

Article

# Money market insights in China: Evidence from visual analytics approach

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**Abstract:** This research employs visual analytics approaches to demystify the complex dynamics of China's money market, spanning from 1984 to 2020. Our objective is to transform intricate financial data into intuitive visual representations, thereby enhancing understanding and decision-making. We utilize advanced visual analytics techniques to analyze key aspects like money supply, deposits, loans, and foreign exchange. The study reveals significant trends and insights, contributing to a more comprehensive understanding of financial dynamics in China. These findings serve as valuable tools for economists and policymakers, guiding more informed decisions in financial governance.

**Keywords:** visual analytics; money market; China; financial data; economic trends

## 1. Introduction

In an era marked by rapid globalization and technological advancements, the financial landscape has become increasingly complex and interconnected [1]. As a critical component of this global financial system, the money market is characterized by a complex network of monetary instruments, including money supply, deposits, loans, and foreign exchange. The understanding of these elements is crucial for a broad range of stakeholders, from policymakers to investors [2]. However, the methods without visual analysis often fall short of capturing the dynamic nature of these financial interactions, leading to a gap in comprehensive understanding and effective decision-making [3,4].

This gap underscores the need for innovative approaches in financial analysis [2]. The emergence of sophisticated data visualization technologies presents a unique opportunity to address this challenge. By harnessing these technologies, our research aims to transform the financial data into a format that is not only understood but also efficiently utilized. We propose a novel approach through visual analytics, a method that goes beyond traditional number-crunching by converting complex financial data into more intuitive and interactive visual representations. This approach not only aids in simplifying complex data but also in revealing hidden patterns and trends that are crucial for a deeper understanding of the money market.

Focusing specifically on China's rapidly evolving economic landscape, our study leverages visual analytics to decipher and illustrate the intricacies of its money market. By integrating advanced visualization techniques including line graphs, Voronoi diagrams, block diagrams [5–7], and so on, we aim to provide a clearer, more comprehensive view of key financial indicators, addressing both historical trends and current dynamics. We not only collect the time series data from the money market in

China but also visually present the collected data through different visualization techniques. This enhanced analytical framework is not only beneficial for academic research but also instrumental for practitioners and policymakers in making more informed and strategic financial decisions.

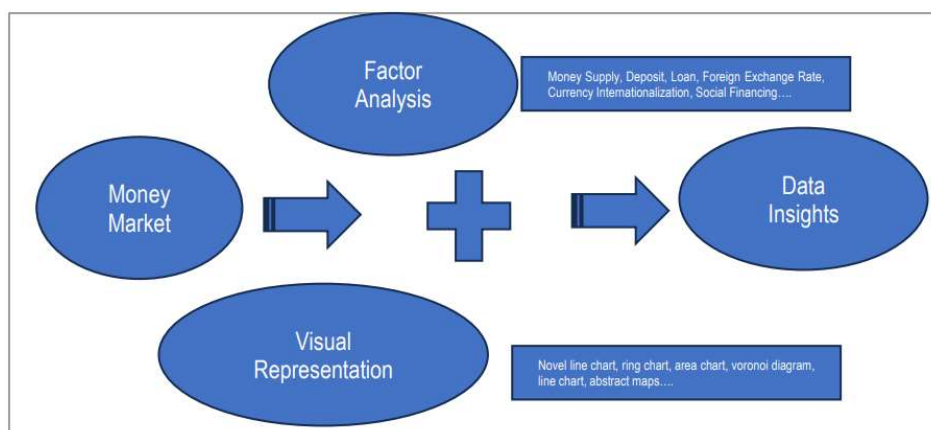
## **2. Literature review**

Visualization and Visual Analytics [8] focuses on the development and application of visualization techniques and visual analytics principles. Seminal works in this field have established the importance of visual methods in interpreting complex datasets. Thomas and Cook's [9] framework for visual analytics has been particularly influential, emphasizing the integration of analytical reasoning with interactive visual interfaces. Cheng and Mueller [10] and Huang et al. [11] further expanded on this by exploring the role of visual analytics in a decision-making approach. The evolution of these methodologies has been crucial in enabling the effective visualization of complex and dynamic data, laying the groundwork for our study.

The application of visual analytics in the financial domain has seen significant growth, driven by the increasing complexity of financial markets and the need for more intuitive analysis tools [12]. Research in this area has explored various aspects of financial data visualization. Ziegler et al. [13] demonstrated the use of visual analytics in understanding stock market behaviors, providing insights into market dynamics through interactive visual representations. Leite et al. [14] applied visual analytics to identify fraudulent events. Nadini et al. [15] cluster objects associated with NFTs according to their visual features and show that collections contain visually homogeneous objects. These studies underscore the potential of visual analytics in enhancing the understanding of financial markets, directly informing our approach to visualizing key aspects of the money market such as money supply, foreign exchange, and interest rates.

