
RESEARCH INSTITUTE FOR HOUSING AMERICA **SPECIAL REPORT**

# Managing Mortgage Product Development Risk

Clifford V. Rossi
Robert H. Smith School of Business
University of Maryland

RESEARCH INSTITUTE FOR HOUSING AMERICA **SPECIAL REPORT**

# Managing Mortgage Product Development Risk

Clifford V. Rossi

Robert H. Smith School of Business
University of Maryland



MBa®
MORTGAGE BANKERS ASSOCIATION

RIHA
RESEARCH INSTITUTE
FOR HOUSING AMERICA

# RESEARCH INSTITUTE FOR HOUSING AMERICA



MBa®
MORTGAGE BANKERS ASSOCIATION

RIHA
RESEARCH INSTITUTE
FOR HOUSING AMERICA

# Table of Contents

**Executive Summary** . . . . . 1

**Introduction** . . . . . 2

**Product and Process Risk** . . . . . 5

**Product Morphing** . . . . . 8

**Impact of Product and Process on Loan Performance** . . . . . 11

**Standard Components of Product Development** . . . . . 16

**Product and Process Assessment Tools** . . . . . 19

**Conclusion** . . . . . 26

**Technical Appendix** . . . . . 27

**References** . . . . . 30

# Executive Summary

Mortgage banking is a highly cyclical business, prone to expansion and contraction as market conditions change. Mortgage product innovation is healthy for the industry and consumer so long as product risks and process quality are well understood. This study provides the industry with a framework for addressing both in an integrated manner. A similar approach is also recommended for evaluating all processes used over the loan lifecycle.

Intrinsic risks associated with mortgage products and processes amplified aggregate losses of mortgage originators, investors and servicers following the mortgage boom of 2004–2007. In many instances product development acceded to market pressures as the economy expanded and regulatory oversight waned. Competition and a benign economic environment led to risk layering, where combinations of risky attributes significantly elevated strategic, market, credit, operational, reputational, legal and regulatory risk to firms. As products morphed over time in response to greater risk layering, it masked how these products would perform under stress and the impact of the manufacturing process quality to control risk.

The potential for products to morph over time as features change in response to market conditions can lead to poor pricing, risk and business decisions. In this study, an empirical analysis of how product morphing translates into greater risk is conducted along with statistical analysis quantifying the relationship between process and credit risk. I find that lenders with high repurchase rates (a proxy for process quality) relative to other lenders produced loans with statistically greater default risk, controlling for other borrower, macroeconomic, loan and collateral risk attributes. This process impact was particularly important during a period in which product risk increased from 2003–2008.

The central interest of this study is development of a set of simple assessment tools that facilitate the effective development of mortgage products going forward. This focus is of heightened interest due to potential macroeconomic changes on the horizon, important demographic shifts that may require different products for nontraditional borrowers and even the possibility of industry expansion into non-QM mortgages. For example, there has been renewed interest in originating 99 and 100 percent LTV loans as well as mortgages with debt-to-income (DTI) ratios up to 50 percent. Under such circumstances it is critical that lenders as well as investors and aggregators redouble their efforts to strengthen the processes used in the mortgage manufacturing process.

This study recommends a more formalized approach to assessing mortgage product risk that takes into account both product and process risk. Specifically, firms should systematically identify the important features of potential products and assess their individual contribution to overall financial and nonfinancial risks for the firm.

Leveraging systems engineering and commercial real estate risk rating methodologies, the paper describes scorecards for assessing product risk and process quality. The product scorecard takes into account risk layering, specific product features and target market factors in establishing a product risk score. Similarly, the process quality scorecard takes into account how various activities important to product development impact firm risk. A product development risk matrix is also presented. It is based on the final scores from both scorecards that can be used to determine whether a product should be implemented, revisions made to product and/or process before deployment, or rejected for implementation. Such tools can be customized and provide a means of evaluating mortgage products and for identifying potential gaps in processes and product prior to product release.

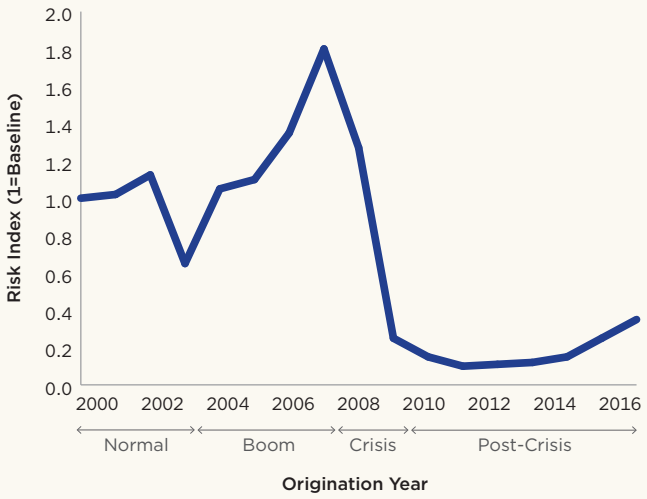
# Introduction

Intrinsic risks associated with mortgage products and processes amplified aggregate losses of mortgage originators, investors and servicers following the mortgage boom of 2004–2007. In many instances product development acceded to market pressures as the economy expanded and regulatory oversight waned. The years since the financial crisis have afforded its survivors an opportunity to redouble their efforts to improve the practices and controls used in loan production.

The central interest of this study is development of a set of simple assessment tools that facilitate effective development of products. This focus is of heightened interest due to potential macroeconomic changes on the horizon, important demographic shifts that may require different products for nontraditional borrowers and even the possibility of industry expansion into non-QM mortgages.

The minutes of the December 2016 Federal Open Market Committee (FOMC), for instance, concluded that the potential for expansionary fiscal policy was higher than it has been in years.[1] Coupled with renewed interest by the Administration to reform aspects of the Dodd-Frank Act, such policies could bring on a period of growth that tests the effectiveness of existing mortgage product development processes.[2] Household growth along with an increase in the entry of millennial age borrowers to the housing market have been observed along with strong immigration growth in recent years.[3] These shifts in borrower demographics could lead to a variety of new products to support this demand.

**FIGURE 1.**
**CONFORMING MORTGAGE RISK LAYERING INDEX**




Product development in the mortgage industry, unlike other industries is not marked by a great deal of consistency in approach or application. Since the crisis three important, and not mutually exclusive, changes have dramatically stifled product development initiatives and innovation in the years since the crisis. The first was the promulgation of the Qualified Mortgage rules by the Consumer Financial Protection Bureau (CFPB).[4] The QM rules profoundly changed the market by stipulating what product features would limit lenders from facing legal challenges by borrowers encountering mortgage problems later on. Second, credit conditions have been unusually tight by historical standards (as illustrated by Figure 1 and described below). A third change has been the heightened focus on mortgage compliance among lenders as a result of increased regula-

1. Board of Governors of the Federal Reserve Systems, Minutes of the Federal Open Market Committee, December 13–14, 2016.
2. Michael C. Bender and Damian Paletta, Donald Trump Plans to Undo Dodd-Frank Law, Fiduciary Rule, Wall Street Journal, February 3, 2017.
3. Joint Center for Housing Studies at Harvard University, The State of the Nation's Housing 2016, pp. 13–17.
4. Bureau of Consumer Financial Protection, Ability-to-Repay and Qualified Mortgage Standards under the Truth in Lending Act, 12 CFR Part 1026, January 10, 2014.

tion in this area.[5] In addition to the Qualified Mortgage rule, the CFPB has promulgated regulations on appraisals and the TILA-RESPA Integrated Disclosure rule, among others. With product risk at unusually low levels by historical norms, the effect of process risk on firm loss is muted and therefore could be understated in current product assessment processes. Generally speaking, mortgage product development processes have not been tested since the crisis and the danger to the industry is when the cycle turns.

This study seeks to answer the following questions:

- What is mortgage product risk and how does it differ from credit risk?
- How does the process and infrastructure used to originate, service and manage mortgage products contribute to firm risk?
- How are mortgage product and process risks related to overall loss exposure for a firm?
- What frameworks can be used by the industry to standardize product and process risk in a consistent manner to improve product development decision-making and risk management?

The issues central to this study are equally relevant for mortgage banking institutions originating and selling product to an investor as well as for portfolio lenders holding the mortgage asset on balance sheet. Mortgage products represent combinations of borrower, loan, collateral and other risk factors that vary in terms of their impact on firm losses over time. As the crisis unfolded, the impact of mortgage product development went well beyond the traditional financial risks of credit, liquidity, market and interest rate risk. Operational, reputational, regulatory, strategic and legal risks rose in prominence during this period.[6] The mortgage process facilitated the increase in these nonfinancial risks.

The process surrounding the acquisition, management and servicing of mortgage loans is also directly related to a firm's loss exposure. Firms with relatively weak processes for managing mortgage loans have a greater likelihood of incurring more losses than firms with better processes, all things equal. In this study I perform a statistical analysis of GSE-eligible loans and find that controlling for all other borrower, loan, collateral and market risk factors, a significant process effect remains as proxied by a variable distinguishing lenders with high repurchase rates. While the exact nature of the process effect cannot be identified in the data directly, idiosyncratic impact of the lender's processes is picked up by looking at a lender's repurchase rate. This result is consistent with anecdotal evidence from a number of sources highlighting lenders with process deficiencies during the mortgage boom that suffered major losses or worse.[7] This result underscores the importance that process plays in mortgage risk and argues that assessing process risk in a systematic manner is critical to the mortgage product development process.

Based on an empirical analysis of the lifetime default of GSE-eligible loans in a sample drawn from 2000–2003 I show that over time default performance of later vintages from 2004–2008H1, reflecting a period of expanded credit terms risk, were significantly underestimated and that the degree to which default is underestimated rises with the loan's risk profile.[8] The implication is that firms need to recognize that significant expansion of the risk characteristics of a mortgage product over time leads to product morphing, a condition that over time reduces the value of historical mortgage performance data from being an accurate reflection of credit risk. More importantly, product morphing raises the risk profile of the product over time. Nowhere is product morphing better illustrated than with the option ARM product. Originally created as a niche portfolio product, over time lenders greatly expanded the features and credit characteristics of the product. These included various low documentation programs such as stated income stated asset (SISA) combined with lower FICO scores and higher LTVs than the original option ARM product. The processes of many such lenders were determined later by regulatory reviews to have been deficient in critical ways that increased risk for these institutions.[9] What was not anticipated at the time of origination was the importance of understanding how changes in product and process quality could lead to overall losses that would be multiples above those predicted based on the performance of the original portfolio option ARM product.

5. Consumer Financial Protection Bureau, Semi-annual report of the Consumer Financial Protection Bureau, 2016.
6. Douglas Robertson, So That's Operational Risk! (How operational risk in mortgage backed securities almost destroyed the world's financial markets and what we can do about it), Office of the Comptroller of the Currency, OCC Economics Working Paper 2011-1, March 2011. Al Yoon, Total Global Losses From Financial Crisis: $15 Trillion, Wall Street Journal, October 1, 2012. Brena Swanson, "OCC terminates JPMorgan and EverBank mortgage servicing consent orders," HousingWire, January 5, 2016.
7. U.S. Senate Permanent Subcommittee on Investigations, Wall Street and the Financial Crisis: The Role of High Risk Home Loans, Hearing, April 13, 2010 and Kirsten Grind, The Lost Bank, Simon & Schuster, 2012.
8. The 2004–2008H1 sample was truncated at the end of the first half of 2008 (i.e., H1) as by then significant credit tightening had taken place in response to the crisis as described in Board of Governors of the Federal Reserve System, October 2016 Senior Loan Officer Opinion Survey on Bank Lending Practices, p. 10.
9. US Department of the Treasury and FDIC, Offices of Inspector General, Evaluation of Federal Regulatory Oversight of Washington Mutual Bank Report No. EVAL-10-002 April 2010.

This perspective leads to the major contribution of this study for the industry; namely the development of a product and process risk scorecard that can be used on a firm- and industry-wide basis in mortgage product development. Leveraging best practices from other industries and activities such as ISO product quality standards, systems engineering, including NASA processes for assessing risk associated with manned spaceflight and also commercial lending credit rating processes, I develop a set of illustrative mortgage process and product scorecards. Key features of mortgage products and processes are identified, and a process for weighting each component and assigning a rating or score to each is described. The results from both scorecards can be mapped to a risk matrix that can be used in conjunction with the firm's risk appetite statement to inform management of whether or not to move forward with a product or modify its scope and required controls. Importantly, it can quickly identify deficiencies along the process continuum that require attention prior to any product release and can be used in the strategic planning and capital allocation process.

The study suggests that a more formalized approach to assessing mortgage product risk can heighten awareness of linkages between product development, mortgage processes and risk exposure for firms. A similar approach would also be useful for evaluating all processes used over the loan lifecycle. In particular, firms could combine their product and process ratings to create a consistent assessment of product design outcomes that link to predetermined thresholds of acceptability for product development and deployment.

