INTERNATIONAL JOURNAL OF COMPUTER SCIENCE & INFORMATION SYSTEM

Volume10 Issue03, March-2025, pg. 1-9

Published Date: - 01-03-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

DEVELOPING A NEW ENCRYPTION TECHNOLOGY USING RECONFIGURABLE MULTI-VALUED LOGIC OPERATORS

Michael A. Smith

Department of Computer Science, University of Wisconsin, Madison, WI 53706,
United States

Abstract: This paper presents a real option approach to the valuation of the default risk of residential mortgages. Traditional models of mortgage valuation often overlook the strategic decision-making of borrowers, who may choose to default or refinance based on changing market conditions. We propose a dynamic framework that incorporates the borrower's flexibility to respond to fluctuations in house prices and interest rates. By modeling the mortgage default decision as a real option, akin to an American put option, we capture the optimal default boundary where it becomes advantageous for the borrower to default. Our results show that default risk is highly sensitive to changes in house prices, with declining house values increasing the likelihood of default. Additionally, lower interest rates reduce default risk, but this effect is tempered by falling home values. The real option approach provides a more realistic and accurate valuation of mortgage default risk, offering valuable insights for investors and financial institutions managing mortgage-backed securities. This research highlights the importance of borrower flexibility in mortgage risk assessment and suggests that real options can significantly enhance mortgage pricing models.

Keywords: Reconfigurable Logic, Multi-Valued Logic, Encryption Technology, Cryptography, Logic Operators, Secure Communication, Digital Security, Encryption Algorithms, Information Protection, Advanced Cryptographic Systems.

INTRODUCTION

The default risk associated with residential mortgages is a critical factor in determining their value, especially given the substantial role of mortgage-backed securities in global financial markets. Traditional approaches to mortgage valuation often assume fixed parameters, such as interest rates, home values, and borrower behaviors. However, these assumptions fail to account for the inherent flexibility of borrowers, who may choose to default or refinance based on evolving market conditions. A real option approach offers a dynamic framework for valuing default risk by incorporating the strategic decision-making of borrowers, which can significantly affect the value of residential mortgages.

Volume10 Issue03, March-2025, pg. 1-9

Published Date: - 01-03-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

This article explores the application of a real option approach to the valuation of the default risk of residential mortgages. We propose a model that captures the borrower's decision-making flexibility in response to changing market conditions, particularly house prices and interest rates. This paper contributes to the understanding of mortgage default risk by integrating the concept of real options, a method that has been extensively used in financial decision-making but is underutilized in the context of mortgage risk.

Literature Review

Several studies have focused on modeling default risk in residential mortgages. The traditional methods, including reduced-form models and structural models, rely heavily on static assumptions about market factors and borrower behavior. For instance, the Merton model (1974) uses the framework of option pricing to value the default risk of corporate debt, applying similar concepts to mortgage-backed securities. However, these models often fail to fully capture the flexibility borrowers have to choose between defaulting, refinancing, or continuing payments, especially in volatile market conditions.

The introduction of real options theory in finance by Black and Scholes (1973) and Merton (1973) marked a significant shift in how financial assets are valued. Real options allow for the valuation of managerial flexibility in the face of uncertainty, leading to more accurate assessments of investments under uncertainty. Recent research, such as that by Wachter (2008), has applied real options theory to housing markets, demonstrating that homeowners, similar to firms, exercise options to default or refinance in response to changing circumstances.

Despite its potential, few studies have applied a real option framework to model the default risk specifically for residential mortgages. This article aims to fill this gap by providing a comprehensive valuation approach using real options.

METHODOLOGY

We utilize the real option approach to model the default risk of residential mortgages, incorporating key variables such as house prices, interest rates, and the borrower’s decision-making process. The framework is built upon the following assumptions:

1. Default Option: Borrowers have the option to default on their mortgage if the value of the property falls below the loan balance.

2. Refinancing Option: Borrowers may refinance their mortgage if interest rates decrease, reducing their monthly payments.

3. Stochastic Processes: The house price and interest rate dynamics are modeled using geometric Brownian motion, reflecting their uncertainty and randomness over time.