Our study is grounded in the belief that visual analytics can significantly enhance the comprehension of key financial indicators such as money supply fluctuations, the dynamics of deposits and loans, the intricacies of foreign exchange markets, the emerging trends in currency internationalization, the evolving landscape of social financing, and the critical interplay of various interest rates. By presenting these elements through visual analytics, we aim to provide a clearer, more comprehensive view of the money market, thereby facilitating informed decision-making and contributing to the field of financial analysis and education.

In this paper, we will explore how visual analytics can be effectively applied to dissect and understand the multifaceted nature of the money market. **Figure 1** illustrates our comprehensive framework, which encompasses both factor analysis and visual representation. Through these dual approaches, we can readily glean insights from the money market data.



**Figure 1.** Comprehensive visual analytics framework for the money market.

### 3. Materials and method

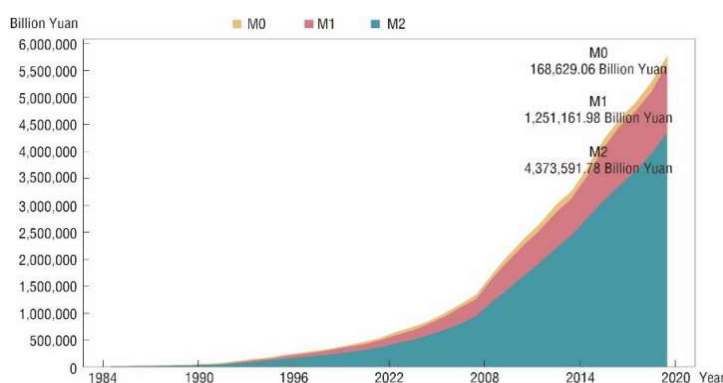
#### 3.1. Data sources and selection

Data for this study was sourced primarily from the China Statistical Yearbook and the People’s Bank of China, encompassing a period from 1984 to 2020. These sources were chosen for their comprehensive coverage and authoritative status in the field of Chinese economic statistics.

#### 3.2. Visual analytics techniques employed

The study utilized a variety of visual analytics techniques to analyze and interpret the financial data, each chosen for its ability to convey complex information in an accessible manner:

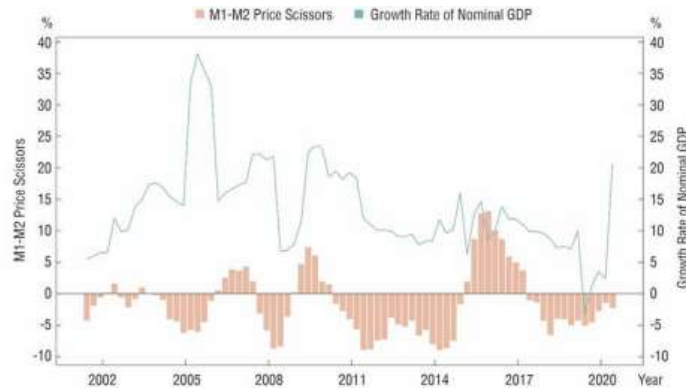
- **Area Charts:** Employed for their effectiveness in visualizing data volumes or quantities over time, area charts display trends and highlight changes between data points. They are particularly useful for showing the magnitude of financial metrics. In our study, they are used to represent trends in financial indicators (refer to **Figure 2**).



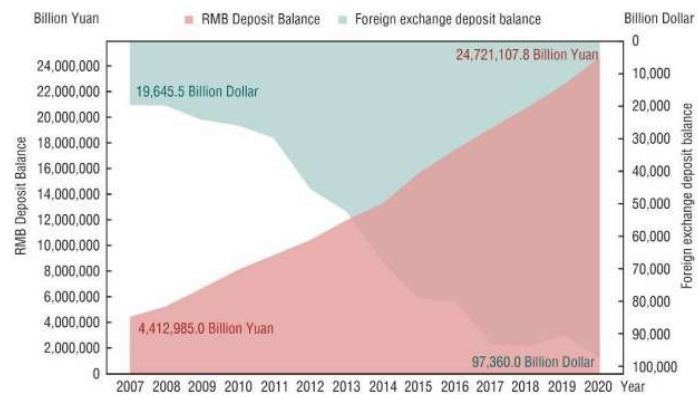
**Figure 2.** Money supply from 1984 to 2020.