# Product and Process Risk

Essential to understanding the overall risk profile of a product is that risks to portfolio lenders and mortgage banks alike are affected by both the intrinsic risk of the product and of the process under which the loan is originated, managed and serviced over its life. Product risk includes all of the inherent features making up the mortgage, such as borrower credit score, LTV and debt-to-income ratio, among others. Product risk also includes the degree of credit risk layering which describes the combination of multiple product risk factors together.

While risk layering directly translates into higher credit risk, it also can mask other nonfinancial risks related to borrower behavior, such as legal, reputation and regulatory risk if the product is not well understood by the borrower. Most important though, as risk layering increases, it places greater strain on the underlying underwriting and risk identification processes, particularly during periods of market expansion when greater numbers of loans are originated.

In order to describe the nature of mortgage product risk layering over time, a multivariate statistical model was created describing the relative default risk in an origination year based on a variety of borrower, collateral and loan risk factors.[10] Figure 1 shows that immediately following the crisis, investors significantly tightened credit standards in part due to changes in attitudes and preferences for mortgage risk by many mortgage banking organizations, in addition to regulatory changes highlighted above, and this has remained largely the case. The risk layering index depicted is computed as the percentage of loans in a given origination year with modeled default rates more than 2 standard deviations above the mean as a percentage of loans originated in the base year (1999) that were above 2 standard deviations in modeled default rates, holding economic conditions constant. Applying this definition of high-risk loan to the sample provides a basis for observing any expansion or contraction in risk layering. The period from 1999 to the present can be categorized into 4 underwriting regimes. The period 1999–2003 reflects the pre-boom, or normal underwriting regime followed by boom where high risk loans in 2007 were originated at a rate more than 1.8 times that observed during the pre-boom period.

The results of the Conforming Mortgage Risk Layering Index aligns relatively well with the Mortgage Bankers Association's Mortgage Credit Availability Index (MCAI) which is a measure of the willingness of investors and/or aggregators to buy loans and underscores the point that understanding the quality of the loan manufacturing process is as important for investors and aggregators as it is for loan originators.

Another aspect of product risk is the target market. Products must be aligned with intended borrowers. Products better served for financially sophisticated borrowers may not be appropriate for others. Borrower selection issues can manifest over time as mortgage products change. A change in a particular underwriting feature can invite a dramatic shift in the composition of borrowers in terms of their ability or willingness to repay the obligation that may be unobserved by the originator. This phenomenon could be facilitated by originators that market products to an unintended set of borrowers that are attracted to the combination of mortgage features. This could be brought on by deficiencies in the origination or sales process, for example, if short-term focused sales compensation programs create incentives to originate to riskier borrowers.

10. Factors included borrower FICO, LTV, DTI, relative loan amount, property type, state, occupancy status, house price appreciation rate, unemployment rate and prevailing interest rate (Freddie Mac Primary Mortgage Market Survey rate for fixed-rate 30-year mortgages), among others. The risk index was developed by imposing the average values of the macroeconomic factors over time so as to neutralize the effect of cycle on the index.

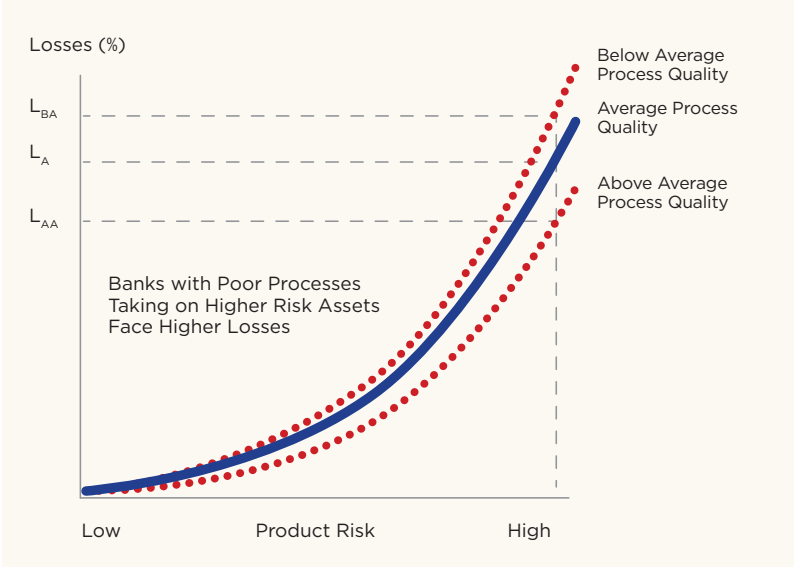
Likewise, a well-defined business strategy is important and a poorly defined risk appetite or product development strategy could also facilitate an adverse selection of borrowers.

The loan process encompasses activities like loan underwriting, appraisal, sales compensation, pricing, risk management, governance, disclosure, servicing, product delivery, and marketing, among others. The quality of the processes and controls used to originate, manage and service products over time factor directly into the overall risk profile of the firm. Evidence from the mortgage crisis supports this point and underscores the relationship between product and process risk. As option ARMs began proliferating among a number of primarily west coast oriented lenders around 2004, two important changes occurred. First, in order to make the product more widely available and to improve the delivery of the product to the market, important features used to control risk (borrower ability-to-repay and collateral quality) underwent significant changes in their terms.[11] Increasingly higher debt-to-income ratios were allowed as were higher loan-to-value (LTV) ratios over time. This was coupled with important product changes such as allowing lower documentation requirements to determine borrower employment, income and assets. At the same time, processes to handle these new low documentation loans and to confirm the quality of property values as down payments declined and home prices rose were not strengthened to compensate for the greater risk of these combined product features.

To visualize the relationship that product and process risk has on aggregate loss, consider Figure 2. Losses depicted on the vertical axis include all financial and nonfinancial risks associated with a mortgage product. Product risk is defined on the horizontal axis. For example, a fixed-rate 30-year, fully documented GSE-eligible loan today would be depicted on the far left side of the product risk axis as compared to an option ARM loan originated during the mortgage boom which would be found toward the far right end of the product risk axis. Superimposed on the graph are three process risk curves. The middle curve is associated with a lender exhibiting an average level of process risk as defined previously. The uppermost curve reflects a lender having a below average quality process and the bottommost curve represents a lender with an above average quality manufacturing process.

Overall losses rise with product risk. But for any level of product risk, process risk differences lead to different levels of firm loss. This outcome is observed by looking at the impact on loss from a risky product. For the same

**FIGURE 2**
**LOSSES, PRODUCT AND PROCESS RISK**




level of product risk, the total losses range from a low of LAA to a high of LBA, reflecting differences in process quality. It could be for instance that only full appraisals conducted by in-house appraisal staff are used to assess value for firm AA while company BA uses a much more streamlined appraisal process that is embedded with the loan production team. Inferior sales compensation practices, poor governance and oversight and a lack of transparent disclosures could also characterize lender BA's processes. As a result, this firm experiences much higher credit and nonfinancial risks than lender AA.

The impact that process quality has on firm loss varies across the product risk continuum. Poor processes may not be as apparent for low risk products compared with high risk ones for a variety of reasons. A low level of credit risk aligned with high quality borrower and collateral and simple product features reduces the potential for both credit and nonfinancial-related losses. However, as risk layering and product complexity increases, it places a strain on deficient processes that can manifest into overall higher losses than a well-controlled process.

This construct forms the basis for advocating the need to incorporate a systematic assessment of product and process risk into the product development process. It can also help better align product risks with the firm's risk appetite because it suggests how the combined effect of product and process risk can be translated into total loss.

Whether the firm is a portfolio lender or mortgage bank, risk associated with a mortgage product comes in a variety of forms. For a buy and hold portfolio lender, these include direct financial risks such as credit losses associated with

11. The Financial Crisis Inquiry Commission Report, The Final Report of the National Commission on the Causes of the Financial and Economic Crisis in the United States, pp. 83–102., January 2011.

the default of the borrower, potential market or interest rate risk associated with holding the asset on the balance sheet, and liquidity risk associated with a product's salability in the market, particularly during times of stress. For all institutions selling mortgages either through an aggregator or directly to an investor, the potential for rep and warrant risk exists as well.

No less important to the firm's risk profile are a collection of nonfinancial risks. Chief among these is the strategic risk of a product. Strategic risk is characterized by its impact on the business from all vantage points including profitability, market impact and relevance, external constituent impacts and perspectives, among others. Other risks include potential regulatory, legal or reputational losses that could be suffered as a result of some weakness in the product or process.

These risks are influenced heavily by the behavior of borrowers, originators and investors, among others. Ultimately, as the owner of mortgage credit risk, the investor defines a product's features through underwriting guidelines and pricing. Understanding the drivers of risk exposure as described by a mortgage product's features can help lenders selling loans mitigate potential rep and warrant and nonfinancial risks whereas portfolio lenders can directly reduce their financial and nonfinancial risk exposures by better understanding these risks.

# Product Morphing

Mortgage cycles as seen from the results depicted in Figure 1 have a significant effect on the characteristics of mortgages over time. Expansionary credit policies during boom periods give way to contraction during a bust episode. These fluctuations complicate our understanding of mortgage performance over time since key product characteristics and macroeconomic conditions change. Whether the product under examination is new or has evolved from an existing product, the potential for misunderstanding the risk associated with product innovation is significant whenever historical data is the primary source of product performance analysis.

The quality of the loan manufacturing process affects the risk profile of both new and enhanced products. Product enhancements range from minor adjustments to an existing product to major changes in credit, loan and collateral terms such that it effectively results in an entirely different product from its original form. Such changes can affect borrower behavior and ultimately product credit risk. For example, expanding maximum LTVs from 90 to 100 percent while relying on a faulty collateral valuation process could amplify credit exposure by increasing the likelihood of inflated property values and the borrower's incentive to default. I define changes in borrower, loan and/or property characteristics of an existing product over time that significantly raise the risk profile of the loan as product morphing. This incremental creep in product and credit terms away from the original products features when combined with risk layering and process quality issues creates greater potential risk in the future.

One of the most difficult issues to unravel is the relative impact of changes in product features that increase risk (product morphing) versus shifts in product mix that a firm incurs over the cycle. In particular, adverse product mix shifts may be influenced by business conditions that happen to raise the credit risk profile of new originations. To gain a better understanding of the impact of each of these on product development, consider the following example for an originator. Mortgage originations are grouped into four

**FIGURE 3A. PRODUCT MIXING AND MIX SHIFT EXAMPLE — BASE CASE**

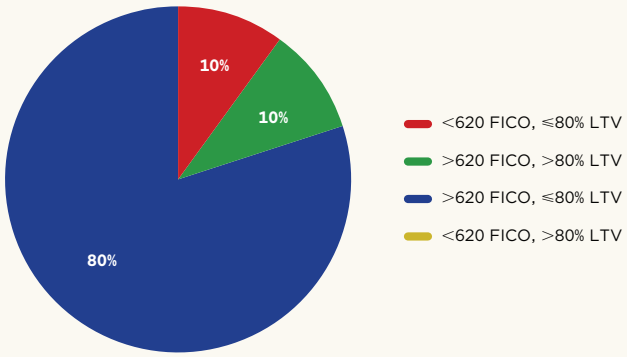
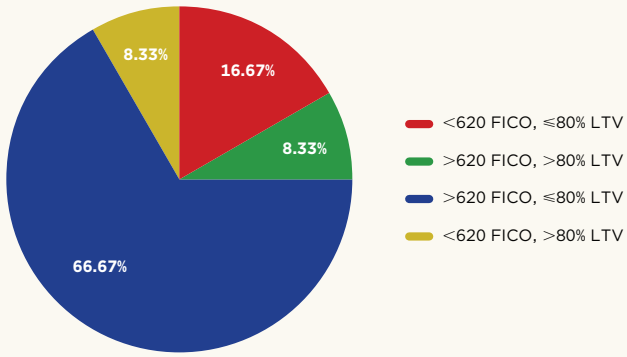



**FIGURE 3B. PRODUCT MIXING AND MIX SHIFT EXAMPLE — PRODUCT MIX + MORPHING**



combinations of FICO (<620 and >=620) and LTV (<=80% and 80%). Initially, a lender might have a base case origination profile that looks like that in Figure 3a. Over time, due to an expansion of product mix into the <620 FICO, <80% LTV segment and product morphing into a new segment (<620 FICO, >80% LTV) the resulting origination profile over time looks like Figure 3b.

To assess the change in firm risk, I assume that each of the four categories has a relative default risk multiplier as indicated in Table 1. The lowest risk category, (>=620 FICO, <=80% LTV) is defined as the baseline risk and its risk multiplier is set at 1.0. It is also assumed that the lifetime default risk of the baseline category is 1%. All other category risk multipliers are above 1.0 indicating relative default risk that is greater than the baseline category. For example, the product morphing category risk multiplier implies that loans in this group will default 2.5 times more than the baseline.