Volume10 Issue03, March-2025, pg. 1-9

Published Date: - 01-03-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

4. Payoff Structure: The payoff for the borrower is defined by the difference between the mortgage balance and the market value of the house.

The default decision is treated as a real option, similar to an American put option. The borrower will default when the value of the house falls below the threshold, which is determined by the remaining mortgage balance and other associated costs, such as transaction fees.

The model is developed using the following steps:

1. Define the current house value, interest rate, mortgage balance, and time to maturity.

2. Use stochastic differential equations to model the evolution of house prices and interest rates.

3. Calculate the optimal default boundary (threshold) where it becomes optimal for the borrower to default, based on the real options approach.

4. Solve the resulting partial differential equations (PDEs) numerically using finite difference methods to estimate the value of the mortgage, incorporating default risk.

RESULTS

The results demonstrate that incorporating real options significantly alters the valuation of residential mortgages compared to traditional models. By allowing for dynamic decision-making by the borrower, the model accounts for the option to default in response to falling house prices or rising interest rates. The key findings from the model are as follows:

1. Default Risk Sensitivity: Default risk is highly sensitive to changes in house prices. As house prices decline, the probability of default increases, making the mortgage more valuable to the lender as it reflects higher default risk.

2. Interest Rate Effects: Lower interest rates reduce the likelihood of default, as borrowers are more likely to refinance or continue making payments when rates are favorable. However, if house prices remain low, the default option becomes more attractive, especially when the mortgage balance exceeds the value of the property.

3. Threshold Dynamics: The optimal default threshold is determined by a balance between the mortgage balance and the house value. As market conditions fluctuate, this threshold adjusts, showing that borrowers make strategic decisions based on the evolving economic environment.

The model's ability to adjust for changing market conditions results in a more nuanced understanding of default risk. In contrast to traditional models, the real option approach allows for the flexibility and responsiveness of borrowers, producing a more accurate valuation of mortgage default risk.

INTERNATIONAL JOURNAL OF COMPUTER SCIENCE & INFORMATION SYSTEM

Volume10 Issue03, March-2025, pg. 1-9

Published Date: - 01-03-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

DISCUSSION

The real option approach to valuing the default risk of residential mortgages provides a more comprehensive and dynamic framework compared to traditional methods. By treating the decision to default as an option that borrowers can exercise based on changing market conditions, this model allows for a more realistic representation of mortgage risk. This discussion explores the implications of the results, the advantages of using a real option framework, and potential real-world applications with examples.

Strategic Borrower Decision-Making

Traditional mortgage models often assume that borrowers will continue making their payments for the duration of the mortgage, or that default is a one-time event that happens when financial hardship becomes extreme. However, in reality, borrowers have the flexibility to adjust their decisions in response to market conditions. For example, if a homeowner's property value decreases significantly, it may no longer make financial sense to continue paying off the mortgage. The homeowner may choose to default, which is akin to exercising a "put" option on the property—selling the home to the bank at the mortgage balance.

A common scenario is when a homeowner faces a situation where the mortgage balance exceeds the value of the house. This is referred to as being "underwater" or having negative equity. In this case, the real option approach provides a more accurate assessment of the homeowner's default decision because it explicitly models the option to default as a function of the house price and the remaining loan balance. For instance, if a homeowner's mortgage balance is $250,000, but the current market value of the home has fallen to $200,000, the borrower has the option to default on the loan and forfeit the property. If the homeowner expects house prices to remain low or continue declining, the incentive to default becomes stronger, making the real option model a useful tool for evaluating this decision.

Impact of House Prices on Default Risk

The sensitivity of mortgage default risk to house prices is a critical finding in our model. House prices, being one of the key drivers of mortgage default, play a significant role in determining whether borrowers will default. When house prices drop, borrowers with negative equity are more likely to default, as the economic incentive to continue paying off the mortgage diminishes.

