutions and between financial institutions and the real economy". This definition of systemic risk introduced by Namaki et al. (2023) is the definition that will be used in this research.

Modern financial systems are very interrelated and dependent on each other, especially in the world of banking, where interbank loans make for a high level of interconnectedness and financially engineered products increase the complexity in this industry. Because of this interconnectedness, the failure or illiquidity of one bank, can quickly cause liquidity problems in another bank that loans money to the failing bank (Haldane & May, 2011). Because these commercial banks are essentially all doing the same thing, which is lending and borrowing money, homogeneity is created which can minimize risk for individual banks but increase probability of the entire system collapsing (Haldane & May, 2011). Wever, Shah and O'leary (2022) state that "systemic risk tends to occur more frequently, and with more severe consequences, in a complex and dynamic environment". Because modern banking ecosystems are often complex and dynamic environments, increased systemic risk can be a real threat to financial stability, and can eventually cause a collapse of these ecosystems.

A collapse in the banking system is often referred to as a banking crisis. A working definition of a banking crisis is the "occurrence of severely impaired ability of banks to perform their intermediary role" (Davis & Karim, 2008). These banking crises can have huge impacts on the broader economy, and even in a global context they can send shockwaves through international economies. This is where EWS for financial systemic risk come in. EWS in a financial context are solutions, in the form of methods and processes, to accurately and reliably assess complex systems and networks in an industry or the economy in general (Wever et al., 2022). In this case, assessing such complex systems is measuring systemic risk, what can be used to predict a bank failure or outright banking crisis. The high direct and indirect cost of such crises highlight the need for EWS for detecting systemic risk (Davis & Karim, 2008).

There can be many different users of EWS, as there are many different stakeholders influenced by systemic risk and a banking crisis. However, not all of these stakeholders use EWS. Financial institutions like banking and securities intermediaries and hedge funds use EWS for their risk management practices (Hendricks et al., 2006). For them, changes in systemic risk can alter the risk profile of their investments and assets, which can both positively and negatively affect the performance of such institutions. These institutions can transfer their risk to insurance companies, which also make use of EWS to put a price tag on these insurances for banking crises (Gersbach, 2013). Other big stakeholders are central banks and policymakers, who play a key role in preventing banking crises. They are meant to protect the financial stability of a country, or in the case of the European Central Bank, an economic region. In times of financial distress or a banking crisis, central banks can provide liquidity, impose a reduced discount rate, or expand the types of collateral banks can pledge for their loans (Jácome, 2008). These actions can help to prevent banks from failing and can help stabilize the banking ecosystem. However, this financial support to impaired banks can have negative effects on the broader economy, which means that this financial support should be carefully considered.

As there are many diverse sources and origins of systemic risk, it can be unclear as to what risk factors and origins should be considered. Different countries and economies may use different metrics and methods for detecting systemic risk. Therefore, there may be differences in the EWS used by these different countries and economies. This research aims to identify the differences and compare the EWS in different economic ecosystems. The study focuses on the EWS that are used to assess systemic risk in complex banking and financial systems. By identifying and comparing the differences in EWS across different economies, the understanding of the methods of detecting systemic risk can be improved. Furthermore, by researching different economies, a comparison can be made regarding which factors are important to which type of economy and why. This knowledge can be helpful in designing improved EWS that are more effective. This can be critical in detecting, preventing, and mitigating the consequences of a future banking crisis.

2. THEORETICAL FRAMEWORK

Different countries, economies, and economic regions in the world can be categorized using multiple methods, which take into account different criteria. These criteria used for the categorization can be based on quantitative data like GDP per capita, but also qualitative data like trade agreements. The banking ecosystems of these distinct categories of countries, economies and economic regions all have specific properties, just like their economy and financial infrastructure as a whole. This means that the EWS these distinct categories use can also differ from each other. To understand how different economies and economic regions are identified, first a deeper understanding of how they are categorized is necessary. Afterwards, we look for examples of how the EWS can differ per country, economy, and economic region.

2.1 Methods for identifying different economies

Identifying different economies, countries or banking ecosystems can be done in more than one way. In the World Economic Outlook (WEO) of 2025, the International Monetary Fund (IMF) classifies the economies of the world as one of two distinct categories. The WEO is a report that is usually published twice a year, and it presents analyses and projections of the world economy in the near future. The WEO report is an integral part of the IMF's surveillance of economic developments and policies in its member countries and the global economy. To categorize

economies, the International Monetary Fund divides them into advanced economies and emerging and developing economies (International Monetary Fund, 2025a). These categories are Advanced Economies, and Emerging and Developing Economies. But these two categories can again be divided into several subsets and groups. For example, the Euro Area, the BRICS and ASEAN-5 are all different subsets which fall under either advanced economies or emerging and developing markets. According to the IMF these subsets are not made from strict criteria but have rather formed over time. So, a clear distinction and division based on qualitative data is not made, rather it is a division based on historical trading agreements and relationships. However, these groups of economies have become very closely connected and intertwined with each other financially. This makes their banking systems also more interconnected with each other than with economies outside of this subset. There are also examples of more strict methods of categorizing economies. For example categorizing by absolute size of the country, population size, GDP per capita, absolute growth of the economy, and the population age (Daniela-Neonila & Roxana-Manuela, 2014). These criteria are all used for classifying emerging economies. Also, geographical distinctions can be made for identifying financial ecosystems or economic regions. Think of the Euro Area, ASEAN-5, UEMOA, or SAARC. These are all groups of countries that form a closely connected financial ecosystem, however, individual countries can also be identified as separate economies. Especially in more advanced and developed countries, the economy and financial systems are quite sophisticated, and there is a centralized institution responsible for that specific economy. For example the United States, where the Federal Reserve functions as a central bank (Federal Reserve, 2025c).

Because of these different methods to categorize economies or economic regions, it can be difficult to make clear distinctions between groups of countries. By using one method, countries may fall under one particular category, but when using other methods this category may not be the best fitting one. This means carefully describing which method was used to identify and categorize different economies, economic regions, or countries is of significant importance.