The impact of product morphing and product mix is decomposed in Table 1. In the base case scenario, each category's illustrative share of total originations (designated as the weight in Table 1) is multiplied by its risk multiplier to show that segment's relative contribution to overall default risk. For the base case scenario, the overall default rate is 1.035% (1.035 x 1%). By comparison, the product morphing and adverse mix scenario results in a total default rate of 1.162%. Product morphing and adverse product mix increase default rates overall by 0.21% and 0.073%, respectively. Another way of looking at it, product morphing accounts for nearly three quarters of the increase in default rates between the two scenarios given the assumptions made in this example.

Most product development focus in the mortgage industry is on changing or extending the features of existing products. At the most basic level mortgage products are defined along two dimensions; payment and lien type. Fixed-rate versus adjustable rate, and fully amortizing, interest only, or balloon, characterize the type of payments among first and second lien products. Beyond this, other attributes such as loan purpose or documentation type are simply variations on a theme in the arrangement of a set of attributes that comprise a mortgage loan. So-called nontraditional mortgages developed before 2008 including Alt A and subprime loans were simply extensions of core products. In the case of option ARMs, one of the most toxic loans originated during that period, the structure of that product significantly changed over time to one that bore no resemblance to its progenitor product first originated in 1981. With an option ARM a borrower was able to make one of four payment types; a fully amortizing fixed-rate 15- or 30-year payment, an interest only payment or a minimum payment based on a teaser rate that was lower than the note rate on the loan. This latter payment type would result in negative amortization and became frequently used by option ARM borrowers before the crisis. The transformation of the option ARM and other products during this period exemplifies the product morphing phenomenon.

To gain a better perspective on the concept of product morphing and how it plays into the development process and risk profile of the firm over time, some review of the history of the option ARM product is useful. World Savings and Loan, a large west coast thrift that pioneered the product for their retained portfolio, introduced the option ARM in 1981. The product began as one to fill a niche for financially sophisticated borrowers with a need for flexibility in their mortgage payments to align with an income stream that could vary due to sales commissions, bonus payments and related fluctuating compensation structures.[12] As a thrift institution, a major concern for World Savings was interest rate risk. Mortgage lenders such as World Savings faced the challenge of making sure their variable rate deposit liabilities were matched with variable rate mortgage assets. With a natural tendency to

12. Golden West 10-K report, 2005, p. 55.

**TABLE 1: DECOMPOSITION OF PRODUCT MORPHING AND MIX SHIFT EXAMPLE**

| | | MARGINAL EFFECT ON DEFAULT RATE | | | | |
|---|---|---|---|---|---|---|
| | RISK MULTIPLIER | BASE CASE | | PRODUCT MIX + MORPHING | | DIFFERENCE |
| | | WEIGHT | RELATIVE EFFECT (%) | WEIGHT | RELATIVE EFFECT (%) | (%) |
| <620 FICO, <=80% LTV | 1.100 | 0.100 | 0.110 | 0.167 | 0.183 | 0.073 |
| >=620 FICO, >80% LTV | 1.250 | 0.100 | 0.125 | 0.083 | 0.104 | -0.021 |
| >=620 FICO, <=80% LTV | 1.000 | 0.800 | 0.800 | 0.667 | 0.667 | -0.133 |
| <620 FICO, >80% LTV | 2.500 | 0.000 | 0.000 | 0.083 | 0.208 | 0.208 |
| **Total Default Rate** | | | **1.035** | | **1.162** | **0.127** |

maintain a positive on-balance sheet duration gap, a firm like World Savings would be attracted to a product such as an option ARM that would have a shorter duration than a standard fixed-rate mortgage.[13] Thus, the option ARM served the thrift as an effective hedge against interest rate risk given that these were portfolio products. At the outset the product was well controlled from a credit risk perspective. The process for underwriting option ARMs at World Savings featured the use of in-house appraisal staff, a focus on moderately priced properties relative to the local market, and strict borrower collateral requirements; (the average LTV of ARMs in the portfolio in 2004 and 2005 was 68 and 69%, respectively).[14] Further the firm relied heavily on manual underwriting and regular pre- and post-funding QC reviews of loans. Keeping the asset on balance sheet required greater vigilance surrounding the processes and underwriting features of these loans.[15] To gain some perspective on how the World Savings option ARM portfolio performed over time, consider Figures 4a and 4b.

Credit performance of World Savings residential mortgages (nearly all of which were reported as option ARMs by the thrift[16]) compared to that of all other depositories residential mortgage portfolios was consistently better from 1996–2006. Over time the company would increase the securitization of its mortgage originations. Table 2 describes this growth in securitization activity at the thrift.

In May 2006, Wachovia bought Golden West, the parent company of World Savings. As part of its strategy to leverage the Golden West mortgage platform, Wachovia expanded the option ARM product, eventually reaching a portfolio size of $170B in the product. As can be seen in Figure 4b, delinquency rates of the post-Wachovia merger option ARM portfolio deteriorated relative to the industry.

Incremental slippage in product risk and process quality lie at the heart of product morphing and so understanding its effects are key to developing a systematic framework for managing these changes in product composition. Further insight into the impact of product morphing can be gained from a statistical analysis of mortgage loan performance over time.

13. Duration is a measure used at assess the sensitivity of a fixed-income asset's or liability's value to changes in interest rates.
14. Golden West 10-K report, 2005, p. 53.
15. Since the crisis, greater attention on making loans saleable in the secondary market has occurred for a variety of reasons including stronger rep and warrant requirements.
16. Golden West 10-K report, 2015, p.34.

**TABLE 2: GOLDEN WEST SECURITIZATION ACTIVITY 2003–2005***

| YEAR | MBS ISSUANCE (BILLIONS OF DOLLARS) |
|---|---|
| 2005 | 34.3 |
| 2006 | 24.5 |
| 2007 | 13.7 |

* Wachovia embraces Golden West's option arms, "Asset Securitization report," Allison Pyburn, May 15, 2006.

**FIGURE 4A. NONCURRENT LOAN TO ASSET RATIOS 1996–2006**

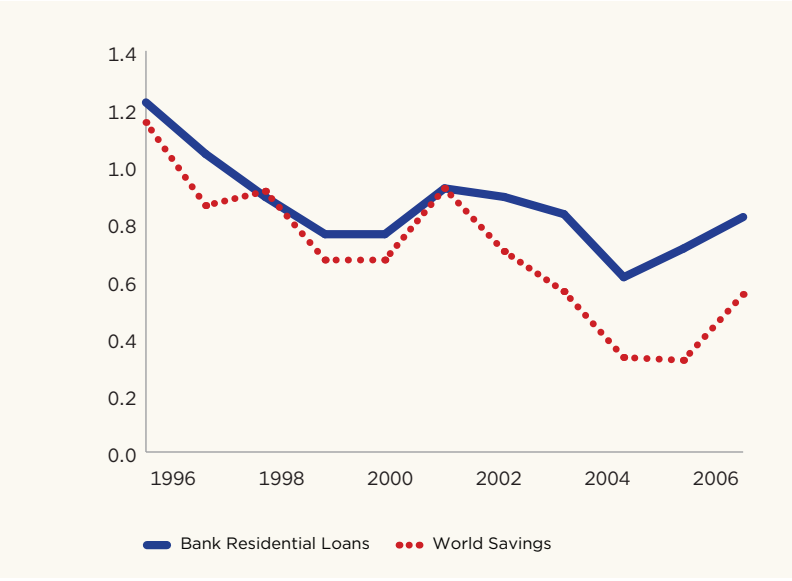
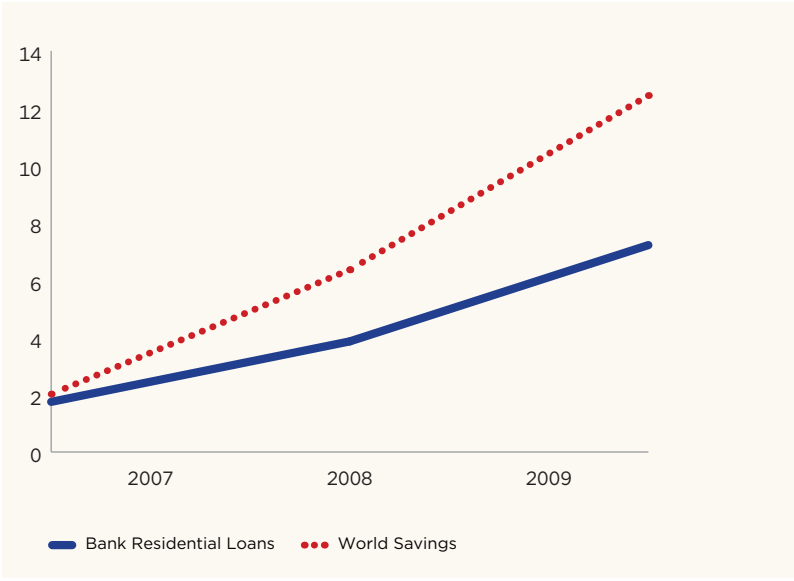



**FIGURE 4B. NONCURRENT LOAN TO ASSET RATIOS 2007-2009**




Note: Data reflected in this table reflect performance after the acquisition of Golden West by Wachovia.

# Impact of Product and Process on Loan Performance

Good product development includes an analytical assessment of expected credit performance of a new or enhanced product taking into account expected changes in market conditions, and borrower and loan characteristics. Historical loan level performance is an excellent data source for such analysis, however, it can be misleading at times if markets and products change significantly. Inferences drawn regarding potential credit losses from one period or product configuration can wind up materially different from those of another time. This error can not only lead to wrong decisions being made about a product but also the frailties of a product and its associated processes used in its manufacture can remain hidden from view until a precipitating event manifests as it did with the crisis of 2008.

To demonstrate this issue, a statistical model measuring the probability that a loan becomes 90 days past due or worse (90DPD+) over its life was estimated from a representative loan sample of loans originated between 2000–2003 drawn from the Fannie Mae and Freddie Mac credit performance data. Defining default as 90DPD+ is consistent with other industry and academic studies.[17] Specific technical details on the model are provided in the appendix. The model is consistent with the type of analysis that would be performed by analysts interested in pricing product risk by estimating the trajectory of loan defaults over time so that the periodic mortgage cash flows can be properly discounted. The model incorporates a number of borrower, loan, property and economic factors associated with mortgage default. A summary of the factors used is found in Table 3. It is important to note that this analysis only focuses on one aspect of a lender's overall risk; namely borrower default. Such models commonly used in mortgage product development ignore the full range of risks that product features could affect such as fraud, legal, operational, reputational and regulatory risks. Despite this limitation on the data, a focus on just default can shed light on the effect that product morphing and risk layering can have on a lender's understanding of product risk over time.

The model was estimated at the loan level from a random sample of 110,000 GSE mortgages originated between 2000–2003. Each loan's status; current, prepaid, or 90DPD+ was captured each quarter through March 2016 and used in estimating the survival model of default.[18] Upon further study of the number of actual 90DPD+ observations remaining in the data after quarter 40, a decision was made to truncate the performance window at that point to ensure sufficient observations on defaults remained from which to draw statistically meaningful results from the sample. This approach does not produce a life of loan estimate of default, however, historical experience suggests that the vast majority of loan defaults occur before the 10th year following origination. The actual 90DPD+ rate for the development sample was approximately 3.5 percent. The 2000–2003 origination years were selected for model estimation as a benchmark underwriting regime. In other words, this is a period representing a more normal underwriting environment. Consistent with Figure 1, it is clear that the periods following 2003 of boom, bust and

17. Dunsky et al., FHFA Mortgage Analytics Platform, Federal Housing Finance Agency, July 10, 2014 and Deng et al., Mortgage Termination, Heterogeneity and the Exercise of Mortgage Options, Working Paper No. W99-002, Program on Housing and Urban Policy, University of California, Berkeley, 1999.

18. Survival models can generate estimates of default across a loan's life, thus making them useful techniques for pricing mortgage risk.

post-crisis diverge from the 2000–2003 period in terms of credit risk characteristics and ultimately loan performance.

A validation sample of approximately the same size as the development sample was drawn from the same period to use in gauging the adequacy of the model's fit against actual performance. All variables included in the model were statistically significant and carry the expected relationship to default. Since this is the type of model that would be used to price credit risk as part of the product assessment process, it is useful to examine the predictive quality of the model over time as well as on a cumulative default basis. A profile of the cumulative estimated and actual 90DPD+ rates over time is shown in Figure 5.