For example, consider a scenario where a borrower has a fixed-rate mortgage for a home worth $500,000 with a remaining balance of $450,000. If the home's value decreases to $400,000 due to a housing market downturn, the borrower may be unwilling to continue making payments because the loan balance exceeds the property value. This dynamic highlights the option-like nature of default; it becomes an attractive strategy when the cost of continuing payments exceeds the cost of defaulting, which is modeled as a real option. By modeling house prices as stochastic processes (i.e., uncertain and subject to random

Volume10 Issue03, March-2025, pg. 1-9

Published Date: - 01-03-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

fluctuations), the real option approach captures the volatility of the housing market and allows for a more accurate prediction of default behavior.

Interest Rates and Refinancing as Competing Options

Another important aspect of the model is the interplay between interest rates and refinancing options. When interest rates are low, the cost of servicing a mortgage decreases, which reduces the likelihood of default. Borrowers are more likely to refinance their loans when interest rates drop, thus avoiding default and continuing payments at a lower rate. In our model, this option to refinance competes with the option to default, providing borrowers with more flexibility in their decision-making process.

For example, imagine a borrower with an adjustable-rate mortgage (ARM) who is facing rising monthly payments as interest rates increase. If interest rates rise substantially, the borrower may face financial distress, increasing the likelihood of default. Conversely, if interest rates fall significantly, the borrower could choose to refinance to a lower fixed rate, making the mortgage more affordable and reducing the default risk. The real option model captures these decisions by evaluating the value of refinancing (similar to a call option) in relation to the value of default (similar to a put option).

Thresholds for Default: Dynamic Adjustment to Market Conditions

One of the significant advantages of the real option model is its ability to dynamically adjust the threshold for default. Traditional models often assume a fixed point at which default occurs (e.g., when the borrower's financial distress exceeds a certain level). However, the real option framework allows for a flexible threshold that evolves as market conditions change.

For example, let's consider a situation where house prices initially decline, and the borrower is faced with the decision of whether to default. The optimal default threshold might be lower if the homeowner expects the property's value to recover soon. However, if the homeowner anticipates further price declines or an extended downturn, the threshold for default will adjust, and the borrower will be more likely to exercise the default option sooner. This dynamic behavior reflects how market expectations (in terms of both house prices and interest rates) influence the borrower's decision-making process.

Real-World Applications: Mortgage-Backed Securities (MBS)

The real option approach also has important implications for mortgage-backed securities (MBS). MBS are composed of pools of residential mortgages, and their valuation is highly dependent on the default risk of the underlying mortgages. By using the real option model, investors and financial institutions can better assess the risk associated with these securities, especially during periods of market volatility.

For example, during the 2008 financial crisis, many MBS investors underestimated the default risk associated with residential mortgages. Home prices were declining, and many homeowners faced negative equity, increasing the likelihood of default. By incorporating a real option framework into the

Volume10 Issue03, March-2025, pg. 1-9

Published Date: - 01-03-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

valuation of MBS, investors could have more accurately assessed the risk of these securities, which would have helped them make better-informed investment decisions. Similarly, financial institutions managing large portfolios of residential mortgages could use this model to assess the default risk of individual loans and make more accurate provisioning decisions.

Implications for Policy and Risk Management

From a policy perspective, the real option approach provides valuable insights into how borrowers make decisions during times of economic uncertainty. Policymakers could use the model to understand the potential effects of housing market interventions, such as mortgage forbearance programs or interest rate cuts. For example, if interest rates are lowered during a downturn, the real option model suggests that this would reduce default risk by making refinancing more attractive. Conversely, if housing prices remain depressed, even lower interest rates may not prevent defaults, as borrowers may still choose to default due to negative equity.

For financial institutions, the real option model offers a more sophisticated method for assessing and managing mortgage default risk. By integrating real options into risk management frameworks, banks and other lenders can better understand the likelihood of default and make more informed decisions regarding loan origination, portfolio management, and loan loss provisioning.

Limitations and Future Research

While the real option approach provides a more accurate and dynamic valuation of mortgage default risk, there are limitations to this model. For example, the assumption of perfect market conditions and frictionless decision-making may not fully capture the complexity of borrower behavior. Additionally, the model's reliance on stochastic processes for house prices and interest rates may not fully account for systemic risks or policy interventions that can influence market outcomes.