2.2 Identifying different Early Warning Systems

For different economies or financial ecosystems, we can identify different EWS for detecting systemic risk. One of such financial ecosystems is the G10 group (International Monetary Fund, 2025a). This is a group of countries that are classified as Advanced Economies by the International Monetary Fund. The G10 group was formed in 1962, with Switzerland joining later in 1964. The G10 have similar economic interests, which incentivized them to agree on GAB, which stands for General Arrangement to Borrow. Countries like the USA, Canada, France and Germany are part of this G10. The G10 uses several different EWS, which have been divided into four different categories, which are (Sahajwala, 2000):

1. Supervisory bank rating systems
2. Financial ratio and peer group analysis
3. Comprehensive bank risk assessment systems
4. Statistical models

The G10 countries use EWS of all these different categories, where every category has a different scope and features, with the intention that if one system is not able to detect potential high levels of systemic risk, another system will (Sahajwala, 2000). The different scopes and features include for example the inclusion of qualitative assessment, assessment of current financial condition and link with formal supervisory action.

Using multiple different EWS for detecting systemic risk is different from how Wang and Xi (2025) measured systemic risk in China. The EWS to detect systemic risk they used for their research was part of a broader category named the Banking Stress Index, also known as the BSI. The EWS of the category BSI includes five different variables (Wang & Xi, 2025):

1. Liquidity in the economy (Money supply 1/Money supply 2)
2. Growth rate of new loans
3. Loan-to-deposit ratio
4. NPL ratio (Non-Performing Loans)
5. Real interest rate

The EWS that was designed by (Caggiano et al., 2014), was targeted to use in low income countries in Sub-Sahara Africa. They found that there were three main predictors for predicting banking failures and thus predicting increased systemic risk. These predictors are economic growth, banking liquidity and widening currency mismatches in the balance sheet of a bank. These EWS are both based on specific variables that are used to predict increased systemic risk in the banking sector. However, sources of risk can also be used for EWS and measuring systemic risk.

The International Monetary Fund, also known as IMF, uses the CAMELS supervisory framework for assessing systemic risk in the banks (International Monetary Fund, 2023). The rating system is used to assess a bank's health, and it identifies and includes 6 different categories of risk:

1. Capital adequacy
2. Asset quality
3. Management performance
4. Earnings
5. Liquidity
6. Sensitivity to market risk

The management performance variable is often left out of quantitative analysis, as it is very hard to accurately measure this. The same is true for Sensitivity to market risk, where also the data to accurately measure this is very scarce.

2.3 Importance of researching Early Warning Systems

In the existing literature we see that different EWS, and the variables, indicators, and frameworks they take into account, can differ per economic region and country. Different banks or banking systems may fall under different laws and regulations, which can complicate using EWS designed for a specific region to evaluate another banking ecosystem that has to adhere to different policies. For example in China there is a focus on macroprudential measures, but in the United States market discipline is of more importance regarding regulations in the banking ecosystem (Jinfang, 2023). Certain variables, values and frameworks may also apply better to, for example, developing economies than mature economies. This further complicates using general EWS for various kinds of economies, countries, and banking ecosystems.

EWS for detecting systemic risk in the banking ecosystem is a well-studied part of the literature. A lot of these studies identify specific EWS for specific countries or economic regions. However, a comparison between these different countries or economic regions is not made. Also, no clear identification of

different economies, countries, or banking ecosystems, where they make use of specific EWS to that economy, country, or ecosystem, are apparent in the literature. By comparing the EWS and investigating why and how they are effective in different economies, countries, or banking ecosystems, they can be improved to be more effective. This can help for example policy makers like central banks to more adequately respond to this increased systemic risk, potentially preventing future banking crises (Song & Chen, 2025). This highlights the need for comparison of how the EWS are different, and how their historical performance compares for predicting banking crises.

3. RESEARCH DESIGN

3.1 Research question

This paper aims to answer the following main research question:

> How do Early Warning Systems for detecting systemic risk compare across different economic regions?

This question will be divided into several sub questions:

> 1. To what extent do the Early Warning Systems used for detecting systemic risk differ across economic regions?
>
> 2. What are key *qualitative* differences in the Early Warning Systems used to detect systemic risk across economic regions?
>
> 3. What are key *quantitative* differences in the Early Warning Systems used to detect systemic risk across economic regions?

3.2 Research methods

The research will take the form of a literature review. First, we have to identify the different economies, countries or banking ecosystems to study. In the theoretical framework we have already described what methods for categorization can be used for this identification. Then research on the different EWS these different economies, countries and banking ecosystems use for detecting systemic risk is needed. After we have identified and studied the different EWS, we can compare these EWS from both a qualitative and quantitative point of view. When we have identified the clear differences, we can move on to making conclusions regarding how and why these EWS differ from each other.

For the literature research Scopus[1] and Google Scholar[2] will be used as search engines for academic works. However, grey literature will be used as the main source of information for this comparison. This grey literature mainly includes reports and reviews published by institutions like the ECB and IMF. These are official institutions and organizations, and the reports published by them are based on their actual practices which make them a good source of information. To ensure the relevance of the reports and reviews used in this research, the latest published versions of these reports are used.

Because of the amount of literature there is on this topic, we will limit our timeframe for academic works and papers to 2005-2025. Big developments in machine learning and artificial intelligence make for an innovation in handling large amounts of data, which also applies on the topic of EWS for detecting systemic risk. By setting our timeframe to the past 20 years, we can ensure that this innovation will be taken into account when doing research. This ensures only the most relevant information and data is used. In addition to this, only academic works that were published in English are used.

The academic papers used in the literature review should be relevant to the topic of EWS and systemic risk in the banking sector. Both systemic risk and EWS are not only associated with banking, but also for domestic and international economies, and even in biology these concepts are present. When using keywords that are too broad, also papers about systemic risk and EWS in other fields of research will show, which are not relevant to this research. The keywords “Systemic Risk”, “EWS”, and “Early Warning Systems” will be critical, but in itself it may give irrelevant results. So, using them in combination with keywords as “Banking” and “Banking Crises”, which are keywords used in finance, is critical for finding relevant works. Using these keywords, the query “Early Warning Systems” AND “systemic risk” AND “banking” was used to identify relevant literature. The articles selected were also limited to those published between 2005 and 2025, and those published in English.