- **Line Charts:** Chosen for their effectiveness in analyzing trends within continuous datasets over time, line charts in this study were particularly utilized for visualizing trends in interest rates and exchange rates (see the line charts in **Figure 3**). Comparing area charts and line charts, **Figure 4** features area charts

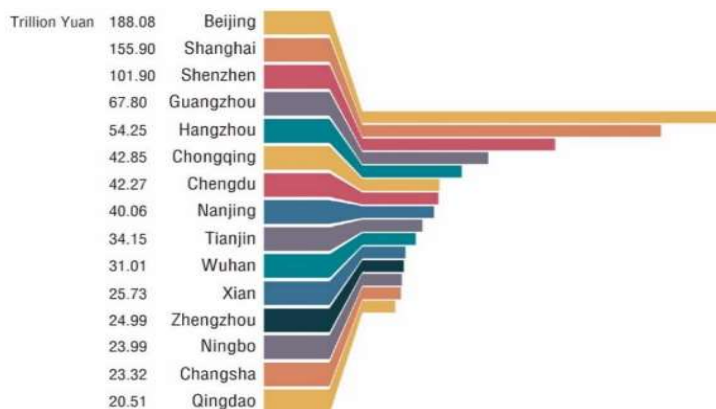
where lines are present, but the emphasis is placed on utilizing the area to represent the data rather than the line plot. Stream Graph: This updated version of a traditional stacked area chart provides an intuitive visualization of changes over time in a more fluid and organic way, ideal for displaying time-series data (see **Figure 5**).



**Figure 3.** M1-M2 Money Supply Gap and Nominal GDP Growth Rate.

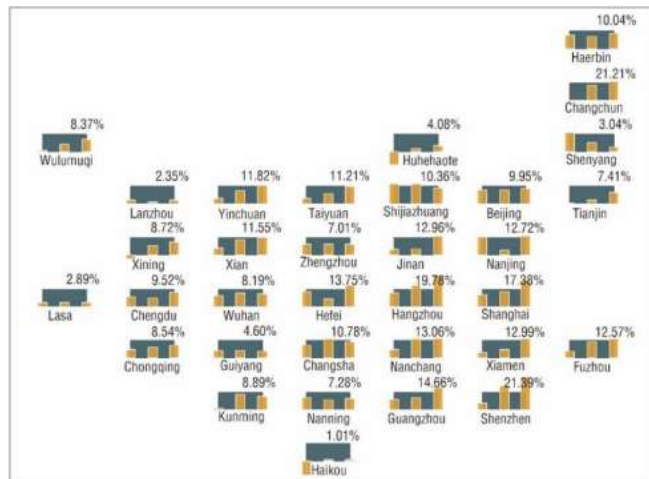


**Figure 4.** Domestic and foreign currency deposit balances.



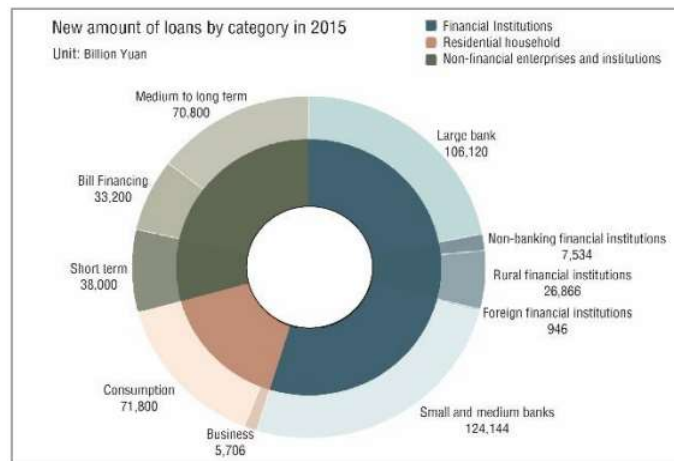
**Figure 5.** Top 15 cities in national domestic and foreign currency deposit balances.

- **Geospatial Mapping:** This technique was used to plot financial data on maps of China, providing a visual representation of geographical distribution and regional differences in financial indicators such as deposit flows and loan distributions (refer to **Figure 6**).

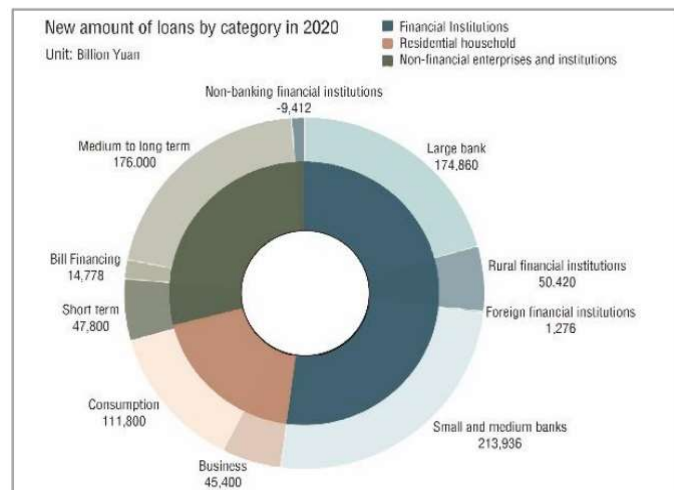


**Figure 6.** Growth rate of domestic and foreign currency deposit balances in selected municipalities, provincial capitals, and separately-planned cities from 2017 to 2020.