The model result tracks the actual loan performance exceptionally well up to about quarter 23 and then slightly underestimates actual performance thereafter. The error rate of the cumulative 90DPD+ model evaluated at quarter 40 is about 8.5 percent (i.e., 3.5% actual vs. 3.2% modeled).

**TABLE 3: EXPLANATORY VARIABLES USED IN 90DPD+ MODEL**

| VARIABLE | DESCRIPTION | EXPECTED SIGN |
|---|---|---|
| FICO | Borrower credit score at origination | – |
| LTV | Original loan-to-value ratio | + |
| DTI | Original debt-to-income ratio | + |
| Rate Spread | Note rate less current period market rate (Freddie PMMS F30) | – |
| HPI | Annualized house price appreciation rate | – |
| Loan Amount | Loan amount divided by median loan amount for the MSA or state | U-shaped |
| Loan Purpose | Baseline is Purchase | |
| | Cash-out Refinance | + |
| | Rate & Term Refinance | – |
| Channel | Baseline is Retail | |
| | Correspondent | + |
| | Broker | + |
| Seasoning | Quarter when loan originated | Varies |
| Modification | Was the loan ever modified in its life | – |
| Occupancy Status | Baseline is Owner-occupant | |
| | Investor | + |
| | 2nd Home | + |

If over time a lender applying this model decides to incrementally expand an existing product, comfortable that the estimated relationships of key risk factors are stable, what would be the consequences of this product morphing? To examine this effect, the original model was run against approximately 77,000 GSE loans originated between 2004 through the first half of 2008 (2008H1). This period experienced much higher defaults (actual 90DPD+ rate was 11.9%) than the development period and as shown in Figure 1 exhibited a greater credit risk profile.

To analyze the effects, two different sets of results are derived from the modeled output. The first shown in Figure 6

**FIGURE 5. ACTUAL VS. ESTIMATED 90DPD+ RATE (2000–2003)**

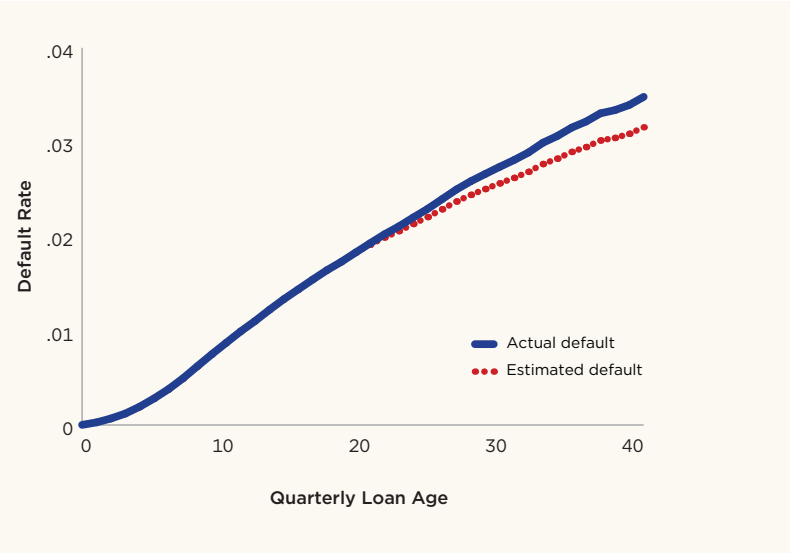



**FIGURE 6. ACTUAL VS. ESTIMATED 90DPD+ RATE (2004–2008H1)**

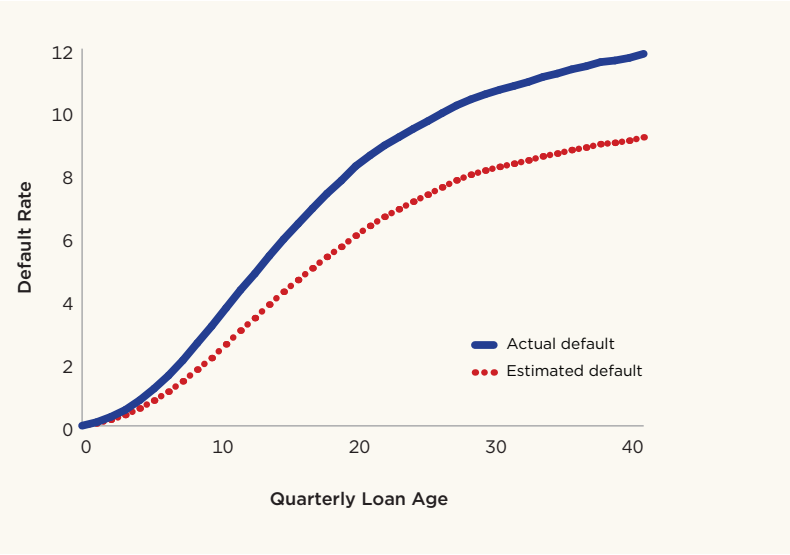
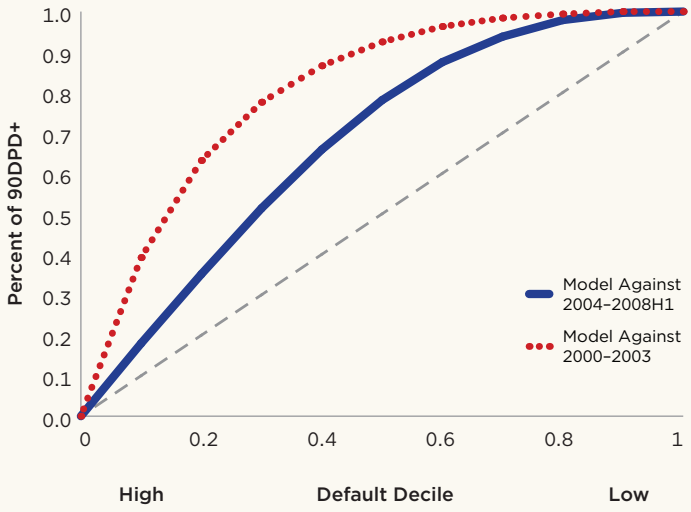


FIGURE 7. CUMULATIVE ACCURACY PROFILE RESULTS: 90DPD+ MODEL




compares the estimated to actual cumulative 90DPD+ rate for the 2004–2008H1 sample. The model clearly underestimates default over time by a wide margin (nearly 23%) which if used to determine loan profitability and pricing as well as for making strategic product development decisions, would lead the lender to experience much greater losses than anticipated.[19]

19. This result also demonstrates the importance of mitigating model risk, in particular the fact that statistical models are rearward-looking, coupled with the long seasoning ramp of mortgages, can lead to significant errors in model performance as product morphing accelerates.

Such model errors derive largely from three sources; changes in macroeconomic climate not represented in the original data; changes in the type of borrowers over time; and risk layering changes. The last two effects directly speak to issues of process and product risk that lead to riskier outcomes than expected from the original model.

To gain another perspective on how products with significantly expanded credit risk characteristics undercut any perceived product advantage, consider Figure 7. The diagram depicts a model cumulative accuracy profile (CAP). Where Figures 5 and 6 compare actual to modeled default rates over time, the CAP characterizes model accuracy by its ability to successfully rank order default and non-default outcomes. The CAP plots the cumulative percentage of defaulted loans against the cumulative percentage of loans in the sample, ranked according to decile of predicted probability. To present the CAP results, loans originated between 2000–2003 and 2004–2008H1 were run through the model separately and then rank ordered by decile of estimated 90DPD+ rate from high to low, the decile containing the highest estimated 90DPD+ loans is labelled as 0.1 on the Percent of Loans axis and the decile labelled 1 has the lowest probability of default.

Loans in the highest default decile are associated with greater risk layering than loans falling in the lowest default deciles. This can be observed from Table 4, which shows by score decile the average values for several important risk characteristics for the two samples. Each of the risk attributes shows a general pattern of increasing risk for each attribute from low to high score decile within each sample, indicating a high degree of risk layering exists in the highest scoring deciles.

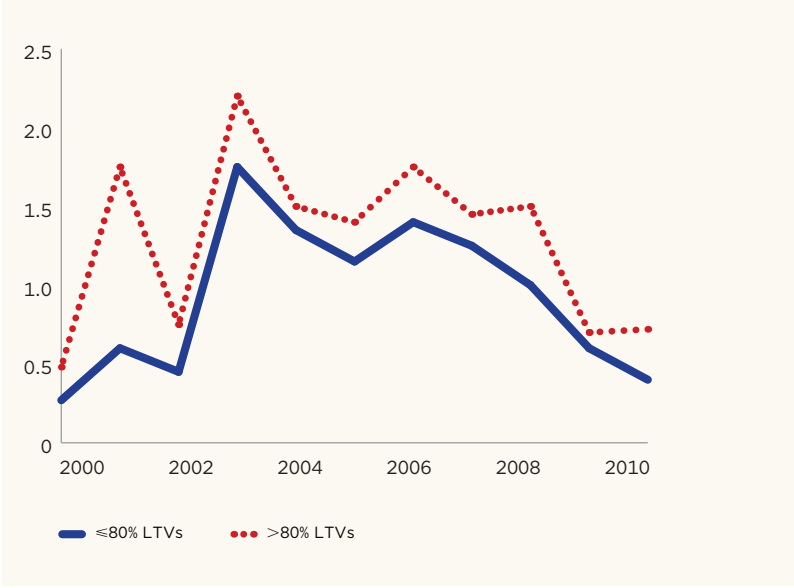
TABLE 4: KEY RISK ATTRIBUTES BY SCORE DECILE

| MODEL RISK | FICO | | LTV | | DTI | | INVESTOR % | |
|---|---|---|---|---|---|---|---|---|
| DECILE | 2000–2003 | 2004–2008H1 | 2000–2003 | 2004–2008H1 | 2000–2003 | 2004–2008H1 | 2000–2003 | 2004–2008H1 |
| 1 | 786 | 742 | 49 | 68 | 25 | 36 | 4 | 6 |
| 2 | 774 | 759 | 64 | 64 | 29 | 34 | 4 | 6 |
| 3 | 760 | 754 | 68 | 67 | 30 | 35 | 5 | 8 |
| 4 | 748 | 749 | 71 | 70 | 32 | 35 | 6 | 9 |
| 5 | 733 | 743 | 72 | 74 | 33 | 36 | 6 | 10 |
| 6 | 718 | 735 | 74 | 75 | 34 | 37 | 7 | 12 |
| 7 | 699 | 723 | 75 | 76 | 34 | 38 | 9 | 12 |
| 8 | 685 | 707 | 76 | 78 | 36 | 39 | 8 | 13 |
| 9 | 666 | 686 | 77 | 80 | 37 | 40 | 6 | 13 |
| 10 | 641 | 658 | 80 | 83 | 38 | 41 | 6 | 13 |

A perfectly predictive model would be shown in Figure 7 as the line along the y-axis and following along the top of the figure (assuming that actual defaults comprise less than 10 percent of the sample). In other words, the model would correctly identify 100% of all defaulted loans in the highest decile of estimated default rates. By contrast the dashed line segment in the chart would represent a model that has no predictive value since a random sample of 10 percent of all loans would be expected to identify 10 percent of defaulted loans. Figure 7 shows that the model has good predictive value against the 2000–2003 validation sample but is significantly less predictive against the 2004–2008H1 sample, corroborating the earlier findings that the model substantially underestimates actual performance for the 2004–2008H1 sample. The higher risk profile of the 2004–2008H1 sample and the model's large error illustrates the impact that product morphing can have on limiting a firm's understanding of risk over time. It should be noted that the samples used in this analysis are likely to underestimate the magnitude of the effect of product morphing and risk layering since they were from GSE-eligible, fully documented fixed-rate 30-year mortgages. Had these samples been from non-GSE, nontraditional mortgages originated over a similar period, the errors may have even be greater than those presented.