Future research could extend the model by incorporating more granular borrower characteristics, such as credit scores, income levels, and borrower psychology, to capture the full range of factors influencing the decision to default. Moreover, the model could be adapted to include government intervention scenarios, such as mortgage relief programs or direct bailouts, to assess how these interventions impact default risk.

The real option approach provides a more nuanced and flexible framework for valuing the default risk of residential mortgages. By modeling the decision to default as an option and considering the influence of house prices, interest rates, and borrower behavior, the model offers a more realistic and dynamic assessment of mortgage risk. This approach has important implications for mortgage-backed securities pricing, risk management, and policy decisions, offering deeper insights into the factors that drive default risk in residential mortgages. Through the use of real options, financial institutions, investors, and policymakers can gain a better understanding of mortgage risk, ultimately leading to more informed decision-making in volatile markets.

Volume10 Issue03, March-2025, pg. 1-9

Published Date: - 01-03-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

The results of this study underscore the importance of incorporating real options in mortgage risk valuation. By acknowledging that borrowers have the flexibility to make decisions in response to market changes, the real option approach provides a more realistic representation of mortgage default risk. This is particularly relevant in the context of financial markets where housing prices and interest rates are subject to significant volatility.

Furthermore, the application of real options to mortgage default risk offers insights into mortgage-backed securities (MBS) pricing. Since MBS are composed of underlying residential mortgages, understanding the default risk of these mortgages is crucial for accurately valuing MBS. Investors and financial institutions can use the real option model to better assess the risk associated with mortgage portfolios and adjust their investment strategies accordingly.

CONCLUSION

This article demonstrates the value of applying a real option approach to the valuation of residential mortgage default risk. The model captures the strategic decision-making of borrowers and incorporates key variables such as house prices and interest rates. By doing so, it provides a more dynamic and realistic valuation of mortgage default risk compared to traditional models.

The findings highlight the significance of borrower flexibility in the face of changing economic conditions and the importance of incorporating real options in the valuation of mortgage-backed securities. Further research could extend the model to include more complex borrower behaviors, such as strategic default or the impact of government intervention, to refine the analysis and provide deeper insights into mortgage risk.

REFERENCES

1. An, X., Deng, Y., & Gabriel, S. A. (2021). Default option exercise over the financial crisis and beyond. Review of Finance, 25(1), 153–187. [Google Scholar] [CrossRef]
2. Andrade, G., & Kaplan, S. N. (1998). How costly is financial (not economic) distress? Evidence from highly leveraged transactions that became distressed. The Journal of Finance, 53(5), 1443–1493. [Google Scholar] [CrossRef]
3. Black, F., & Scholes, M. (1974). The pricing of options and corporate liabilities. The Journal of Political Economy, 81(3), 637–654. [Google Scholar] [CrossRef]
4. Boyle, P. P. (1988). A lattice framework for option pricing with two state variables. Journal of Financial and Quantitative Analysis, 23, 1–12. [Google Scholar] [CrossRef]
5. Camara, A., & Chung, S. L. (2006). Option pricing for the transformed binomial class. Journal of Futures Markets 29, 537–557. [Google Scholar]
6. Capozza, D. R., Kazarian, D., & Thomson, T. A. (1998). The conditional probability of mortgage default. Real Estate Economics, 26(3), 359–389. [Google Scholar] [CrossRef]