- Ring Charts: Employed for their ability to display hierarchical relationships within data, these charts are particularly useful in visualizing the structure and composition of financial datasets (see **Figure 7**).



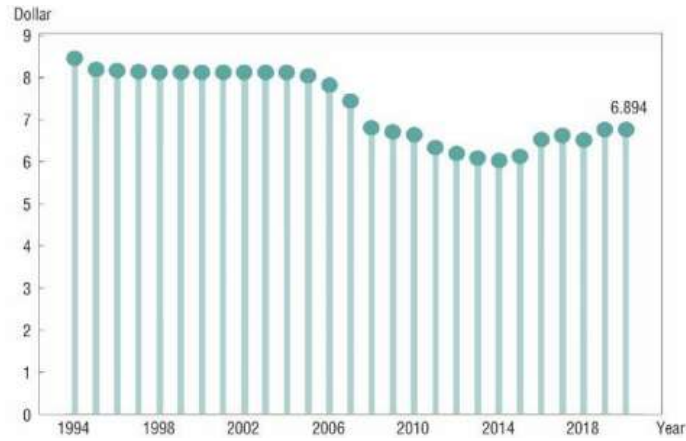
**(a)**



**(b)**

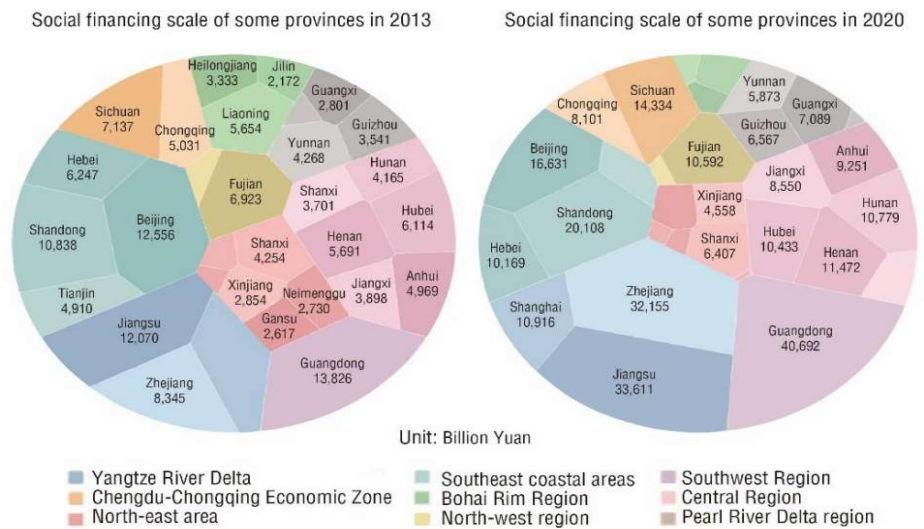
**Figure 7.** Overview of New Loan Amounts by Category in 2015 and 2020.

- Bar Charts and Histograms: These visual tools were used to compare the distribution and frequency of various financial indicators across different categories and over distinct time periods, offering a clear view of distribution patterns (refer to **Figure 8**).



**Figure 8.** Exchange Rate Changes (1 US Dollar to RMB).

- Voronoi Diagram: Used to visually break down complex datasets into simpler, more comprehensible segments, helping to illustrate the relationships between different data points (refer to **Figure 9**).



**Figure 9.** Social Financing Scale in Selected Provinces for 2013 and 2020.

Each of these visual analytics techniques was carefully selected and applied to effectively communicate the intricate details of China’s financial data, aiding in the comprehension and analysis of complex financial trends and relationships.

### 3.3. Data processing and cleansing

The study involved rigorous data processing to ensure the accuracy and compatibility of data from various sources. This included data cleansing, integration, and normalization.

- Analytical Tools Used

For the analysis and visualization, the study utilized Tableau for interactive dashboards, Python (with Matplotlib and Seaborn) for custom scripts, and R (with ggplot2) for statistical visualizations.

- **Methodological Approach**

The methodology followed a structured approach, starting from data collection and preparation to exploratory data analysis, visualization development, and finally, interpretation of the results.

- **Ethical Considerations**

All data used in this study is publicly available and does not involve sensitive personal information, adhering to the highest standards of research ethics.

## **4. Results and discussion**

In this section, 1) we utilize line charts and bar charts to visually explore the dynamics of money supply; 2) we utilize area charts, geospatial mapping, and the stream graph to understand the trends in deposit flows; 3) we utilize ring charts to examine patterns in loan distribution; 4) we utilize bar charts to show the foreign exchange dynamics; 5) we utilize geospatial mapping and the Voronoi diagram to show the developments in social financing; 6) we utilize bar charts to trace the evolution of currency internationalization; 7) we utilize line charts to present the currency rate trends.