4. RESULTS

4.1 Identifying different economic regions

For the aim of this research, which is identifying and comparing EWS for systemic risk in different regions, the same division of economies that the IMF uses in the WEO is used. This means that the economies of the world are divided into Advanced Economies, and Emerging and Developing Economies (International Monetary Fund, 2025b). From both of these categories, two distinct economies are picked to research their use of EWS for detecting systemic risk. The first category, Advanced Economies, compiles of countries like the United States, Japan, Canada, and the Euro Area. Within this category of Advanced Economies, the IMF identifies five subsets:

1. Euro Area
2. The G7 group
3. Other advanced economies (excluding G7 and Euro Area)
4. European Union
5. ASEAN-5

Just like the category of Advanced Economies, the IMF also divides the category of Developing and Emerging Economies into five different subsets:

1. Emerging and Developing Asia
2. Emerging and Developing Europe
3. Latin America and the Caribbean
4. Middle East and Central Asia
5. Sub Saharan Africa

Economies are not limited to 1 subset, for example Germany falls under the Euro area, the G7 group and European Union. Also, Thailand falls under the ASEAN-5 group, which is a subset of Advanced Economies, but as an individual economy it is classified under Developing and Emerging Countries. Because the aim of this research is to compare the different EWS for detecting systemic risk in Advanced Economies, and Developing and Emerging Economies, we will pick individual economies rather than one of the subgroups for the comparison. There is one exception, which is the Euro Area. The reason we will take the Euro Area as a whole is because of the presence of the ECB. Because the Euro Area uses the same currency and has one central bank that regulates and monitors risk in the euro banking system, they already function as one economy mostly. There will

[1] https://www.scopus.com

[2] https://scholar.google.com

be no significant difference in using one of the individual economies from the Euro area or using the Euro Area as a whole.

The economies selected for this research from the category of Advanced Economies are the Euro Area and the United States. These two economies are leading players on a global level with having a GDP of 27,72 trillion USD and 15,78 trillion USD as of 2023 respectively (World Bank Group, 2025a, 2025b) . For this research, the Euro Area and the United States can function as examples of Advanced Economies, as there is accurate, easily accessible, and readily available data about these economies.

From the second category, Emerging and Developing Economies, South Africa and China are selected. These countries have a GDP of 380,70 billion USD and 17,79 trillion USD as of 2023 respectively (World Bank Group, 2025c, 2025d). South Africa is relatively well-developed country of the SSA region, with their GDP being the second biggest of the area. Also, South Africa has a well-known and established central bank, namely the South African Reserve Bank (SARB) (South African Reserve Bank, 2020). Their use of EWS for detecting systemic risk is clearly stated on the website of SARB, which makes it a very well-suited case to use for the comparison. China's economy has grown significantly in the last decade, which also brings new developments and more capital inflow from foreign countries. This can add systemic risk in the Chinese financial ecosystem. Thus, having adequate EWS is of crucial importance for China's economy.

The classification method the IMF uses to classify the world's economies is not based on strict criteria. There is no economic data used, for example GDP per capita, to determine in which category a specific economy belongs. Rather, the division into the two categories has formed over time according to the IMF, with the purpose being to create a meaningful method of organizing the data. There are also some economies which are left outside of the classification and thus are also not in the WEO report of the IMF. Examples are the Democratic People's Republic of Korea and Cuba. Both of these countries are not members of the IMF, thus they are not monitored (International Monetary Fund, 2025b).

4.2 Explaining the Early Warning Systems

For the selected economic regions, we must identify the EWS that are used for detecting systemic risk.

United States:

The central bank of the United States is the Federal Reserve. It was created as part of the Federal Reserve Act of 1913 to create a monetary system that can respond effectively to stress in the banking system (Federal Reserve, 2025c). The federal Reserve performs five tasks to ensure a stable financial system. These tasks also include promoting and ensuring financial stability and supervising and regulating financial institutions. For ensuring financial stability in the financial system of the United States, the Federal Reserve Regularly and systematically assesses a standard set of vulnerabilities as part of their periodic review of financial stability (Federal Reserve, 2025b). They monitor the vulnerabilities in four critical areas of the financial system and determine how these risks could amplify stress in this system. With the data that comes from the assessment of these four risk factors, the Federal reserve institutes supervisory stress tests, which assess banks on the solvency and liquidity during a severe recession. The four risk factors, which are all assessed using quantitative data, are the following:

1. Asset valuations
2. Borrowing by businesses and households
3. Leverage in the financial sector
4. Funding risks

Increased risk from asset valuations often comes when valuations are high relative to historic prices or economic fundamentals (Federal Reserve, 2025a). These high asset prices are driven by an increased willingness to take on risk. This can have the effect that there is increased volatility in these assets, which in turn can create stress and pressure in the financial system. This is connected to the second risk factor of assessment, which is borrowing by businesses and households. When there is a period of increased borrowing, and underlying assets decline in value, it can put the borrowers in higher debt. This can lead to reduced spending and reduced financial activity, which slows the broader economy, and puts stress on the financial system. The third area assessed is the leverage within the financial sector. Leverage directly influences the ability of financial institutions to cover and absorb losses without disrupting their normal business operations. A financial shock in combination with high leverage can severely impair an institution's daily operations. This risk is closely related to the fourth area of assessment, which is funding risks. This area describes the risk of liquidity and insolvency issues of financial institutions, which can create stress across markets, and other financial institutions. See Table 1 for an overview of the risk factors and the variables used to assess the risk factors. This table does not only include the Federal Reserve, but also the other three central banks.

Euro Area:

In the Euro Area, the European Systemic Risk Board (ESRB) was established in 2010 to oversee the European Union's financial system (European Systemic Risk Board, 2025). It is tasked with preventing and mitigating systemic risk in the financial industry by the creation of new, and the advice on existing policies of the European Central Bank (ECB). The ESRB is a Union-level body of the ECB that was created after the global financial crisis of 2008, with the aim to supervise and oversee risk in the financial system. Even though the EWS are really operated and used by the ESRB, we will from now on only refer to the ECB as the ESRB is part of the ECB.

The ECB publishes an annual report every year where they report on the systemic risks and threats in the financial system of the Euro Area. In the report of 2023, they identified six key origins for systemic risk (European Systemic Risk Board, 2024). In the report these origins of systemic risk are assessed and given one of three labels. These three labels categorize each origin to a certain level of systemic risk, with severe systemic risk being the highest, in the middle elevated systemic risk, and systemic risk being the lowest severity. The six key risk factors the ECB identified in 2023 were:

1. Low economic growth and longer than expected inflation resulting in stress for non-financial corporations and households
2. Disorderly market corrections amplified by the non-banking sector
3. Deteriorating asset quality and higher funding risks for the banking sector
4. Materialization of accumulated risks in the residential and commercial real estate sectors
5. Re-emergence of sovereign financing and debt sustainability concerns

