

MATHEMATICAL ANALYSIS OF BANK DEPOSITS AND INVESTMENT GROWTH USING DIFFERENTIAL EQUATIONS

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Annotatsion: This article investigates the application of differential equations in the mathematical analysis of bank deposits and investment growth. Financial processes such as deposit accumulation, capital investment, and interest generation are dynamic phenomena that evolve continuously over time. Differential equations provide an effective mathematical framework for describing these processes and evaluating their long-term behavior. The study examines the relationship between deposit growth, investment returns, interest rates, and capital accumulation through mathematical models. Particular attention is given to continuous compound interest models and investment growth functions that are widely used in banking and financial analysis. The research demonstrates how differential equations can be employed to forecast future financial outcomes, optimize investment strategies, and assess the impact of changing economic conditions on capital growth. The findings indicate that mathematical modeling based on differential equations is a valuable tool for understanding financial dynamics and supporting informed decision-making in banking and investment management. Furthermore, the study highlights the practical significance of mathematical methods in evaluating long-term financial sustainability and economic development.

Keywords: differential equation, bank deposits, investment growth, compound interest, financial modeling, capital accumulation, interest rate, mathematical analysis, economic forecasting, financial dynamics.

INTRODUCTION

In today's rapidly developing financial environment, banking institutions and investment organizations play a crucial role in promoting economic growth and financial stability. Bank deposits and investments are among the most important financial instruments that contribute to capital formation, wealth accumulation, and sustainable economic development. Understanding the dynamics of deposit growth and investment returns is essential for individuals, businesses, and policymakers who seek to make informed financial decisions. Mathematical modeling has become an

indispensable tool in financial analysis. Among various mathematical methods, differential equations are particularly useful for describing financial processes that change continuously over time. Since the value of deposits and investments is affected by factors such as interest rates, inflation, market conditions, and reinvestment policies, differential equations provide an effective framework for analyzing these dynamic relationships. One of the fundamental applications of differential equations in finance is the modeling of compound interest. Unlike simple interest, compound interest allows earned interest to generate additional returns over time, leading to exponential growth of capital. Differential equations accurately describe this process and help estimate future values of investments and savings accounts. As a result, financial institutions widely use mathematical models to evaluate investment strategies and forecast financial performance. The application of differential equations extends beyond banking activities. They are used in portfolio management, pension fund planning, insurance mathematics, risk assessment, and economic forecasting. Advances in computer technology and financial software have further increased the practical importance of differential equation models by enabling analysts to simulate complex financial scenarios and predict long-term trends. The purpose of this study is to investigate the mathematical analysis of bank deposits and investment growth using differential equations. The research focuses on developing mathematical models that describe capital accumulation, examining the effects of interest rates on financial growth, and demonstrating the practical applications of differential equations in banking and investment management.

The role of differential equations in financial analysis. Financial systems involve continuous changes in capital values over time. The growth of savings accounts, investment portfolios, and business capital can be effectively represented through differential equations. These mathematical tools enable researchers to determine how rapidly financial assets increase or decrease under specific economic conditions. Differential equations are particularly valuable because they allow analysts to model real-world financial situations and predict future outcomes. By understanding the relationship between capital and time, investors can make more informed decisions regarding savings and investment strategies. In financial mathematics, continuous growth models are widely applied because many economic processes operate continuously rather than at discrete intervals. Consequently, differential equations provide a realistic representation of financial behavior.

Mathematical model of bank deposit growth. The growth of a bank deposit under continuous compound interest can be represented by the following differential equation:

$$dD/dt = rD$$

- (D) represents the amount of money deposited in the bank;
- (r) is the annual interest rate;

$$D(t) = D_0 \cdot e^{(rt)}$$

denotes the rate of change of the deposit over time. The solution of this differential equation is:

$$dI/dt = kI$$

where:

- (D_0) is the initial deposit amount;
- (e) is the mathematical constant approximately equal to 2.71828;
- (t) represents time.