### **4.1. Visually exploring the dynamics of money supply**

Money supply is a key factor in the analysis of the money market. Central banks generally classify the money supply into different levels based on the size of liquidity, in accordance with the needs of macroeconomic monitoring and regulation. Under the current monetary statistical system in China, the money supply is divided into three tiers—Cash in Circulation (M0), Narrow Money Supply (M1), Broad Money Supply (M2).

**Figure 2** displays the recent changes in China's money supply. Overall, there has been an increasing annual growth in China's money supply. By the end of 2020, the broad money supply (M2) balance reached 43,735,917.78 billion yuan, a year-on-year increase of 10.10%, which is 1.4 percentage points higher than the end of the previous year. The balance of cash in circulation was 1,686,290.06 billion yuan, up 9.2% year-on-year; M1 reached 12,511,619.8 billion yuan, up 8.6% year-on-year.

By the end of 2020, China's money multiplier reached 6.96 times. The money multiplier is closely related to the reserve requirement ratio. Since the total money supply = bank deposits/reserve requirement ratio and the money multiplier = 1/reserve requirement ratio, a larger money multiplier implies a lower reserve requirement ratio. Reducing the reserve requirement is one of the expansionary monetary policies of the central bank. By lowering the statutory reserve requirement ratio, the central bank affects the quantity of funds available for banks to lend, thereby increasing the scale of credit, boosting the money supply, and enhancing liquidity in the financial market. When capital flows into various industries, it can stimulate economic growth. Since 2014, the People's Bank of China has been implementing a policy of reducing the reserve requirement ratio, gradually decreasing it, and thereby increasing the money

multiplier. By 2020, the reserve requirement ratio for small and medium-sized depositary financial institutions was 9.5%, and for large depositary financial institutions, it was 12.5%.

To analyze more about the M1 and M2, we use the line chart; see **Figure 3**. The line chart shows the relationship between the M1-M2 gap and nominal GDP. The M1-M2 gap effectively reflects the activity level of non-financial corporations and indicates market reactions to future economic expectations. Comparing it with a series of economic data reveals that the M1-M2 gap can be used as a leading indicator for judging credit and economic trends, generally leading other economic data by 2 to 4 quarters.

Since 2002, across five economic cycles, the difference in growth rates between M1 and M2 has shown a leading effect on the growth rate of nominal GDP, typically leading by about six months. After 2011, as the overall macroeconomy entered a state of low volatility and high growth, the correlation between the M1-M2 growth rate and economic growth rate weakened, but it remained significant. The relatively more frequent changes in the M1-M2 growth rate gap have a strong predictive value for economic growth. As seen in **Figure 3**, starting from the year 2000, the historical M1-M2 growth rate fell into negative territory six times. The longest period was from 2011 to 2015, lasting 57 months, with an average gap of  $-5.97\%$ . In January 2019, the year-over-year growth rate difference of M1-M2 dropped to a low of  $-8.0\%$ . In February, due to a slight rebound in M1, the growth rate difference has risen to  $-6.0\%$ .

#### **4.2. Understanding trends in deposit flows**

The balance of domestic and foreign currency deposits represents the total amount of Renminbi and foreign currency deposits. The balance of various deposits in financial institutions, in both domestic and foreign currencies, reflects the attractiveness of the financial market for capital. The appeal of a region's financial market for funds also indicates its potential for economic development. Additionally, the amount of capital determines whether the economy can operate smoothly and robustly. Therefore, the balance of domestic and foreign currency deposits is an important indicator of economic development. Statistically, the deposit balance refers to the total value of corporate and personal deposits in a financial institution on a given statistical day. This is usually measured using the value at the end of the month or year.

**Figure 4** uses an area chart to show the changes in domestic and foreign currency deposit balances from 2007 to 2020. The growth in domestic and foreign currency deposit balances is a driving force for the development of various factor markets in a market economy. In the long term, there has been a significant increase in the deposit balances in China's financial market, with a generally stable growth rate. The RMB deposit balance grew from 4,412,985.0 million yuan in 2007 to 24,721,107.8 million yuan in 2020, an increase of approximately 5.6 times. In 2007, the foreign exchange deposit balance was 1964.55 billion USD, which grew to 9736.0 billion USD in 2020, an increase of about 4.9 times.

**Figure 5** uses an updated area chart to display the year-end deposit balances of various financial institutions. By 2020, China's deposit balance had exceeded the



significant threshold of 20 trillion yuan, with the largest contribution coming from savings deposit balances.

The data shown represents the top 15 Chinese cities in terms of domestic and foreign currency deposit balances. Beijing leads all cities, with its domestic and foreign currency deposit balance reaching 18.808 trillion yuan by 2020. Shanghai, Shenzhen, and Guangzhou follow closely behind, each surpassing 10 trillion yuan.

**Figure 6** illustrates Beijing's economic status among all cities and also reflects the corporate strength and financial power of the residents in Beijing, Shanghai, Shenzhen, and Guangzhou.