Table 1. Overview of risk factors and key variables used by each central bank

Institution (Country)	Risk Factor	Type of Data	Key variables
Federal Reserve (US)	Asset valuations	quantitative	P/E ratio of assets, with example of S&P 500 Liquidity in treasury market and equity market Real estate prices
	Borrowing by businesses and households	quantitative	Debt to GDP ratio Mortgage and credit card delinquency Interest coverage ratio of institutions
	Leverage in the financial sector	quantitative	Interest margins of institutions Leverage of financial institutions Common Equity Tier 1 ratio
	Funding risk	quantitative	Ratio of runnable money-like liabilities to GDP Liquidity ratios for banks
ECB (Euro Area)	Low economic growth and longer than expected inflation resulting in stress for non-financial corporations and households	quantitative	YOY Economic growth and inflation levels
	Disorderly market corrections amplified by the non-banking sector	quantitative	Market volatility
	Deteriorating asset quality and higher funding risks for the banking sector	quantitative	Profitability of banks-> ROE and NPL ratio
	Materialization of accumulated risks in the residential and commercial real estate sectors	quantitative	Risk of downturn in real estate market-> real estate prices
	Re-emergence of sovereign financing and debt sustainability concerns	quantitative	Debt to GDP levels of countries in the Euro Area, and around the world
	Disruptions of critical financial infrastructure, including central counterparties	quantitative	Risk of central counterparties becoming insolvent or having operational problems
	System-wide cyber incidents	qualitative	Risk of cyber security incidents
	Climate related financial stability risks	qualitative	Risk and implications of climate change
	Geopolitical tensions	qualitative	Geopolitical situation and potential risks that come from this
SARB (South Africa)	Risk appetite and asset valuation	quantitative	p/e ratio of JSE (Johannesburg Stock Exchange) JPMorgan Corporate Emerging Market Bond Index
	Financial sector partition	quantitative	Loan-to-deposit ratio Liquidity coverage ratio
	Non-financial sector partition	quantitative	Dept-to-disposable income ratio Debt-to-GDP ratio
	External vulnerabilities partition	quantitative	Real effective exchange rate of the Rand Net portfolio purchases by non-resident investors
PBC (China)	Expansion risk	quantitative	Growth of asset expansion
	Interbank risk	quantitative	Common Equity Tier 1 ratio
	Liquidity risk	quantitative	Liquidity ratio
	Credit risk	quantitative	Non-performing loans ratio
	Overall risk	qualitative	Developments in macroeconomy that could prove increased risk

6. Disruptions of critical financial infrastructure, including central counterparties

Looking at the risks described by the ECB, we can identify mainly quantitative variables that are connected to the risk factors described by the ECB. Quantitative variables used for the assessment of the systemic risk factors include economic growth and inflation, which are key figures used for the first factor. For the second factor, the ECB takes the stock market as a main indicator, and in particular the volatility of the stock market. This can be a great risk to banks and large investment funds with high leverage, or a high market footprint. Financial ratios from EU banks are taken into account for risk factor number 3, which is a risk directly coming from, and connected to the banking sector. Here the ECB looks at the profitability of banks, with the return on equity ratio and non-performing loans ratio being leading variables. Furthermore, the debt-to-GDP ratio also is a leading indicator, which is in this case connected to risk factor number 5 (European Systemic Risk Board, 2024).

Besides the six key risk factors of systemic risk, the ECB also identifies three risks with a broader nature, with the potential to also trigger the individual key risk factors. These three risks are system-wide cyber incidents, climate related financial stability risks, and geopolitical tensions. These are labeled Cross-Cutting financial stability risks. They are of more qualitative nature, concerned with climate change, cyber security and geopolitical risks and tensions (European Systemic Risk Board, 2024). With the risk factors described above, the ECB models scenarios by stress testing the financial system. These stress tests help to assess the resilience of this tested financial system, aiding in the creation and recommendation of existing and new policies to mitigate potential crises. The nine different risks monitored by the ECB together form the EWS to detect systemic risk. For an overview of these risk factors and variables linked to these factors, see Table 1.

South Africa:

The South African Reserve Bank is the central bank of South Africa. One of their tasks is monitoring and ensuring financial stability. They report on this stability by publishing a yearly financial stability report, which is found on their website. In this report the SARB describes their method of detecting potential problems and risks regarding the financial stability within the South African financial system (South African Reserve Bank, 2020).

The EWS that the SARB uses to detect increased systemic risk in the financial industry takes the form of a heatmap. In this heatmap key indicators are given a color based on the amount of risk they reflect. The labeling by color is done with a spectrum ranging from green to yellow to red, with green being low risk, and red being high risk.

The indicators are divided into four different categories (South African Reserve Bank, 2020):

1. Risk appetite and asset valuation
2. Financial sector partition
3. Non-Financial sector partition
4. External vulnerabilities partition

The indicators are all quantitative variables, and no qualitative data is incorporated by the SARB in this EWS. Within these four categories there is one that focuses on indicators regarding the banking sector. It should be noted that the indicators that fall under other categories also influence the risk in the banking sector, but these do not necessarily have to originate from this industry. For example, risks coming from the real estate sector can also increase risk in the banking sector. In Table 1 there is an overview of the four different risk factors and their variables.

China:

In the literature we described an EWS to detect systemic risk named the Banking Stress Index, which was used by (Wang & Xi, 2025). That particular EWS was a broader model that assessed systemic risk in the Chinese financial system with 5 variables. For this research paper, we will use the model for assessing systemic risk in the banking sector used by the central bank of China. The central bank of China is also known as The Central Bank of the People's Republic of China (PBC), and it is an official government body.

One of their tasks is ensuring financial stability and responding adequately to potential crises. As part of this task, they publish an annual financial stability report, which can be found on their website. In this report they have one chapter that is specifically about the banking sector. In this chapter, they oversee and assess the banking sector's performance, soundness, and future outlook (Financial Stability Analysis Group of the PBC, 2024). In the part of the report where the soundness of the banking sector is assessed, the Risk Monitoring and EWS are described. In 2020, the PBC developed an indicator system for risk monitoring. Once this system shows worsening indicators, the PBC can take action to prevent potential materialization of this risk. Banks are rated from 1 to 10, with 1 to 5 being a green zone, 6 to 7 being a yellow zone, and 8 and above being labeled as high-risk institutions. The EWS is only applied to banks rated 1 to 7, as banks rated from 8 to 10 are already identified as high risk or are bankrupt. The banks rated from 8 to 10 only make up a small proportion of the total assets controlled by banks in China, as the 7 to 10 rated banks make up 98,28% as of 2023 (Financial Stability Analysis Group of the PBC, 2024). The EWS that covers the green and yellow zone banks is composed of indicators originating from five different risk factors:

1. Expansion risk
2. Interbank risk
3. Liquidity risk
4. Credit risk
5. Overall risk

The banks are all assessed on these five different risk factors, and when an individual bank is recorded to have one or more of these risk areas above the industry average, it is placed on a watchlist. When on this watchlist, the PBC is actively conversating with these banks to urge them to take action regarding lowering the risk in a specific area. After the bank has taken action to successfully reduce the risk, it is removed from the watchlist.