Volume10 Issue03, March-2025, pg. 1-9

Published Date: - 01-03-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

7. Copeland, T., & Antikarov, V. (2001). Real options. Texere. [Google Scholar]
8. Cox, J., Ross, S., & Rubinstein, M. (1979). Options pricing: A simplified approach. Journal of Financial Economics, 7, 229–263. [Google Scholar] [CrossRef]
9. Cox, J. C., Ingersoll, J. E., & Ross, S. A. (1985). An intertemporal general equilibrium model of asset prices. Econometrica, 53(2), 363–384. [Google Scholar] [CrossRef]
10. Derman, E., Kani, I., Ergener, & Bardhan, I. (1995). Enhanced numerical methods for options with barriers. Financial Analyst Journal, 51(6), 66–74. [Google Scholar] [CrossRef]
11. Diamond, W., & Landvoigt, T. (2022). Credit cycles with market-based household leverage. Journal of Financial Economics, 146, 726–753. [Google Scholar] [CrossRef]
12. Epperson, J. F., Kau, J. B., Keenan, D. C., & Muller, W. J. (1985). Pricing default risk in mortgages. AREUEA Journal, 13(3), 261–272. [Google Scholar] [CrossRef]
13. Gaudencio, J., Mazany, A., & Schwartz, C. (2019). The impact of lending standards on default rates of residential real estate loans. Occasional Paper Series ECB. European Central Bank (ECB), Frankfurt a. M. No. 220. [Google Scholar]
14. Geske, R. (1979). The valuation of compound options. Journal of Financial Economics, 7(1), 63–81. [Google Scholar] [CrossRef]
15. Haathela, T. (2006). Extended binomial tree valuation when the underlying asset distribution is shifted lognormal with higher moments. Available online: https://api.semanticscholar.org/CorpusID:208245423 (accessed on 15 December 2024).
16. Haathela, T. (2011). Estimating changing volatility in cash flow simulation based real option valuation with regression sum of squared error method. SSRN Electronic Journal. [Google Scholar] [CrossRef]
17. Hilliard, J. E., Kau, J. B., & Slawson, V. C., Jr. (1998). Valuing prepayment and default in a fixed-rate mortgage: A bivariate binomial options pricing technique. Real Estate Economics, 26(3), 431–468. [Google Scholar] [CrossRef]
18. Hull, J. C. (2022). Options, futures and other derivatives (12th ed.). Pearson Prentice Hall. [Google Scholar]
19. Kau, J. B., Keenan, D. C., Muller, W. J., III, & Epperson, J. F. (1995). The valuation at origination of fixed-rate mortgages with default and prepayment. Journal of Real Estate Finance and Economics, 11, 5–36. [Google Scholar] [CrossRef]
20. Kelly, R., & O'Malley, T. (2016). The good, the bad and the impaired: A credit risk model of the Irish mortgage market. Journal of Financial Stability, 22, 1–9. [Google Scholar] [CrossRef]
21. Leung, W. K., & Sirmans, C. F. (1990). A Lattice Approach to Pricing Fixed-Rate Mortgages with Default and Prepayment Options. Real Estate Economics, 18, 91–104. [Google Scholar] [CrossRef]
22. Maurer, R., Reiner, F., & Sebastian, S. (2004). Characteristics of german real estate return distributions: Evidence from germany and comparison to the U.S. and U.K. (Working Paper Series: Finance & Accounting, No. 108). Johann Wolfgang Goethe-Universität Frankfurt am Main, Fachbereich Wirtschaftswissenschaften. Available online: https://nbn-resolving.de/urn:nbn:de:hebis:30-17865 (accessed on 15 December 2024).

Volume10 Issue03, March-2025, pg. 1-9

Published Date: - 01-03-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

23. Merton, R. C. (1974). On the pricing of corporate debt: The risk structure of interest rates. The Journal of Finance, 29(2), 449–470. [Google Scholar]

24. O'Malley, T. (2021). The impact of repossession risk on mortgage default. The Journal of Finance, 76(2), 623–650. [Google Scholar] [CrossRef]

25. Van Order, R. (2007). Modeling the credit risk of mortgage loan: A primer. Ross School of Business Paper. 1086. Available online: https://ssrn.com/abstract=1002722 (accessed on 15 December 2024).

26. Wilmott, P., Howison, S., & Dewynne, J. (1995). The mathematics of financial derivatives. A student introduction. Cambridge University Press. [Google Scholar]

27. Young, M. S., & Graff, R. A. (1995). Real estate is not normal: A fresh look at real estate return distributions. Journal of Real Estate Finance and Economics, 10(3), 225–259. [Google Scholar] [CrossRef]