The other area of empirical focus of this study is on lender process. As described in Figure 2, it was hypothesized that lender process can have a significant impact on the lender's overall product risk exposure. Weak processes would be associated with higher overall risk and that risk rises with the riskiness of product features. To examine this issue a sample of GSE loans originated between 2000–2010 were used to estimate two models predicting the probability of a loan ever becoming 90 days past due or worse.[20] The models were segmented by LTV in order to see whether process effects differed by this key risk attribute. As a result, Model 1 was estimated on loans with LTVs at or below 80% and Model 2 was fit on all other LTVs. After the crisis, considerable attention was given to the appraisal process showing that many lenders had not followed USPAP guidance on appraisal practices and management during the housing boom.[21] This would translate in many loans having inflated property values and thus lower LTVs than should have been the case. The sample period 2000–2010 was selected to capture the effects of process quality over a broad period of time. Similar risk factors used in estimating the previous models as shown in Table 3 along with several macroeconomic factors were used in this analysis as well.[22] In addition to these variables, an additional categorical variable was included that split the sample into two groups: lenders in the highest quartile of repurchase rates on defaulted loans and all others over the sample period. This repurchase rate variable was interacted with each origination year. Loan repurchase rates indicate some flaw was identified in the underwriting process that led to a violation in one of the GSEs' contractual underwriting requirements. As such it serves as a proxy for process quality above and beyond the other risk factors captured in the model.[23]

**FIGURE 8. RELATIVE DEFAULT PERFORMANCE OF HIGH REPURCHASE RATE LENDERS VS. ALL OTHER ORIGINATORS (2000–2010) <80% AND >= 80% LTVS**




The model coefficients including those for the repurchase rate categorical variables were statistically significant across the two samples at the 5% level. The relative effect of lenders with high repurchase rates to estimated default risk was measured as the odds ratio derived from the estimated repurchase variable coefficient.[24] In Figure 8, the first takeaway from the analysis is that the impact of process quality, captured by the repurchase variable, varies substantially over time. This could be attributed to changes in management, resources and process over time, among other factors. For example, controlling for all borrower, collateral, loan and economic factors available in the

20. This sample was selected to provide a broad assessment of lender effects over different underwriting periods.

21. Uniform Standards of Professional Practice

22. Changes in home prices, unemployment rates and interest rates were captured in this model.

23. This approach is methodologically consistent with other empirical studies of banking cost structure and lending such as a study by Berrospide and Edge. See Jose M. Berrospide and Rochelle M. Edge, The Effects of Bank Capital on Lending: What Do We Know, and What Does it Mean?, Finance and Economics Discussion Series, Divisions of Research & Statistics and Monetary Affairs, Federal Reserve Board, Washington, DC, 2010.

24. The odds ratio is computed as $\Psi = e^{B}_{i}$. An odds ratio (risk multiplier) can be interpreted in this application as the ratio of odds for a high repurchase lender's effect on default risk relative to all other lenders not among the top repurchase firms identified in the GSE sample.

GSE data, lenders with high repurchase rates originating loans in 2001 exhibit 2.75 times greater default risk than all other lenders for LTVs >80%. One possible explanation for the 2001 result is the effect of the 2001 recession. In a study of mortgage banking cost structure, for example, I found statistical evidence of cost inefficiency variation by economic and market performance.[25] The nature of the mortgage cycle from expansion to contraction could lead to differences among lenders and across origination periods. In contrast to 2001 effects, for 2000 and 2002, high repurchase rate lenders actually show better default performance than all other firms. During the period 2004–2008H1, high repurchase rate lenders with >80% LTV mortgages were riskier than all other lenders controlling for other risk factors. Similar results are generally found for LTVs below 80%. The average risk multiplier across all origination years for high repurchase rate lenders with LTVs greater than 80% is 1.38 compared to .91 for LTVs less than or equal to 80% for these same lenders. It implies that >80% LTV GSE-eligible mortgages originated by high repurchase rate lenders are 1.38 times riskier than similar LTV loans originated by other lenders, while these same lenders experienced .91 times the risk of all other lenders over the period for <80% LTV product. While factors directly attributed to specific process deficiencies leading to high repurchase rates cannot be observed, the results are consistent with multiple sources highlighting process issues of a number of firms during the mortgage boom such as appraisal and underwriting problems that resulted in significant repurchases from the GSEs.

The results in particular showing risk multipliers over 1 for the 2003–2008 origination period for LTVs greater than 80% provide empirical support to the claim that mortgage process quality and product risk are strongly related. Risk layering increased during this period and with it credit risk. Issues relating to income verification or appraisal accuracy could trigger a putback of a loan to an originator if it was found to violate the representations and warranties of the contractual terms by the lender to the GSE. Such deficiencies in the underwriting process underscore the importance of process quality and its connection to changes in credit risk profile owing to changes in product attributes and mix over time.

The implications from this analysis are instructive for mortgage product development. First, the historic data used in analyzing new and enhanced products may not be comparable with the characteristics of future products. Option ARM loans and borrower risk profiles in the World Savings portfolio in 2003 looked very little like the option ARM loans that were mass marketed later by a number of originators. Second, it is difficult to determine using historical data how changes in product characteristics will lead to changes in the type of borrowers attracted to the new product. Borrowers using option ARMs before 2003 were looking less at these loans as affordability products that could be refinanced as home prices rose, and more for the financial flexibility they offered. Over time, the product expanded into a form that was essentially unrecognizable from where it started out.

Third, the application of statistical models can provide a false sense of security, particularly if it can be shown that the models are tracking historical performance well to that point. Unfortunately, changes in borrower risk profile and behavior can lead product development to underestimate the nature of prospective risks based on existing models trained on loans that are not reflective of the target product. Fourth, basing decisions regarding product development on poor data and analysis is compounded by poor process. Lastly, the lender effects identified by repurchases suggests that above and beyond borrower, loan, property and economic factors, there remains a process variable generally associated with higher default risk. Given other corroborating documentation on process weaknesses occurring during the housing boom, the lender effect result should at least heighten sensitivity to process quality as an important consideration in product development.

25. Clifford V. Rossi, Mortgage Banking Cost Structure: Resolving an Enigma, Journal of Economics and Business, 50(2):219–234, March 1998.

# Standard Components of Product Development

Many of the considerations in product development in the mortgage industry bear some resemblance to product development efforts in other industries. Considerations across industries in new product design and development include strategic objectives associated with the product and assessment of market and competitive conditions, design and manufacturing issues of the product, quality control, supply chain and product distribution, marketing, cost estimation, pricing and profitability, business continuity and legal and regulatory considerations.

These same issues are found in mortgage products. Consequently, following a standard product development process in an integrated fashion across functional areas of the firm is critical to conducting effective product assessment. Alignment of key product development areas found in other industries to mortgage product development is contained in Table 6. Such a development process considers the entirety of the product lifecycle and is not simply focused on short-term results. Under the design and manufacturing component, product and process assessments to mortgage product development feature prominently and will determine the overall direction and scope of the product.

Product development begins and ends with strategy. As the concept for a new product or enhancement of an existing product is put forth, it must first be vetted against the lender's risk appetite statement describing the kind of risks it is willing to take. For instance, a risk appetite statement that stipulates the use of only prime consumer loan products would quickly dispatch proposals for nontraditional products that do not meet the criteria for prime lending. Further, an understanding of current and prospective market conditions under which a new product will be exposed to is critical to defining or limiting key product features. This type of analysis also extends to scenario and stress testing that should be performed to understand how a prospective product will perform. Proper governance and oversight of the product development process is required at the board and senior leadership levels to ensure transparency and discussion regarding the merits and limitations of products under consideration. And no product should ever go to market without a set of approved key performance indicators (KPIs) and associated key risk indicators (KRIs) and tolerances that provide a basis for gauging product success.[26]

Design, testing and manufacturing set up is one of the most challenging and important phases of product development regardless of industry. Certainly in sectors where a design failure can lead to some catastrophic event such as death or injury a heightened focus and even regulation of a product's design and manufacturing becomes an accepted part of the process. For instance, the average time for a new drug to reach the market from preclinical testing is 11–14 years and only 8 percent of new drugs even make it to the FDA approval process.[27] To further put the product development timeline into perspective, Boeing management first started to contemplate the need to replace its aging 747 aircraft with a more modern jet that eventually became the 787 Dreamliner back in 1999. While mortgage product development clearly does not have the health and safety issues associated with it as that seen in the pharmaceutical and aircraft industries where years of testing and evaluation are typical, it still needs to follow a methodical process to ensure its long-term viability.

26. An example of a KPI would be risk-adjusted return on capital in excess of 15%. Likewise an example KRI would be an early payment default rate (i.e., defaults within the first 12 months of origination) less than .1 percent.

27. DiMasi, Joseph A., Ronald W. Hansen, and Henry G. Grabowski. 2003. The Price of Innovation: New Estimates of Drug Development Costs. Journal of Health Economics 22: 151–85.

The design phase in mortgage product development entails working through the details of how the new mortgage loan will work. Specifically, that includes describing important product features such as payment and terms and understanding how those can affect borrower behavior and circumstances under various scenarios. Details on how loans will be underwritten and by who require considerable analysis by credit risk teams in conjunction with product developers. This is also where considerations of automated and manual underwriting processes are made.

TABLE 6: KEY MORTGAGE PRODUCT DEVELOPMENT COMPONENTS

| PRODUCT DEVELOPMENT FOCUS AREA | MORTGAGE PRODUCT EQUIVALENT |
|---|---|
| Strategy | • Consistency with risk appetite statement<br>• Culture<br>• Assessment of market & competitive landscape<br>• Product contribution to business model (e.g., diversification, cross-selling)<br>• Governance and oversight<br>• Key performance indicators and Key risk indicators |
| Design & Manufacturing | • Staffing<br>• Product features (e.g., terms, payment types, index)<br>• Policies & procedures in place<br>• Credit guidelines<br>• Target borrowers<br>• Pre-release testing<br>• Approval & exception authority<br>• Exception process<br>• Underwriting process (including manual and automated processes)<br>• Appraisal process |
| Quality Control | • Post-closing review process<br>• Fraud detection process<br>• Ongoing internal and external audit assessment<br>• MIS Management performance reporting |
| Financial Evaluation | • Operation expenses<br>• Estimated financial and nonfinancial losses<br>• Pricing & risk-adjusted returns (including fees)<br>• Secondary marketing<br>• Mortgage servicing rights<br>• Capital allocation and portfolio management<br>• Model risk |
| Supply Chain & Distribution | • Origination channel distribution<br>• Workflow<br>• Counterparty assessment<br>• Loan documentation & delivery<br>• Best execution<br>• Vendor management<br>• Pipeline management process<br>• Closing & funding<br>• Servicing process<br>• Recourse, repurchase, indemnification practices<br>• Default & collections |
| Marketing & Sales | • Disclosure documentation<br>• Sales compensation |
| Business Continuity | • Integrity of delivery systems<br>• Data capture and security<br>• Contingency planning — scenario / stress analysis |
| Legal & Regulatory | • Compliance review |

Specifically, it is here that a comprehensive assessment of the quality of the underlying processes used for underwriting, appraisal, documentation preparation, closing and other key activities to loan origination, portfolio management and servicing are conducted relative to determinations of a new product's overall risk characteristics. This is where process and product risk scorecards can strengthen the integrity of the design and development process.

In a dynamic product development process, quality control (QC) enables lenders to obtain tangible evidence on the processes applied in originating new products to determine if any weaknesses across the origination chain are leading to material issues. This is where creating a QC plan ahead of a new product's entry into the market is critical to providing updated insights into how the product is performing. Those results can help identify deficiencies of the process or product that can be addressed. Conducting a comprehensive financial evaluation of a prospective product's profitability, including costs, capital allocation and losses is a common practice in product development, however, understanding how a product's features can affect firm losses arising from operational breakdowns, regulatory, legal and reputational issues must also be factored into the financial analysis.

For many industries, understanding the product supply chain and distribution channels is key to effective product management and it is also the case for mortgages. Included in such assessments is determination of what channels are appropriate for a particular product, and evaluating the rigor of the firm's counterparty, servicing and default and collections practices ensures that weaknesses that are identified can be remedied in advance of broad product rollout.

Heightened regulatory focus on mortgage disclosures and related documentation, sales compensation practices and overall compliance review integrated into the product development process can ward off potential regulatory, legal and reputation risk issues later on. Finally, data capture, security and technology assessment are essential to the product development process.

# Product and Process Assessment Tools

In the absence of a standard process for evaluating mortgage products, a review of product development applications from other industries can shed light on opportunities that might be leveraged in the mortgage business. What is common to all of these examples is a standardized framework for assessing the prospect for success, potential risks and mitigation strategies across the entire product life cycle.

Insights from the systems engineering discipline can serve as a backdrop for strengthening the mortgage product development process. Reaching as far back as the 1940s with applications at Bell Laboratories, systems engineering describes the processes used to design and develop complex systems over a product's life and finds applications in various forms to many different industries from rocket design to consumer electronics. Systems design is often characterized as a process that is holistic and interdisciplinary in nature and scope. The essential steps in systems engineering entail the following as described by NASA in their space flight projects:[28]

- Identification and quantification of systems goals
- Evaluation of alternative designs
- Selection of best design
- Validation of the selected design
- Post-implementation assessment of design

While there are a number of frameworks that have come to be used in systems engineering applications, one that has a number of appealing features is Quality Function Deployment (QFD) and has been described as a process to transform qualitative product and user requirements into quantitative terms.[29] An example of a well-known tool applied to enterprise product development using the QFD process is the House of Quality (HOQ) matrix which captures and consolidates critical information on a product's design and process in an integrated manner. A stylized example of such a template is shown in Figure 9. The body of the template (designated as C) relates information on specific customer demands (A) for a product against a number of product design requirements (B). Applying this to a mortgage, a customer requirement might be that the product's terms and features are easily understood. A design requirement could be that product disclosure documents provide adequate clarity and explanation. Each cell in the table forming the section C represents the importance that each design process brings to that specific customer requirement. This could be represented as a qualitative or quantitative assessment depending on the analyst's preference.