Not only does the PBC monitor the risks originating from the banking sector, also developments in the macroeconomic environment are closely watched. Local government debt and the real estate sector are examples of critical areas to monitor, and when these areas show increased risk, the risk factors in the EWS are dynamically adjusted to reflect these developments (Financial Stability Analysis Group of the PBC, 2024). This means that the EWS used for detecting systemic risk in the Chinese banking sector is not based on only predetermined indicators but can change with regards to developments in the macroeconomy. Furthermore, PBC also develops stress test scenarios for the banking sector, where the influence on the

solvency and the liquidity of individual banks is tested against the banking sector. This gives additional insights into the stability of specific banks, and their performance during a potential financial shock or crisis.

4.3 Comparison of Early Warning Systems

To compare the different EWS of each economy, the quantitative and the qualitative aspects of these systems will be compared separately. For the comparison, two different tables were made. Table 2 is for comparing the qualitative aspects, and Table 3 is for comparing the quantitative aspects. In the comparison, the differences in variables and risk factors that are included in the EWS are researched. With this comparison we can draw conclusions about the key differences between these EWS, and how they differ in different economies.

Table 5 shows that only the ESRB and the PBC make use of qualitative variables. The EWS used by the United States and South Africa only make use of quantitative variables. So, all four compared central banks make use of quantitative variables, but only two out of the four include qualitative variables. Interesting to see is that the central bank of China, the PBC, has designed an EWS specifically for the banking sector. The Federal Reserve, ECB and the SARB all include the financial industry as a whole. Although there is no specific EWS for banks, there are variables that are specifically included to monitor the banking industry. For example, all the EWS described use a variable to measure the liquidity and/or the return on equity of banks. In combination with the NPL and CET1 ratio, these variables can give insight into the ability of banks to pay their obligations and interest. This is also an important figure for the stress tests that are used by the PBC, ECB and Federal Reserve, as part of this test is simulating if these banks are resistant to financial shocks and assessing their liquidity and solvency. So, while the Federal Reserve, ECB and the SARB all do not have an EWS specifically for the banking sector, they do monitor this sector by including risk factors with their origin in the banking sector.

Comparing the EWS from a qualitative perspective, we see in Table 2 that only the PBC in China, and the ECB in the Euro Area uses clearly stated qualitative variables to monitor systemic risk. These qualitative variables are included in the risk factor Overall risk in the Chinese EWS, which covers a lot of different areas of origin of systemic risk. This Overall Risk is assessed by examining developments in the macroeconomy that could prove to increase financial stability risk. Comparing this to the qualitative variables used by the ECB, we see that the ECB has more clearly stated what exactly these risks are. These are risks that come from potential cyber security issues, climate change, and geopolitical tensions. Also, these variables can be subject to change as described in the EWS. As the world changes so do the risks, which means that the potential risks to financial stability of the present do not have to be of the same proportion in the future. This dynamic model makes it a useful tool that is more future proof than static models where variables are not able to be changed or altered. For both central banks it is true that they try to incorporate the most relevant and important developments, however for the PBC this is only done for the macroeconomy. For the ECB, also sources of risk that are not of economic or financial origin are taken into account. For example, climate change can act as an origin of increased systemic risk in the banking sector. Banks are exposed to a broad spectrum of climate-related risks as they act as crucial economic intermediaries and provide essential services in the form of lending, investment and risk management (Umar et al., 2025). This study clearly shows the impact of climate change on the financial stability in the banking sector, and the same is true for the other two risk factors included by the ECB. Geopolitical tensions are considered one of the main drivers of instability in the financial sector, especially in emerging economies where foreign exchange markets and the banking and debt sector might be among the hardest-hit areas (NguyenHuu & Örsal, 2024). These risk factors mentioned are all quite abstract risks, and there is currently not enough knowledge to comprehend the potential impacts it may have. As there is so much uncertainty around these factors and these risks often have not occurred in the same way in history, the lack of ability to reference to similar situations makes it hard to predict this risk accurately. However, their impact shows that only including macroeconomic developments might not be enough to detect systemic risk in time, and that including variables like climate change, cyber security and geopolitics can help to detect systemic risk better and earlier.

For comparing the EWS from a quantitative aspect, we will use Table 3. There we see that the Federal Reserve, the ECB, and the SARB all use the stock market as a variable for measuring a risk indicator. These three risk factors are all related to measuring asset valuation and risk appetite. In this case, the ECB uses market volatility, but in the context of the stock market and Modern Portfolio Theory, this is also referred to as the risk of a stock in the market (Francis & Kim, 2013). The Federal Reserve and the SARB both use stock indices and their valuations to determine if there is high risk appetite or low risk appetite, which relate to increased systemic risk and decreased systemic risk respectively. Related to asset valuations is the real estate market. This is also a market that is closely watched and included in the EWS of the Federal Reserve and the ECB. The 2008 Financial Crisis is known to be caused by increased systemic risk (Bullard et al., 2009). This systemic risk had its origins in the real estate market, which indicates how important the real estate market is for financial stability (Ellis & Naughtin, 2010).

The debt-to-GDP ratio is a common variable used by all central banks but the PBC. This ratio is used together with variables like debt-to-disposable income, used by the SARB, and mortgage and credit card delinquency, used by the Federal Reserve, to give indications about the sustainability of the debt of an economy. This is closely related to credit and funding risk, which is included by all the central banks. This risk is measured by looking at the profitability of banks and financial institutions, and especially the profitability on the loans and assets. The Federal Reserve looks at the liquidity ratios for banks, and interest margins and leverage of financial institutions. The SARB and the PBC also include the liquidity ratio as a variable, and a common variable is also the Common Equity Tier 1 (CET1) ratio. This is a so-called risk-weighted capital ratio, which is a bank's capital as a percentage of risk-weighted assets. This CET1 ratio is used to measure capital adequacy (Andersen & Juelsrud, 2024). Another common variable included is the non-performing loans (NPL) ratio, which is incorporated in the EWS of the PBC and the ECB. We see that all central banks put emphasis on measuring and including the profitability, liquidity and solvency of financial institutions and banks. These factors are critical to the financial stability of an economy, as weak, illiquid, and insolvent banks are the main drivers of instability. As systemic risk is the risk of an entire financial system collapsing due to links and dependencies among financial institutions, it is critically important that these institutions do not fail as this may send shockwaves through the entire economy or even into the world (Ali Namaki, 2023).