This model shows that bank deposits increase exponentially when interest is continuously compounded. The higher the interest rate, the faster the growth of the deposit. For example, if an individual deposits \$10,000 at an annual interest rate of 5%, the value of the deposit will grow significantly over time due to compound interest. The model is widely used by financial institutions to estimate future account balances and determine optimal savings plans for customers.

Mathematical analysis of investment growth. Investment growth can also be modeled using differential equations. When investments generate returns that are reinvested, the capital grows continuously according to the following equation:

$$I(t) = I_0 \cdot e^{(kt)}$$

where:

- (I) represents investment capital;
- (k) denotes the average rate of return;
- ($\frac{dI}{dt}$) is the rate of investment growth.

The solution is:

$$A = P \cdot e^{(rt)}$$

where (I_0) is the initial investment value. This equation demonstrates that investment growth follows an exponential pattern when returns are continuously reinvested. The model helps investors evaluate long-term profitability and compare different investment opportunities. For instance, an investment portfolio with an average annual return of 8% will experience substantial growth over a period of several years. Therefore, mathematical models provide valuable information for financial planning and investment management.

Comparison of deposit and investment growth models. Although both deposits and investments can be described by exponential differential equations, their characteristics differ significantly. Bank deposits generally offer lower risk and stable returns, while

investments often involve higher risks but potentially greater profits. Differential equation models enable analysts to compare these financial instruments quantitatively. By varying interest rates and return rates within the models, it becomes possible to evaluate different financial strategies and identify the most effective approach for capital growth. Financial institutions frequently use such models to design savings products, investment funds, and retirement plans that meet the needs of different customers.

Practical applications in modern banking and finance. The application of differential equations in modern finance extends to various fields, including investment management, pension planning, insurance mathematics, and economic forecasting. Financial analysts use mathematical models to estimate future asset values, evaluate investment risks, and optimize portfolio performance. Technological advancements have further enhanced the usefulness of differential equations. Modern financial software allows analysts to solve complex mathematical models and simulate various economic scenarios. As a result, differential equations have become an essential component of contemporary financial decision-making. The integration of mathematical modeling into banking and investment management contributes to greater accuracy, improved risk assessment, and more effective long-term financial planning.

Growth of bank deposits and investments under different annual rates of return

Initial Capital (USD)	Annual Interest / Return Rate (%)	Period (Years)	Final Deposit Value (USD)	Final Investment Value (USD)
10,000	3	5	11,618	11,593
10,000	5	5	12,840	12,824
10,000	7	5	14,191	14,190
10,000	10	5	16,487	16,487
10,000	12	5	18,221	18,221

Table presents the growth of bank deposits and investments over a five-year period under different annual interest and return rates. The calculations are based on continuous growth models represented by differential equations. The results demonstrate that both bank deposits and investments increase significantly as the interest or return rate rises. At an annual rate of 3%, an initial capital of \$10,000 grows to approximately \$11,618 after five years. When the rate increases to 5%, the final value reaches \$12,840. Higher rates generate even greater growth, with capital reaching more than \$18,000 at a 12% annual return rate. These findings illustrate the exponential nature of financial growth modeled through differential equations. The analysis also

indicates that small increases in interest or return rates can produce substantial differences in accumulated capital over time. This phenomenon highlights the importance of interest rates and investment performance in long-term financial planning. Consequently, differential equation models provide valuable tools for evaluating savings strategies, investment opportunities, and future financial outcomes.

CONCLUSION

This study examined the use of differential equations in analyzing the growth of bank deposits and investments. The findings demonstrate that differential equations provide a powerful mathematical framework for describing continuous financial processes and evaluating the dynamics of capital accumulation. The analysis showed that both deposit growth and investment growth can be effectively modeled through exponential differential equations. These models help explain how interest rates and investment returns influence the value of financial assets over time. Furthermore, mathematical modeling enables financial institutions and investors to forecast future outcomes and develop efficient financial strategies. The study also highlighted the practical significance of differential equations in banking, investment management, and financial planning. Their application supports more accurate forecasting, better risk assessment, and improved decision-making processes. In conclusion, differential equations remain one of the most important mathematical tools in modern finance. Their ability to model financial growth and predict future trends contributes significantly to sustainable economic development and effective capital management.

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