### **4.3. Examining patterns in loan distribution**

**Figure 7** illustrates the changes in the amounts of new loans across various categories. It employs a ring chart to clearly represent hierarchical and ownership relationships, using a parent-child structure to display the composition of the data. Each ring represents the proportion of each level, with proximity to the center indicating a higher level. Between two adjacent layers, the inner layer encompasses the outer one, with the data becoming more finely categorized as one moves outward. **Figure 6** not only reflects the proportional representation of each data set but also demonstrates their hierarchical structure. For data with multiple levels, this allows for a more intuitive, layered view of the information.

### **4.4. Insights into Foreign exchange dynamics**

The exchange rate reflects the supply and demand of a currency. **Figure 8** shows the recent changes in the exchange rate of the renminbi (RMB) against the US dollar. From 1994 to 2004, the exchange rate was at a relatively high and stable stage. The year 1994 marked a significant turning point in China's foreign exchange reform with the implementation of a managed floating exchange rate system based on market supply and demand.

From 2004 to 2014, the exchange rate exhibited a clear downward trend, related to the overall trajectory of the macroeconomy and reforms in the foreign exchange market system. In 2003, the RMB exchange rate faced significant appreciation pressure. China adopted a series of measures to alleviate this pressure, such as increasing imports from the United States, successfully maintaining the stability of the RMB exchange rate, which stood at 1 US dollar to 8.2767 RMB by the end of the year. After 2014, the RMB exchange rate rose slowly and steadily. By the end of 2020, the exchange rate was 1 US dollar to 6.894 RMB.

### **4.5. Assessing developments in social financing**

The scale of social financing is a comprehensive indicator reflecting the relationship between finance and the economy, as well as the total amount of financial support provided by the financial sector to the real economy. The scale of social financing refers to the total amount of funds obtained by the real economy from the financial system over a certain period (monthly, quarterly, or annually) and is a concept of increment.

The components of social financing include RMB loans, foreign currency loans, entrusted loans, trust loans, undiscounted bank acceptance bills, corporate bonds, domestic stock financing by non-financial enterprises, government bonds, asset-backed securities of deposit-type financial institutions, and written-off loans.

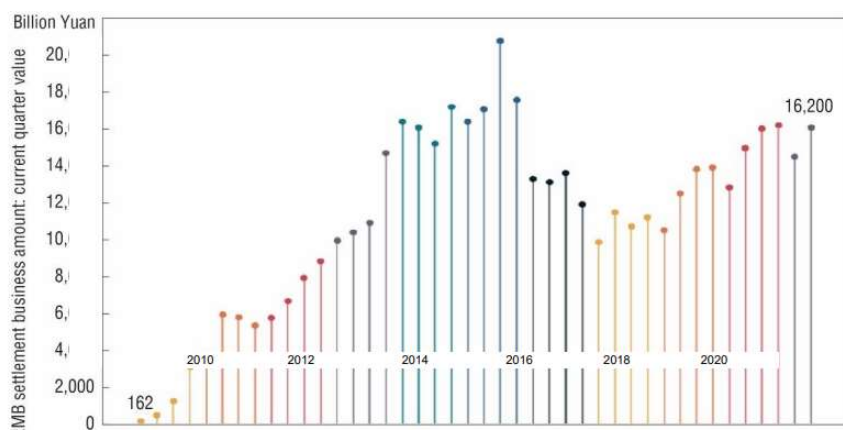
**Figure 9** shows the accounting details of the scale of social financing. Among these components, RMB loans have the largest proportion. As of 2020, new RMB loans amounted to 20,031 billion yuan, followed by government bonds at 8337 billion yuan. Corporate bond financing ranked third, reaching 4446.6 billion yuan at the end of 2020. At the end of the year, while the overall scale of social financing increased significantly, new entrusted loans and new trust loans were negative, amounting to -395.4 billion yuan and -1102 billion yuan, respectively. A negative value in social financing indicates that the amount borrowed in that quarter was less than the amount repaid.

#### 4.6. Tracing the evolution of currency internationalization

The internationalization of the currency (here, RMB) is a long-term strategy. The RMB, as a currency for payment and settlement, has been accepted by many countries. In fact, in many Southeast Asian countries and regions, the RMB has already become a hard currency.

In November 2015, the International Monetary Fund (IMF) announced the formal inclusion of the RMB into its Special Drawing Rights (SDR) currency basket, with the decision taking effect on 1 October 2016. The voting meeting was chaired by IMF Managing Director Christine Lagarde, with representatives from all 188 member countries of the International Monetary Fund participating and voting.

**Figure 10** provides data on the changes in the amount of cross-border trade RMB settlement over recent years. It is evident that since 2010, the volume of RMB settlement in trade has not only grown but also experienced fluctuations, yet overall, it has significantly increased from historical levels. According to statistics from the People’s Bank of China, by the second quarter of 2020, the amount of China’s cross-border trade RMB settlement reached 1.62 trillion yuan. Compared to the first quarter of 2010, when it was just 16.2 billion yuan, this represents an almost 100-fold increase in just a decade.