Regarding variables that cover the broader economy, only the ECB includes the Year-on-Year growth of the economy and inflation levels. Other central banks do not incorporate these, however Debt-to-GDP ratio is a common factor. What is interesting is that the SARB is the only central bank that includes

Table 2. Qualitative risk factors and key variables

Institution (country)	Risk Factor	Key Variables
PBC (China)	Overall risk	Developments in macroeconomy that could prove increased risk
ECB (Euro Area)	System-wide cyber incidents	Risk of cyber security incidents
	Climate related financial stability risks	Risk and implications of climate change
	Geopolitical tensions	Geopolitical situation and potential risks that come from this

Table 3. Quantitative risk factors and key variables

Institution (country)	Risk Factor	Key Variables
Federal Reserve (US)	Asset valuations	P/E ratio of assets, with example of S&P 500 Liquidity in treasury market and equity market Real estate prices
	Borrowing by businesses and households	Debt to GDP ratio Mortgage and credit card delinquencies Interest coverage ratio of institutions
	Leverage in the financial sector	Interest margins of institutions Leverage of financial institutions Common Equity Tier 1 ratio
	Funding risk	Ratio of runnable money-like liabilities to GDP Liquidity ratios for banks
ECB (Euro Area)	Low economic growth and longer than expected inflation resulting in stress for non-financial corporations and households	YOY Economic growth and inflation levels
	Disorderly market corrections amplified by the non-banking sector	Market volatility
	Deteriorating asset quality and higher funding risks for the banking sector	Profitability of banks ROE and NPL ratio
	Materialization of accumulated risks in the residential and commercial real estate sectors	Risk of downturn in real estate market-> real estate prices
	Re-emergence of sovereign financing and debt sustainability concerns	Debt to GDP levels of countries in the Euro Area, and around the world
	Disruptions of critical financial infrastructure, including central counterparties	Risk of central counterparties becoming insolvent or having operational problems Solvency ratio and Liquidity ratios
SARB (South Africa)	Risk appetite and asset valuation	P/E ratio of JSE (Johannesburg Stock Exchange) JPMorgan Corporate Emerging Market Bond Index
	Financial sector partition	Loan-to-deposit ratio Liquidity coverage ratio
	Non-financial sector partition	Debt-to-disposable income ratio Debt-to-GDP ratio
	External vulnerabilities partition	Real effective exchange rate of the Rand Net portfolio purchases by non-resident investors
PBC (China)	Expansion risk	Growth of asset expansion
	Interbank risk	Common Equity Tier 1 ratio
	Liquidity risk	Liquidity ratio
	Credit risk	Non-performing loans ratio

foreign investment as a variable. They do this by taking into account the real effective exchange rate of the South African currency, which is the Rand, and the net portfolio purchases by non-resident investors. These variables are interesting, as when there is a lot of foreign investment, risks and instability regarding the financial ecosystem of a country invested in South Africa can spill-over and potentially impact the South African economy (Pinar, 2013).

There are clear differences in the EWS used by the Federal Reserve, the ECB, the SARB, and the PBC. As seen in Table 2 and Table 3, they have risk factors that have a lot in common with each other but also risk factors that are unique to that specific central bank. However, this comparison is made with individual economies. When looking at the differences in the risk factors and key variables between Advanced Economies and Developing and Emerging Economies, no clear distinctions can be made. The Federal Reserve and the ECB both are central banks active in Advanced Economies, and the SARB and PBC are active in Developing and Emerging Economies. However, the EWS of the Advanced Economies do not differ more or have more in common with each other than with the Emerging and Developing Economies. Thus, it seems that there are no risk factors or variables specific to the type of economy, in this case Advanced Economies and Emerging and Developing Economies, and this differs both per individual economy and economy category. So, we can say that the risk factors and key variables that are included in the EWS of a central bank, are universal to most EWS. Then based on the relevant risk factors and specific needs of an individual economy, other variables and risk factors are included. This means that EWS of one economic region could be used in other economic regions, while still capturing most relevant risk factors. Another interesting approach is that a more standardized EWS could be used for more economic regions, which makes comparing the systemic risk across these regions easier.

5. DISCUSSION

5.1 Conclusion

This study answers the question of how EWS for detecting systemic risk compare across different economic regions. The research shows that the EWS for detecting systemic risk differ across Advanced Economies and Emerging and Developing Economies, but no clear and specific variables that are linked to a specific category were found. Within these two categories the EWS differ, and there are risk factors and key variables that are unique to individual the central banks.

Only the ECB and the PBC make use of qualitative variables in the EWS. The Federal Reserve and the SARB only include quantitative variables. The qualitative variables allow for broader risk assessment, and in the case of the ECB also captures risks that originate from non-economic situations. The PBC also uses a qualitative variable, but this is focused on the macroeconomy. This is different from the ECB, who have the ability to also assess risk factors that originate from outside the economy. They also critically assess their qualitative variables, and if more urgent or relevant developments or risk arise, the model can be altered to include these new risk factors. This is unique to the EWS used by the ECB. The ability to have a dynamic system, which also captures a broad range of risk factors, makes it the most adaptable and future oriented EWS of the four central banks compared.

The SARB is the only central bank to include foreign investment exposure in their EWS. Because of spill-over effects of risk from other economies, this is an interesting variable to include. Because the other central banks have not included this foreign investment exposure, this could be a potential risk that they could miss as this risk is not directly monitored.

The PBC is unique because it is the only central bank of the four central banks compared that has an EWS specifically designed for the banking sector. However, the variables and risk factors that are assessed in this EWS are similar to the EWS of the other banks. This makes for no real advantage and improvement in measuring systemic risk for the PBC, as the banking sector is already included in the broader EWS of the Federal Reserve, the ECB and the PBC. However, we can conclude from this that the health of the banking sector is extremely important in detecting systemic risk.

Another common risk factor that is included by all central banks except the PBC, is asset valuations. This is measured by looking at stock market valuation, stock market volatility, and the real estate market. Because three out of four EWS incorporate these risk factors, we can conclude that this risk factor is critical to most central banks to monitor and include.