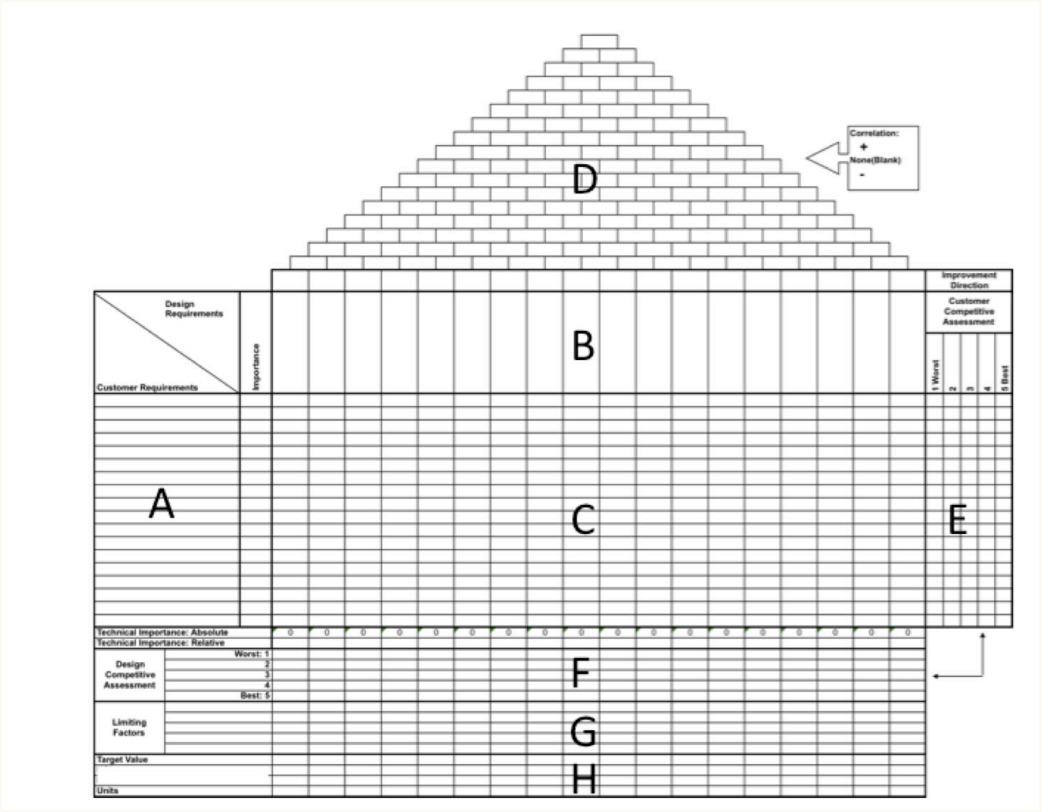
The HOQ template includes an assessment of the correlation between components of product design (section D). For example, there may be a negative correlation between a design process that permits streamlined documentation and another that ensures loan level data quality is high. This would capture the potential downstream effect that low documentation loans had on reducing data quality for conducting ongoing product performance analysis. Such correlations in the HOQ framework are typically qualitative in nature and represented symbolically in the template. For example, a + or – symbol would indicate that the product process correlation factor is positively or negatively correlated.

Other components of the HOQ include an estimate of customer importance of a requirement, an assessment of the quality of a design process and the direction of improvement of the process (e.g., improving, declining, neutral), a competitor assessment against process design elements, limiting factors and an overall assessment (sections E–H).

28. NASA Systems Engineering Handbook. *NASA*. 1995.

29. Akao, Yoji (1994). "Development History of Quality Function Deployment." The Customer Driven Approach to Quality Planning and Deployment. Minato, Tokyo: Asian Productivity Organization.

FIGURE 9. HOUSE OF QUALITY SCHEMATIC




Source: QFD Institute, QFD Online template, Traditional House of Quality, December 11, 2007

The HOQ matrix is sufficiently flexible to accommodate a variety of alternative implementations depending on the level of complexity of the product and sophistication of the user with systems engineering applications.

What systems engineering and a template such as HOQ provides to the mortgage product development process is a structured way of comprehensively relating design and process quality features in a structured and repeatable manner. One of the pitfalls of product and lending decisions during the mortgage boom were a number of decision-maker cognitive biases that led to the proliferation of product morphing and high-risk mortgage products. Focus on short-term objectives such as market share and firm share price can be held in check using a systematic approach to product management. Applying a systems engineering approach to the development process can reduce the potential for such decisions in the future.[30]

Specific to mortgage product design, product risk and process quality can be integrated into a matrix for product development assessment. Some important considerations of such a tool include linking individual product design features and processes to specific risk types. Some of these relationships can be quantified such as borrower, loan and collateral risk attributes represented in a statistical model of default. Other relationships might require a heuristic approach at rank ordering the outcomes. For example, the relationship between the loan exception process and fraud risk might be represented as a qualitative assessment of the process related to risk as low (1) to High (5). Following such an approach aligns with well with NASA's risk-informed decision-making (RIDM) process.[31] The point of such an exercise is that knowledge of all potential risks from each important product feature and process are captured and assessed during the development phase and vetted across alternative designs prior to product deployment.

One way to effectively assess mortgage product risk and process quality that provides a systematic way to consolidate key relationships consistent with good systems engineering principles is to adapt commercial loan risk rating scorecards to the mortgage product development process. Such risk rating scorecards focus on measuring

30. Mark J. Flannery, Paul Glasserman, David K.A. Mordecai, and Cliff Rossi, Forging Best Practices in Risk Management, Office of Financial Research, Working Paper #2, 2012. Also, NASA, Risk Management Handbook, 2011.

31. NASA, Risk Management Handbook, 2011.

the probability of default for a borrower and loss severity upon default. Commercial risk rating tools are suited to the heterogeneous nature of commercial loans where data may not be available to develop more quantitatively based estimates of credit risk. The essence of commercial loan ratings tools is to identify key risks for assessment such as management quality and experience, business and market conditions, and financial health of the business, among others. These factors are then assessed on some quality scale such as 1–5 and weights assigned according to their importance to default and loss severity. Some commercial risk rating scorecards develop separate scores for default risk and loss severity that are combined at the end to assign an overall risk rating for a loan.

Such an approach can be put to use to create a mortgage product development assessment matrix. The core of a mortgage product development rating system consists of two scorecards; one for evaluating potential product risk and the other designed to assess the quality of the processes used to originate, manage and service the loan through its life. The most important aspect of the rating system is consistency in the application of the scorecards, designation of weights tied to overall firm risk and an objective evaluation of process quality and product risk attributes. Ideally cross- functional teams would be assembled to develop the ratings process with final review and signoff from senior risk and business leaders. A variety of configurations of such scorecards is possible depending on the needs of the firm, and an illustrative Process Quality Scorecard (PQS) is provided in Table 7. In Table 9, an illustrative Mortgage Product Risk Scorecard is introduced and together they provide inputs to a Product Decision Matrix, shown in Table 10, which ultimately provides a powerful tool for senior management decision making. I discuss each component of the rating system below.

TABLE 7: ILLUSTRATIVE PROCESS QUALITY SCORECARD

| PRODUCT DEVELOPMENT FOCUS AREA | MORTGAGE PRODUCT EQUIVALENT | PERFORMANCE BENCHMARKS | WEIGHT | SCORE 1–5 | WEIGHT x SCORE |
|---|---|---|---|---|---|
| **Strategy 12%** | Consistency with risk appetite statement | Risk appetite statement exists and products align | 2.00 | 5 | 10 |
| | Culture | Balanced risk and reward culture | 2.00 | 5 | 10 |
| | Assessment of market & competitive landscape | Consideration of market and competitive conditions integrated into process | 1.00 | 5 | 5 |
| | Product contribution to business model (e.g., diversification, cross-selling) | Consideration of business contribution over competitive needs first | 2.00 | 5 | 10 |
| | Governance and oversight | Satisfactory oversight of products by board, senior management, risk and audit | 4.00 | 5 | 20 |
| | Key performance indicators and Key risk indicators | Effective measurement and implementation of risk-adjusted performance metrics | 1.00 | 5 | 5 |
| **Loan Production 17%** | Staffing | Staffing levels and expertise across key processes in place | 3.00 | 5 | 15 |
| | Policies & procedures in place | Comprehensive policies and procedures in place for key processes | 2.00 | 5 | 10 |
| | Credit guidelines | Credit guidelines grounded in strong underwriting principles and augmented by analysis | 3.00 | 5 | 15 |
| | Pre-release testing | Product testing systems and processes in place ahead of release | 1.00 | 5 | 5 |
| | Approval & exception authority | Clear documentation on delegations of authority and exception approval criteria | 2.00 | 5 | 10 |
| | Exception process | System in place for managing exceptions and policies greatly limit exceptions | 2.00 | 5 | 10 |
| | Underwriting process (including manual and automated processes) | Underwriting process balances the use of strong underwriting team with automation | 2.00 | 5 | 10 |
| | Appraisal process | Process fully adheres to USPAP, FHA and GSE standards | 2.00 | 5 | 10 |

Table Continued on Next Page

TABLE 7: ILLUSTRATIVE PROCESS QUALITY SCORECARD (CONT.)

| PRODUCT DEVELOPMENT FOCUS AREA | MORTGAGE PRODUCT EQUIVALENT | PERFORMANCE BENCHMARKS | WEIGHT | SCORE 1–5 | WEIGHT x SCORE |
|---|---|---|---|---|---|
| Quality Control 15% | Post-closing review process | Systems and practices are well-developed to handle volumes | 4.50 | 5 | 22.5 |
| | Fraud detection process | Strong fraud detection program and protocols in place | 3.50 | 5 | 17.5 |
| | Ongoing internal and external audit assessment | Audit program is actively engaged in ongoing product assessment | 3.50 | 5 | 17.5 |
| | MIS Management performance reporting | MIS systems and reporting activities are robust and effective | 3.50 | 5 | 17.5 |
| Financial Evaluation 11% | Operating expenses | Product costs are well understood and factored into ongoing financial analysis | 1.00 | 5 | 5 |
| | Estimated financial and nonfinancial losses | Credit loss estimates are built on strong analytic foundation | 1.00 | 5 | 5 |
| | Pricing & risk-adjusted returns (including fees) | Pricing methodology is robust and incorporates risk-adjusted framework | 1.00 | 5 | 5 |
| | Secondary marketing | Best execution and related processes well developed | 2.00 | 5 | 10 |
| | Mortgage servicing rights | MSR valuation and hedging practices are robust and well-controlled | 2.00 | 5 | 10 |
| | Capital allocation and portfolio management | Portfolio and capital management activities are well-evolved for the risk | 2.00 | 5 | 10 |
| | Model risk | Model governance, validation and oversight is effective | 2.00 | 5 | 10 |
| Supply Chain & Distribution 13% | Origination channel distribution | Wholesale and correspondent lending channels are effectively monitored | 1.50 | 5 | 7.5 |
| | Workflow | Loan production and servicing workflows are well-developed and effective | 2.00 | 5 | 10 |
| | Counterparty assessment | Counterparty assessment process is well-established and rigorous | 1.50 | 5 | 7.5 |
| | Loan documentation & delivery | Documentation and delivery process effective and well-controlled | 2.00 | 5 | 10 |
| | Vendor management | Vendor management process in place and vigorous | 1.00 | 5 | 5 |
| | Pipeline management process | Loan commitment and hedging processes effective and supported by strong controls | 1.00 | 5 | 5 |
| | Closing & funding | Disbursements, documentation and communication processes in place and effective | 1.00 | 5 | 5 |
| | Servicing process | Payments processing and borrower contact processes well-controlled | 1.00 | 5 | 5 |
| | Recourse, repurchase, indemnification practices | Contracts well understood and management of the process is effective | 1.00 | 5 | 5 |
| | Default & collections | Loss mitigation and related default management processes effective with appropriate staffing | 1.00 | 5 | 5 |

Table Continued on Next Page

TABLE 7: ILLUSTRATIVE PROCESS QUALITY SCORECARD (CONT.)