**Figure 10.** Cross-border Trade RMB settlement amount.

#### 4.7. Delving into currency rate trends

The basic operating principle of the interest rate corridor is that the central bank controls the interest rates in the money market around a target rate through the interest rate corridor. The upper limit of the interest rate corridor is the lending rate of the central bank to commercial banks, while the lower limit is the rate for excess reserves deposited at the central bank.

Figure 11 shows the movement of the pledged repo rate of deposit-taking institutions, which is a key focus of the market, within the interest rate corridor." The latest adjustment period for the excess reserve rate was the first quarter of 2021, with a rate of 2.2%, while the standing lending facility rate was 3.2%. The interbank lending rate was controlled at 2.5%. The interbank lending rate has always been kept within the range of the interest rate corridor, which helps to reduce the volatility of market interest rates in the money market and also aids in lowering the operational costs of monetary policy. Through the interest rate corridor mechanism, the central bank can effectively control market interest rates at the desired level.

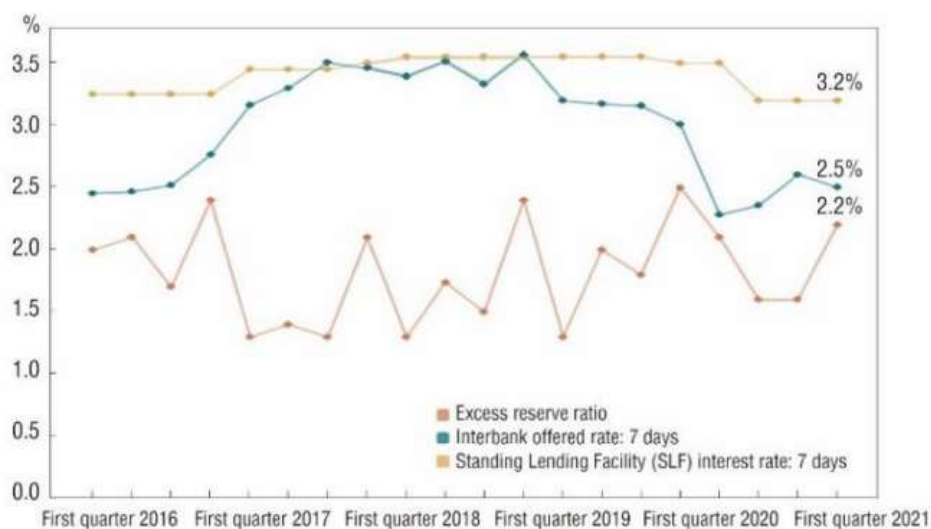


Figure 11. Interest rate corridor.

### 5. Discussion

This section delves deeper into the insights gained from our visual analytics approach and situates these findings within the broader context of financial analysis and policy-making.

#### 5.1. Dynamics of money supply and economic policy implications

The increasing trend in China's money supply, particularly in the M2 aggregate, reflects the country's expansive monetary policies. The significant rise in the money multiplier since 2014 can be attributed to the People's Bank of China's strategy of reducing reserve requirements. This policy decision aims to enhance liquidity and stimulate economic growth by increasing banks' lending capacity. The visual analytics approach has allowed us to not only track these changes over time but also to understand their impact on the broader economy. The insights gained here are crucial

for policymakers to assess the effectiveness of monetary policies and for investors to gauge the market's liquidity conditions.

### **5.2. Deposit flows and regional economic strength**

The study's findings on deposit flows, particularly the significant increases in domestic and foreign currency deposits, highlight the growing attractiveness of China's financial markets. The visualization of these trends, especially in major cities like Beijing, Shanghai, and Guangzhou, reflects the regional economic strength and the concentration of financial power. For policymakers and investors, understanding these regional disparities is vital for strategic planning and investment decisions.

### **5.3. Loan distribution and financial sector health**

The distribution of new loans across various categories, as visualized through ring charts, provides a clear perspective on China's credit market dynamics. The data illustrates the government's focus areas and the health of different economic sectors. This information is particularly valuable for financial institutions to optimize their loan portfolios and for government bodies to assess the effectiveness of their economic policies.

### **5.4. Foreign exchange dynamics and global trade relations**

The visual representation of RMB exchange rate trends against the US dollar offers insights into China's foreign exchange policies and their impact on international trade. The managed floating exchange rate system and its stability over different periods provide crucial information for businesses engaged in international trade and for analysts forecasting currency movements.

### **5.5. Social financing and economic growth correlation**

The analysis of social financing components, including the negative trends in entrusted and trust loans, sheds light on the evolving landscape of China's financial support to the real economy. This aspect of the study is particularly relevant for understanding the correlation between financial sector developments and overall economic growth.