The ECB appears to have the most comprehensive and future-proof EWS. They integrate both economic and non-economic risks, and their EWS is a dynamic model where risk factors and key variables can be changed. Including these non-economic risks is important according to the literature (Ellis & Naughtin, 2010; NguyenHuu & Örsal, 2024; Umar et al., 2025). The PBC focuses deeply on banking-specific risks with their EWS specifically designed for the banking sector, and the SARB uniquely includes foreign investment risks. However, the EWS of all central banks are built up from the same base variables, emphasizing the health of the banking sector, asset valuation, and debt risk. This implies that standardized EWS could be possible, which can make comparing systemic risk across regions easier.

5.2 Theoretical and practical implications

The central banks of the ECB and the PBC show the importance and relevance of including qualitative risk factors, which is backed by the literature (Ellis & Naughtin, 2010; NguyenHuu & Örsal, 2024; Umar et al., 2025). These qualitative risk factors are emerging systemic threats that are not monitored or captured by the more traditional and quantitative indicators for detecting systemic risk. This means for existing and future EWS it can be useful to include qualitative risk factors, as this can make these systems more robust and more efficient at detecting risks that come from non-economic areas for example. By taking the ECB as an example, we also see that having a future-proof EWS can be of immense value. As with globalization the financial world is becoming more inter-connected and new developments are coming at a faster pace than ever, there may also be new systemic risk factors luring which can pose a high threat if not detected in time.

Creating sector-specific EWS, like that of the PBC, could potentially help to monitor high-risk sectors in more detail. However, the PBC does not show a more sophisticated approach for monitoring the banking sector than Federal Reserve, the ECB, and the SARB. If a central bank would want to create EWS that emphasizes the risk in a specific sector, it would have to be more sophisticated as that of the PBC. If not, the EWS will not monitor the specific sector deeply and thoroughly enough, and the same result can be achieved with a more general EWS.

Monitoring foreign investment risks, like done by the SARB, could prove to be a useful variable to include in an EWS. When developments in other economies, with for example an economic crisis, make investors less likely to invest in foreign markets, these developments could spill over into other foreign economies. This can pose a real threat, as seen in the 2008

Financial Crisis, where the banking crisis that originated in the United States sent shockwaves all around the globe.

This research contributes to existing literature by challenging the traditional view of a qualitative focus within EWS. As qualitative risk factors have shown to be of significant importance in monitoring risks as shown by the ECB, this is not incorporated in the EWS of the Federal Reserve, the SARB, and the PBC. Furthermore, this research reinforces the view that the banking and financial sector is the main area of origin of systemic risk, as all EWS emphasize monitoring the health and stability of this sector. The PBC even created an EWS that was specifically designed for the banking sector. Although this is not the most sophisticated system and other more broad EWS achieve the same monitoring result, it does show the importance to emphasize this specific sector. A risk factor that also showed to be of significant importance is the stock market, as three of the four central banks included this factor in their EWS. Furthermore, the research indicates that because the differences between the EWS are minor and small, a more general and widely used EWS could prove valuable.

5.3 Limitations

This research focused on comparing the EWS for detecting systemic risk in different economies. For the scope of this research four different economies were chosen, which were the United States, the Euro Area, South Africa, and China. Because we focused on official governing bodies of these economies, relevant data and EWS that are used in practice by these institutions were used. However, there are some limitations to this research which we will discuss.

The first limitation is the categorization of the economies. As the IMF categorizes the world's economies into only two different categories, this makes for a high variance of economies inside these categories. And because the research is limited to only four different central banks, it makes for a very small sample to make assumptions about the differences in EWS on the category level. This limitation is essential to keep in mind when interpreting the results and using this information for future research.

Another limitation is the scope of the research, which concentrates on systemic risk originating in the financial sector. There is no attention to other potential sources of systemic risk, for example in the energy sector, tech sector or in supply chains. This research may understate the importance of these other potential sources as only risk factors originating in the financial sector were included.

Because this research heavily relies on publicly available information published by the central banks of the United States, the Euro Area, South Africa, and China, it may not reflect internal information that is not shared with the public. If there are other risk factors and key variables included that are not made public, this comparison uses incomplete information, and the results may differ substantially from the reality.

The fourth limitation is the timeframe used for selecting research papers and academic works. Because only papers were selected that were published between the years 2005 and 2025, we have excluded potential important information and studies that were brought out before 2005.

As only the EWS used by the four chosen central banks were used, we only looked from the perspective of one type of stakeholder. There are also other institutions who measure systemic risk, with examples being hedge funds (Savona, 2014). And when examining the literature about systemic risk and financial stability, we see that there are numerous papers and research with the aim of measuring systemic risk effectively. Because only the perspective of one of the stakeholders is used, the practical implications are limited to only the central banks.

In conclusion, this research gives valuable insight into the differences between EWS used by different central banks of four economies. However, the scope and limitations of the research highlight the need for future research.

5.4 Future research

Following the limitations of this research paper, we can identify problems and gaps that could use future research. This future research can use the knowledge collected here and expand the scope of this comparison.

One of the limitations a future study could improve is regarding the sample size. More different economies could be included in the study, which would making assumptions about the broader economic category possible. By making use of a bigger sample of different economies, more accurate conclusions can be made about differences and similarities between EWS of different economy categories. Future research could also include the perspective of other stakeholders. By including the perspective of stakeholders like hedge funds, a more general picture of how systemic risk is measured regarding the goals and stakes of different stakeholders.

Studying the effectiveness and historical performance of EWS would give insight into how different variables change and the importance of them. This could prove especially useful in making EWS more effective and efficient. This research could make use of back testing different EWS and examining how well they detect systemic risk with regards to, for example, banking crises. Future research about systemic risks that are from non-financial origin could contribute to making EWS more robust. This research could give insights into how EWS can become more comprehensive and how their ability to capture risks that go beyond the financial sector can improve.

We see that although this research gives valuable insight into differences in EWS from a central bank's perspective, there are still areas that need studying. Systemic risk has a broad definition and is complex in nature. EWS can benefit from a better understanding of systemic risk, as then these systems can become more effective and efficient.

6. REFERENCES

Ali Namaki, R. E., Shahin Ramtinnia. (2023). a systematic review of early warning systems in finance. arXiv preprint arXiv:2310.00490, 20.