| PRODUCT DEVELOPMENT FOCUS AREA | MORTGAGE PRODUCT EQUIVALENT | PERFORMANCE BENCHMARKS | WEIGHT | SCORE 1–5 | WEIGHT x SCORE |
|---|---|---|---|---|---|
| **Marketing & Sales 12%** | Disclosure documentation | Borrower disclosures conform to regulatory standards | 6.00 | 5 | 30 |
| | Sales compensation | Sales personnel have a balanced risk-return scorecard with long-term focus | 6.00 | 5 | 30 |
| **Business Continuity 11%** | Integrity of delivery systems | Loan delivery systems are well-developed and effective | 3.00 | 5 | 15 |
| | Data capture and security | Loan data quality is good and systems for data capture and retention are robust | 5.00 | 5 | 25 |
| | Contingency planning – scenario/stress analysis | Contingency planning an active part of key mortgage processes | 3.00 | 5 | 15 |
| **Legal & Regulatory 9%** | Compliance review | Effective compliance process actively engaged throughout the mortgage lifecycle | 9.00 | 5 | 45 |
| **TOTAL** | | | 100.0 | | 500 |

In Table 7, the PQS is broken down into several categories representing collections of key processes used at various points in the loan lifecycle and which describe functional processes or business activities. The representation of processes depicted in Table 7 adopts a functional style as shown in the first column. The second column provides a description of the process to be rated. The level of detail on cataloging process can vary but the key issue is to ensure that the PQS reflects all processes deemed significant to the product in question. The third column provides a quality benchmark to guide the rating process. The next column features weights assigned to each process (major focus area). The summary focus area weights in the first column (for example, Strategy has a weight of 12% in the

TABLE 8: PROCESS RISK WEIGHTING MATRIX

| MORTGAGE PROCESS SCORECARD | RISK POTENTIAL EXPOSURE BY PROCESS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PRODUCT DEVELOPMENT FOCUS AREA | CREDIT | OPERATIONAL | REGULATORY | REPUTATION | STRATEGIC/ BUSINESS | LEGAL | POTENTIAL EXPOSURE x RISK CONTRIBUTION | WEIGHT |
| Strategy | 30 | 15 | 15 | 15 | 15 | 10 | 22 | 0.12 |
| Loan Production | 50 | 10 | 10 | 10 | 10 | 10 | 30 | 0.16 |
| Quality Control | 40 | 20 | 15 | 10 | 5 | 10 | 27 | 0.15 |
| Financial Evaluation | 30 | 10 | 10 | 5 | 40 | 5 | 21 | 0.11 |
| Supply Chain & Distribution | 30 | 35 | 10 | 15 | 5 | 5 | 23 | 0.13 |
| Marketing & Sales | 30 | 15 | 15 | 15 | 10 | 15 | 22 | 0.12 |
| Business Continuity | 25 | 30 | 25 | 15 | 15 | 5 | 22 | 0.12 |
| Legal & Regulatory | 15 | 10 | 25 | 15 | 10 | 25 | 17 | 0.09 |
| **SUM** | | | | | | | 183 | 1.00 |
| Risk Contribution | 0.5 | 0.15 | 0.10 | 0.05 | 0.05 | 0.15 | | |

PQS) reflect the sum of the weights of each process from the fourth column associated with the particular focus area. The weights for each focus area reflect the impact of a focus area's potential risk exposure and risk contribution as determined by the assessment team, an example of which is shown in Table 8.

Table 8 provides an example of a process risk-weighting matrix. The first step in the determination of risk weightings is for the firm to identify all potential risk types from a product's release as shown in column 2–6 headings in Table 8 and then to allocate the potential firm losses that could be realized under adverse conditions to each risk, shown in the bottom row as "risk contribution." For example, under a severe economic scenario in this example 50 percent of all firm losses are expected to be associated with credit risk, while only 5 percent are expected to be attributable to reputation risk. While some quantification of these different risks' contribution to total risk may be possible and would be ideal, a subjective assessment based on expert judgment is sufficient.

The risk of each product development focus area is calculated as a weighted combination of different types of risk, again most likely using expert assessment in setting the shares. For example, risk associated with the Loan Product process is mainly comprised of credit risk (50%) with the remainder equally distributed (10% each) across the other risk types.[32] The product of each focus area's potential risk exposure weight and the risk contribution from the bottom row creates a metric of the focus area's contribution of risk to the firm and its relative share provides the area's overall weight to be used in the PQS in Table 7. The individual weights for each process within each area in Table 7 must add up to the focus area weight. The variation in weights shown in Table 7 within each process results from an assessment provided by the evaluation team responsible and knowledgeable for these processes.[33] Each process is rated by the team on a 1–5 scale with a 5 assigned for processes that exceed performance benchmark descriptions and 1 describing processes that are especially weak or nonexistent. An overall PQS score is defined as the sum of the product of

32. Other risks such as liquidity, market and interest rate risk could be built into such a template in similar fashion.

33. To ensure the integrity of the evaluation process, input on the process may be provided from team members that manage that process but final ratings are provided from other team members that are not associated with the process.

**TABLE 9: MORTGAGE PRODUCT RISK SCORECARD**

| PRODUCT RISK CATEGORY | ASSESSMENT FACTOR | DESCRIPTION | WEIGHT | SCORE 1-5 |
|---|---|---|---|---|
| **Product Features 30%** | Complexity | High, Medium, Low | 5 | 5 |
| | Nonstandard features | | | |
| | - Payment type variability | Y/N | 5 | 5 |
| | - Collateral Valuation Process | Full Appraisal / Streamline Review | 5 | 5 |
| | - Documentation Type | Full / Low | 10 | 5 |
| | - Amortization Type | 15, 20, 30, 40 | 5 | 5 |
| **Risk Layering 17%** | <640 FICO | Indicator 0 or 1 | 5 | 5 |
| | >95% LTV | Indicator 0 or 1 | 10 | 5 |
| | Low Documentation | Indicator 0 or 1 | 5 | 5 |
| | DTI >40% | Indicator 0 or 1 | 5 | 5 |
| | Investor-owned | Indicator 0 or 1 | 5 | 5 |
| | Cashout Refinance | Indicator 0 or 1 | 5 | 5 |
| | 2–4 Unit | Indicator 0 or 1 | 5 | 5 |
| | IO, Negam, or Balloon | Indicator 0 or 1 | 5 | 5 |
| **Target Market 25%** | Investor Focus | High/Average/Low | 5 | 5 |
| | Geographic Concentration | High, Medium, Low | 10 | 5 |
| | Breadth of Offering | Narrow, Moderate, Broad | 10 | 5 |
| **TOTAL** | | | 100 | 500 |

KEY: Score of 1 indicates least risky outcome, 5 indicates riskiest

each process's weight by its score. In this configuration of the PQS, the score range is 100–500.

Turning to the Mortgage Product Risk (MPR) Scorecard, it is comprised of three areas of focus; product features, risk layering and target market considerations. Recall that product risk in this scorecard is not focusing on credit risk but on the intrinsic risk that a product's features impose on the firm across all risk types. An example of such a scorecard is shown in Table 9.

The assessment criteria under product features reflect factors whose presence would tend to increase a product's overall risk to the firm. Determining the complexity of the product and the collection of nonstandard features as described in the scorecard provides a visible means of acknowledging the inherent risk to the firm from that dimension of product risk. Risk layering is another key category represented by the presence of one or more of the risk factors identified in this section. The greater the number of factors present in a product, the greater is the amount of risk layering and so the greater the potential risk to the firm. The third category for assessment is target market. The factors to be assessed in this section include the emphasis on investor-owned properties, geographic concentration and the breadth of the product's distribution to the market. As with the PQS a description for each factor is provided and scorecard team members would determine weights. Ratings are based on a 1–5 scale, with 1 indicating low risk. The product of weight and rating summed over all categories provides an overall product score and in this example a maximum score would be 500 points.

Table 10 provides a product policy matrix of decisions regarding new product implementation based on the combination of results from the PQS and MPR scorecards. The scorecards together provide a powerful tool for managing the deployment of new products or enhancements to existing products based on consistent application of the assessment process and pre-established thresholds of performance set by senior management determining a product decision. The example in Table 10 establishes 3 categories of product risk and process quality, creating the 3 x 3 set of product outcomes. The basic idea of the product policy matrix is that processes must be at certain thresholds for products to be released to the market and that product risk is also a determining factor for such outcomes. Where process quality is high (in this example designated by overall PQS scores above 400), any product would be approved for deployment conditional on having met its business objectives. Conversely, high-risk products (i.e., >400 points) would not be approved if the PQS score was less than 400. In some instances, a limited product roll out could be permitted (yellow shaded cells) rather than a full release conditional on demonstrated process improvement. Not only can the product decision matrix stipulate product decisions but also it can isolate specific product risks and process weaknesses that could be addressed. For instance, if a business unit were able to satisfactorily upgrade a core process that resulted in the PQS score going from 390 to 405, it could widen the product's release to the market. This tool then creates an effective incentive mechanism for management to focus on strengthening its core processes.

TABLE 10: PRODUCT DECISION MATRIX

| | | PROCESS RISK SCORE | | |
|---|---|---|---|---|
| | | <300 | 300–400 | >400 |
| PRODUCT RISK | <300 | Implement | Implement | Implement |
| | 300–400 | Proceed with Caution | Proceed with Caution | Implement |
| | >400 | Product Decline | Product Decline | Implement |

# Conclusion

Without a structured approach, mortgage product development can become overly influenced by short-term factors such as competitive pressures to match products to maintain market share, preferred sales arrangements or other strategies as markets expand. The financial crisis underscored the effects that poor product development had on the industry that eventually put many firms out of business.

As products evolve and features change, analytics used to assess loan performance during product development become less accurate and the data used to model these outcomes less reliable as well. Moreover, product development must include an assessment of how important product features can lead to a range of risks that may ultimately result in higher losses to the firm.

As important to understanding a product's effects on overall risk is the quality of the processes used to originate, manage and service a mortgage throughout its life. The linkage between product risk and process quality was established in a conceptual framework and serves as the foundation for an integrated mortgage product rating system. Many industries have drawn on systems engineering frameworks to make better-informed decisions regarding product design and development. Adhering to principles found in such approaches as the House of Quality or in commercial credit risk ratings, a risk rating system was devised to assess a product's inherent contribution to a firm's overall risk as well as an assessment of the processes used to manufacture and manage mortgage loans. By adopting such a scoring system, a firm would have the ability to consistently assess a product's viability by a set of pre-established rules and metrics that mitigates the potential for biased decision making to influence product outcomes.

# Technical Appendix*

A complementary log-log (CLL) model was used to estimate the 90DPD+ survival model. Specifically, the CLL model used in this analysis is a discrete form of the Cox proportional hazard model with piece-wise constant baselines. This can be demonstrated mathematically by the following:

The survivor function is represented as the following integrated hazard function:

$$S(t) = \exp\left(-\int_0^t \lambda(s)\,ds\right).$$

Breaking the integral as follows:

$$S(t) = \exp\left(-\int_0^{t-1} \lambda(s)\,ds - \int_{t-1}^{t} \lambda(s)\,ds\right)$$
$$= \exp\left(-\int_0^{t-1} \lambda(s)\,ds\right) \exp\left(-\int_{t-1}^{t} \lambda(s)\,ds\right),$$

allows one to re-write the survivor function as

$$S(t) = S(t-1) \exp\left(-\int_{t-1}^{t} \lambda(s)\,ds\right).$$

In discrete time we would write $S(t) = S(t-1)(1-d_t)$, where $d_t$ is a discrete hazard (e.g. conditional default rate), and

$$1 - d_t = \exp\left(-\int_{t-1}^{t} \lambda(s)\,ds\right).$$

In the Cox proportional hazard model the hazard is further decomposed into a baseline and scaling factor depending on covariates:

$$\lambda(t) = \lambda_0(t) \exp(x\beta),$$

where $\lambda_0(t)$ is a baseline hazard common to all subjects and $x\beta$ a product of covariates and a parameter vector that is particular to each subject. If we further assume that the baseline hazard rate within any interval of time (t − 1, t) is constant, then,

$$\lambda_0(\tau) = \exp(\alpha_t), \quad t-1 \leq \tau < t$$

We further assume the covariate vector, if time varying, is constant over unit intervals of time. Then we can calculate the integrated hazard over a unit interval as

$$\int_{t-1}^{t} \lambda(s)\,ds = \int_{t-1}^{t} \exp(\alpha_t) \exp(x\beta)\,ds = \exp(\alpha_t) \exp(x\beta).$$

This implies our discrete hazard is

$$1 - d_t = \exp(-\exp(\alpha_t) \exp(x\beta)). \quad (1)$$

A couple of things to note about equation (1): first, we can transform this equation as

$$\ln(-\ln(1-d_t)) = \alpha_t + x\beta$$

which is the complimentary log-log (CLL) model. This shows the CLL model is just Cox proportional hazards with piece-wise constant baselines. Second, noting that $(1-d_t) = S(t)/S(t-1)$, we have

$$\exp(-\exp(\alpha_t) \exp(x\beta)) = \frac{S(t)}{S(t-1)}$$

or

$$\exp(\alpha_t) = -\ln\left(\frac{S(t)}{S(t-1)}\right) \exp(-x\beta)$$
$$= -\ln\left(\left[\frac{S_0(t)}{S_0(t-1)}\right]^{\exp(x\beta)}\right) \exp(-x\beta).$$

Using the fact that $a \cdot ln(z) = \ln(z^a)$, we can rewrite above as

$$\exp(\alpha_t) = -\ln\left\{\left(\left[\frac{S(t)}{S(t-1)}\right]^{\exp(x\beta)}\right)^{\exp(-x\beta)}\right\}$$
$$= -\ln\left(\frac{S_0(t)}{S_0(t-1)}\right). \quad (2)$$

This last expression shows the constant baseline hazard is just minus the log of the ratio of baseline survival functions. This means that given an estimate of the curve $S_0(t)$ (e.g., from the baseline statement in Cox Proportional Hazards

* The author thanks Alan Neale for his input on describing the technical aspects of the survival model framework.

model) we can estimate the constant baseline hazard as in (2) and further estimate the discrete hazard as in (1) which simplifies to $1 - d_t = \left[\frac{S_0(t)}{S_0(t-1)}\right]^{\exp(x\beta)}$.