### **5.6. Currency internationalization and global financial integration**

The visualization of cross-border RMB settlement amounts highlights the RMB's growing role in international trade and finance. The inclusion of the RMB in the IMF's SDR basket marks a significant milestone in China's journey towards currency internationalization, with implications for global financial markets.

### **5.7. Interest rate trends and monetary policy tools**

The analysis of interest rate corridors reveals the central bank's strategies in controlling market interest rates. These insights are vital for financial analysts and investors in understanding the direction of monetary policy and its impact on investment decisions.

## 6. Conclusion and recommendations

This study has successfully utilized visual analytics to illuminate key aspects of the money market, offering a clearer understanding of complex financial dynamics. Our analysis spanned diverse areas, including money supply, deposit flows, loan distribution, foreign exchange markets, social financing, and currency internationalization. Each segment revealed distinct patterns and trends, providing deeper insights into the financial system's workings. The visual approach adopted here proved instrumental in demystifying intricate financial relationships and trends, thereby enhancing our comprehension of the global financial landscape. This research not only highlights the value of visual analytics in financial analysis but also sets a foundation for future explorations in this rapidly evolving field.

However, it is hard for existing visualization technologies to present the causalities between the variables in data that are mutually influential. In our future work, we will solve this problem by combining causality learning technologies with data visualization [16].

**Author contributions:** Initiating ideas and revising the entire paper, SC; programming, data analysis, and writing the entire paper, QG; writing sections and revising the paper, QL; collecting and analyzing the data, XL. All authors have read and agreed to the published version of the manuscript.

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**Conflict of interest:** The authors declare no conflict of interest.

## References

1. Beniger JR, Robyn DL. Quantitative Graphics in Statistics: A Brief History. *The American Statistician*. 1978; 32(1): 1-11. doi: 10.1080/00031305.1978.10479235
2. Rothe J. *Economics and Computation*. Springer Berlin Heidelberg; 2016. doi: 10.1007/978-3-662-47904-9
3. Nkoro E, Uko AK. Autoregressive Distributed Lag (ARDL) cointegration technique: application and interpretation. *Journal of Statistical and Econometric methods*. 2016; 5(4): 63-91.
4. Kurecic P, Kokotovic F. The Relevance of Political Stability on FDI: A VAR Analysis and ARDL Models for Selected Small, Developed, and Instability Threatened Economies. *Economies*. 2017; 5(3): 22. doi: 10.3390/economies5030022
5. Grinstein UMFGG, Wierse A. *Information Visualization in Data Mining and Knowledge Discovery*. Morgan Kaufmann; 2002.
6. Brodlied KW, Gallop JR, Osland CD, et al. (editors). *Scientific Visualization: Techniques and Applications*. Springer Science & Business Media; 2012.
7. Smits AJ. *Flow Visualization: Techniques and Examples*. World Scientific; 2012.
8. Munzner T. A Nested Model for Visualization Design and Validation. *IEEE Transactions on Visualization and Computer Graphics*. 2009; 15(6): 921-928. doi: 10.1109/tvcg.2009.111
9. Thomas JJ, Cook KA. *Illuminating the Path: The Research and Development Agenda for Visual Analytics*. IEEE Computer Society Press; 2005.
10. Cheng S, Mueller K. The Data Context Map: Fusing Data and Attributes into a Unified Display. *IEEE Transactions on Visualization and Computer Graphics*. 2016; 22(1): 121-130. doi: 10.1109/tvcg.2015.2467552
11. Huang T, Cheng S, Li S, Zhang Z. High-dimensional Clustering onto Hamiltonian Cycle. *ICML*. 2023; 13791-13813.
12. Ko S, Cho I, Afzal S, et al. A Survey on Visual Analysis Approaches for Financial Data. *Computer Graphics Forum*. 2016; 35(3): 599-617. doi: 10.1111/cgf.12931

13. Ziegler H, Jenny M, Gruse T, et al. Visual market sector analysis for financial time series data. In: Proceedings of the 2010 IEEE Symposium on Visual Analytics Science and Technology; 25-26 October 2010; Salt Lake City, UT, USA. pp. 83-90. doi: 10.1109/vast.2010.5652530
14. Leite RA, Gschwandtner T, Miksch S, et al. EVA: Visual Analytics to Identify Fraudulent Events. *IEEE Transactions on Visualization and Computer Graphics*. 2018; 24(1): 330-339. doi: 10.1109/tvcg.2017.2744758
15. Nadini M, Alessandretti L, Di Giacinto F, et al. Mapping the NFT revolution: market trends, trade networks, and visual features. *Scientific Reports*. 2021; 11(1). doi: 10.1038/s41598-021-00053-8
16. Guo R, Cheng L, Li J, et al. A Survey of Learning Causality with Data. *ACM Computing Surveys*. 2020; 53(4): 1-37. doi: 10.1145/3397269