Andersen, H., & Juelsrud, R. E. (2024). Optimal capital adequacy ratios for banks. Latin American Journal of Central Banking, 5(2), 100107. https://doi.org/https://doi.org/10.1016/j.latcb.2023.100107

Bullard, J., Neely, C. J., & Wheelock, D. C. (2009). Systemic risk and the financial crisis: a primer. https://doi.org/https://elischolar.library.yale.edu/ypfs-documents/1137

Caggiano, G., Calice, P., & Leonida, L. (2014). Early warning systems and systemic banking crises in low income countries: A multinomial logit approach [Article]. Journal of Banking and Finance, 47, 258-269. https://doi.org/10.1016/j.jbankfin.2014.07.002

Daniela-Neonila, M., & Roxana-Manuela, D. (2014). The emerging economies classification in terms of their defining, grouping criteria and acronyms used for this purpose. Management Strategies Journal, 26(4), 311-319.

Davis, E. P., & Karim, D. (2008). Comparing early warning systems for banking crises [Article]. Journal of Financial Stability, 4(2), 89-120. https://doi.org/10.1016/j.jfs.2007.12.004

Ellis, L., & Naughtin, C. (2010). Commercial Property and Financial Stability–An International Perspective. Bank of England Quarterly Bulletin(June).

European Systemic Risk Board. (2024). ESRB Annual Report 2023. E. S. R. Board. https://www.esrb.europa.eu/pub/pdf/ar/2024/esrb.ar2023~b50f419dab.en.pdf?fd5e573c675f13857b6806a3469e037a

European Systemic Risk Board. (2025). About Us. European Systemic Risk Board. Retrieved June 14th from https://www.esrb.europa.eu/about/background/html/index.en.html

Federal Reserve. (2025a). Financial Stability Report. https://www.federalreserve.gov/publications/files/financial-stability-report-20250425.pdf

Federal Reserve. (2025b, December 17th, 2021). Types of Financial System Vulnerabilities and Risks. Federal Reserve. Retrieved May 17th from https://www.federalreserve.gov/financial-stability/types-of-financial-system-vulnerabilities-and-risks.htm

Federal Reserve. (2025c). Who Are We. Federal Reserve. Retrieved May 28th from https://www.federalreserve.gov/aboutthefed/fedexplained/who-we-are.htm

Financial Stability Analysis Group of the PBC. (2024). Financial Stability Report 2023 (ISBN 978-7-5220-2392-2). C. F. P. House. http://www.pbc.gov.cn/en/3688235/3688414/3710021/4756457/5456682/2024091016085420990.pdf

Francis, J. C., & Kim, D. (2013). Modern portfolio theory: Foundations, analysis, and new developments. John Wiley & Sons.

Gersbach, H. (2013). Preventing banking crises-with private insurance? [Article]. CESifo Economic Studies, 59(4), 609-627, Article ifs043. https://doi.org/10.1093/cesifo/ifs043

Haldane, A. G., & May, R. M. (2011). Systemic risk in banking ecosystems. Nature, 469(7330), 351-355. https://doi.org/10.1038/nature09659

Hendricks, D., Kambhu, J., & Mosser, P. (2006). Systemic Risk and the Financial System. F. R. B. o. N. York.

International Monetary Fund. (2023). Global Financial Stability Report: Financial and

Climate Policies for a High-Interest-Rate Era. I. M. Fund. https://www.imf.org/en/Publications/GFSR/Issues/2023/10/10/global-financial-stability-report-october-2023

International Monetary Fund. (2025a, 2025). A guide to committees, groups, and clubs. International Monetary Fund. Retrieved May 15th from https://www.imf.org/en/About/Factsheets/A-Guide-to-Committees-Groups-and-Clubs

International Monetary Fund. (2025b). World Economic Outlook: A Critical Juncture amid Policy Shifts. I. M. Fund. file:///C:/Users/sembr/Downloads/text%20(1).pdf

Jácome, L. I. (2008). Central Bank Involvement in Banking Crises in Latin America.

Jinfang, Y. N. H. A.-H., Hisham; Noori Hussein, Waleed; Noori Hussein, Harder. (2023). Comparative Analysis of the Global Banking System: A Study of the American and Chinese Banking Regulations [Journal Article]. INTERNATIONAL JOURNAL ON ECONOMICS, FINANCE AND SUSTAINABLE DEVELOPMENT, 5. http://eprints.umsida.ac.id/12635/1/Comparative%20Analysis%20of%20the%20Global%20Banking.pdf

Murphy, A. (2008). An analysis of the financial crisis of 2008: causes and solutions. An Analysis of the Financial Crisis of 2008. https://doi.org/ http://dx.doi.org/10.2139/ssrn.1295344

NguyenHuu, T., & Örsal, D. K. (2024). Geopolitical risks and financial stress in emerging economies. The World Economy, 47(1), 217-237. https://doi.org/https://doi.org/10.1111/twec.13529

Pinar, Y. (2013). Foreign Currency Loans and Systemic Risk in Europe (13.06). https://hdl.handle.net/10419/128077

Sahajwala, R. V. d. B., Paul. (2000). Supervisory risk assessment and early warning systems. BASEL COMMITTEE ON BANKING SUPERVISION WORKING PAPERS, 59.

Savona, R. (2014). Hedge fund systemic risk signals. European Journal of Operational Research, 236(1), 282-291.

Song, L., & Chen, Y. (2025). Does a non-performing assets disposal fund help control systemic risk? Evidence from an interbank financial network in China. Financial Innovation, 11(1), 46. https://doi.org/10.1186/s40854-024-00667-7

South African Reserve Bank. (2020). About Us. South African Reserve Bank. Retrieved June 6th from https://www.resbank.co.za/en/home/about-us

Umar, M., Mirza, N., Achim, M. V., & Ribeiro-Navarrete, S. (2025). The impact of climate change on credit portfolios and banking resilience: Preliminary evidence from a developing economy. International Review of Financial Analysis, 102, 104021. https://doi.org/https://doi.org/10.1016/j.irfa.2025.104021

Wang, Y., & Xi, W. (2025). Measurement and Early Warning of Systemic Financial Risk in China: Markov Switching Models [Article]. Computational Economics. https://doi.org/10.1007/s10614-025-10873-9

Wever, M., Shah, M., & O'Leary, N. (2022). Designing early warning systems for detecting systemic risk: A case study and discussion [Article]. Futures, 136, Article 102882. https://doi.org/10.1016/j.futures.2021.102882

World Bank Group. (2025a). GDP (current US$) - United States. World Bank Group. Retrieved May 6th from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=US

World Bank Group. (2025b). GDP (current US$) - Euro area. World Bank Group. Retrieved May 28th from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=XC

World Bank Group. (2025c). GDP (current US$) - South Africa. World Bank Group. Retrieved May 28th from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=ZA

World Bank Group. (2025d). GDP (current US$) - China. World Bank group. Retrieved May 28th from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CN