Applying the CLL framework for the analysis of 90DPD+ performance between 2000–2003 and 2004–2008H1 in this paper resulted in the output shown in Table A1. The individual coefficients of this model would be used together to generate the hazard rates in each period $t$ that in turn would be used to compute conditional quarterly estimates of default and prepayment. Conditional quarterly estimates of default were generated using actual prepayment rates. Using actual prepayment rates rather than estimates generated from a prepayment CLL-based model avoids subjecting the analysis of default rates to errors resulting from the prepayment model. In practice modeled prepayments could amplify default errors in a competing risk framework where conditional default rates are computed.

For the model controlling for lenders with high repurchase rates using the 2000–2010 GSE loan sample, a logistic regression was used with a default event defined as ever-90DPD+. Since the focus of this analysis was on determining the effect of lender repurchase rates on default rather than on the accuracy of the default model over time, a survival model was not required. The results from the final estimation of this model are shown in Table A2. The CAP results are shown in Figure A1. The accuracy ratio AR shown in Figure A1 lies between 0 and 1 where a perfectly predictive model would have an AR equal to 1. The Kolmogorov-Smirnov (KS) test associated with this model was .49.[34]

34. KS is a nonparametric test of the degree of separation between two distributions, such as a group of 90DPD+ loans versus a group of nondelinquent loans. It is often used in assessing the strength of a binary choice model such as the logistic form. KS measures the maximum distance between two distributions. It has a range of 0–100 where 100 would indicate perfect separation between the distributions and implying that the model is able to effectively distinguish between these two groups. A KS above 30 has been a general industry guideline for binary choice models of mortgage default.

**TABLE A1. CLL SURVIVAL 90DPD+ MODEL 90DPD+ PARAMETERS**

| Parameter | | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| loan_age_qtr | 1 | -17.6571 | 105.6 | 0.028 | 0.8672 |
| loan_age_qtr | 2 | -8.3575 | 1.1263 | 55.0635 | <.0001 |
| loan_age_qtr | 3 | -8.3339 | 1.1268 | 54.7033 | <.0001 |
| loan_age_qtr | 4 | -5.1442 | 0.5606 | 84.2154 | <.0001 |
| loan_age_qtr | 5 | -3.2669 | 0.5282 | 38.2483 | <.0001 |
| loan_age_qtr | 6 | -3.0308 | 0.5284 | 32.8927 | <.0001 |
| loan_age_qtr | 7 | -2.9611 | 0.5296 | 31.26 | <.0001 |
| loan_age_qtr | 8 | -2.6984 | 0.5298 | 25.9412 | <.0001 |
| loan_age_qtr | 9 | -2.6212 | 0.5308 | 24.3877 | <.0001 |
| loan_age_qtr | 10 | -2.4587 | 0.5312 | 21.4197 | <.0001 |
| loan_age_qtr | 11 | -2.4989 | 0.5331 | 21.9762 | <.0001 |
| loan_age_qtr | 12 | -2.3949 | 0.5335 | 20.1525 | <.0001 |
| loan_age_qtr | 13 | -2.4135 | 0.535 | 20.3481 | <.0001 |
| loan_age_qtr | 14 | -2.5352 | 0.5376 | 22.2398 | <.0001 |
| loan_age_qtr | 15 | -2.4193 | 0.5376 | 20.248 | <.0001 |
| loan_age_qtr | 16 | -2.3182 | 0.5377 | 18.585 | <.0001 |
| loan_age_qtr | 17 | -2.2374 | 0.537 | 17.3572 | <.0001 |
| loan_age_qtr | 18 | -2.3528 | 0.5386 | 19.0826 | <.0001 |
| loan_age_qtr | 19 | -2.0839 | 0.536 | 15.1151 | 0.0001 |
| loan_age_qtr | 20 | -2.0638 | 0.536 | 14.8235 | 0.0001 |
| loan_age_qtr | 21 | -2.1758 | 0.5368 | 16.4322 | <.0001 |
| loan_age_qtr | 22 | -2.1145 | 0.5366 | 15.5293 | <.0001 |
| loan_age_qtr | 23 | -2.0201 | 0.5376 | 14.1208 | 0.0002 |
| loan_age_qtr | 24 | -2.1622 | 0.5405 | 16.0053 | <.0001 |
| loan_age_qtr | 25 | -2.2807 | 0.5428 | 17.6528 | <.0001 |
| loan_age_qtr | 26 | -2.2189 | 0.5436 | 16.6629 | <.0001 |
| loan_age_qtr | 27 | -2.3792 | 0.5456 | 19.0157 | <.0001 |
| loan_age_qtr | 28 | -2.16 | 0.5438 | 15.7793 | <.0001 |
| loan_age_qtr | 29 | -2.4706 | 0.5457 | 20.499 | <.0001 |
| loan_age_qtr | 30 | -2.4847 | 0.5458 | 20.7237 | <.0001 |
| loan_age_qtr | 31 | -2.6139 | 0.5473 | 22.8061 | <.0001 |
| loan_age_qtr | 32 | -2.4868 | 0.5456 | 20.7764 | <.0001 |
| loan_age_qtr | 33 | -2.4296 | 0.544 | 19.9445 | <.0001 |
| loan_age_qtr | 34 | -2.9617 | 0.5495 | 29.0545 | <.0001 |
| loan_age_qtr | 35 | -2.8513 | 0.5482 | 27.05 | <.0001 |
| loan_age_qtr | 36 | -3.0918 | 0.5519 | 31.3815 | <.0001 |
| loan_age_qtr | 37 | -2.9809 | 0.5498 | 29.3967 | <.0001 |
| loan_age_qtr | 38 | -2.6984 | 0.5468 | 24.3491 | <.0001 |
| loan_age_qtr | 39 | -2.9891 | 0.5525 | 29.2658 | <.0001 |
| loan_age_qtr | 40 | -2.9874 | 0.5545 | 29.0216 | <.0001 |
| FICO | | -0.00546 | 0.00075 | 53.0328 | <.0001 |
| FICO Spline 640 | | -0.00885 | 0.000971 | 83.0423 | <.0001 |
| DTI | | 0.00904 | 0.00139 | 42.292 | <.0001 |
| LTV | | 0.0257 | 0.00204 | 158.4323 | <.0001 |
| LTV Spline 80 | | 0.00925 | 0.00427 | 4.6893 | 0.0304 |
| Interest Spread | | -0.3959 | 0.0211 | 351.9058 | <.0001 |
| Change Unemplyment Rate (lagged 1 quarter) | | 0.0378 | 0.012 | 9.9231 | 0.0016 |
| Change in HPI | | -1.4824 | 0.1133 | 171.2919 | <.0001 |
| Property Type | | 0.1977 | 0.048 | 16.9535 | <.0001 |
| Correspondent Channel | | 0.0979 | 0.0484 | 4.0955 | 0.043 |
| Other Channel | | 0.2675 | 0.053 | 25.5074 | <.0001 |
| Broker Channel | | 0.3279 | 0.0503 | 42.5259 | <.0001 |
| Purchase Loan | | -0.1751 | 0.0435 | 16.1943 | <.0001 |
| Cashout Refi | | 0.1483 | 0.0423 | 12.2827 | 0.0005 |
| Spring | | -0.205 | 0.0432 | 22.4926 | <.0001 |
| Fall | | 0.1396 | 0.0384 | 13.2369 | 0.0003 |
| Number of Borrowers | | -0.5067 | 0.0336 | 227.9291 | <.0001 |
| Modification Flag | | 4.3859 | 0.1508 | 845.3578 | <.0001 |
| Occupancy Status | | -0.1352 | 0.0503 | 7.2194 | 0.0072 |

**FIGURE A1. CUMULATIVE ACCURACY PROFILE, LENDER REPURCHASE RATE ANALYSIS**

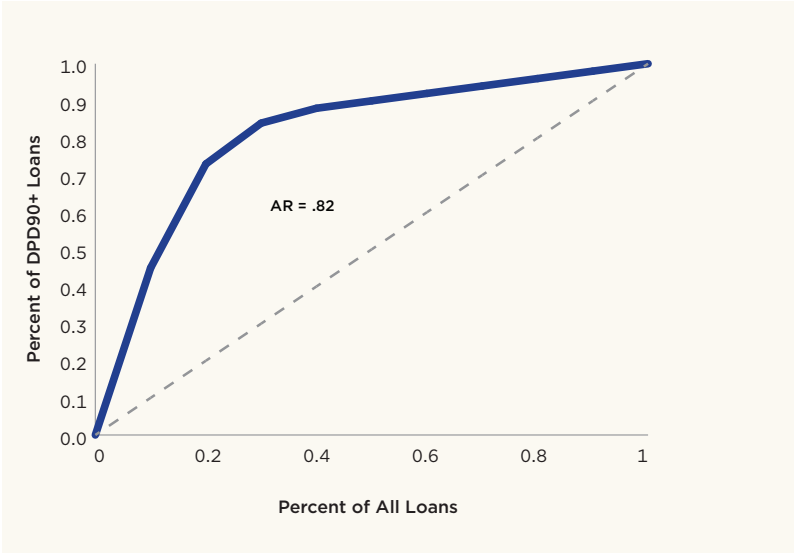


TABLE A2: LENDER REPURCHASE RATE LOGISTIC MODEL PARAMETERS

| | >80% LTV | | <=80% LTV | |
|---|---|---|---|---|
| PARAMETER | ESTIMATE | PR > CHI SQ | ESTIMATE | PR > CHI SQ |
| Intercept | 10.961 | <.0001 | 8.843 | <.0001 |
| LTV | 0.035 | <.0001 | 0.028 | <.0001 |
| FICO | -0.026 | <.0001 | -0.023 | <.0001 |
| FICO Spline 660 | 0.007 | 0.0383 | 0.006 | 0.0428 |
| DTI | 0.029 | <.0001 | 0.024 | 0.0062 |
| DTI Spline 40 | 0.038 | <.0001 | 0.028 | 0.0072 |
| UPB | -1.070 | <.0001 | -0.992 | <.0001 |
| UPB Spline >Median MSA UPB | 1.180 | <.0001 | 1.030 | <.0001 |
| Number of Units | 0.274 | 0.0052 | 0.225 | <.0001 |
| Cashout Refinance | 0.495 | <.0001 | 0.416 | <.0001 |
| Purchase Loan | -0.494 | <.0001 | -0.439 | <.0001 |
| Second Home | -0.348 | 0.0478 | -0.321 | 0.0106 |
| Investor-owned | -0.240 | 0.0406 | -0.195 | 0.0383 |
| Number of Borrowers | -0.100 | 0.0051 | -0.087 | 0.0049 |
| High Repurchase/2000 | -0.713 | <.0001 | -1.050 | <.0001 |
| High Repurchase/2001 | 1.012 | <.0001 | -0.511 | <.0001 |
| High Repurchase/2002 | -0.248 | <.0001 | -0.799 | <.0001 |
| High Repurchase/2003 | 0.811 | <.0072 | 0.560 | <.0001 |
| High Repurchase/2004 | 0.405 | <.0001 | 0.336 | <.0001 |
| High Repurchase/2005 | 0.336 | <.0001 | 0.140 | <.0001 |
| High Repurchase/2006 | 0.560 | <.0025 | 0.300 | <.0001 |
| High Repurchase/2007 | 0.372 | <.0001 | 0.223 | <.0001 |
| High Repurchase/2008 | 0.476 | <.0001 | 0.010 | 0.0063 |
| High Repurchase/2009 | -0.288 | <.0001 | -0.673 | 0.0041 |
| High Repurchase/2010 | -0.163 | <.0001 | -0.916 | 0.0082 |

# References


Akao, Yoji (1994). "Development History of Quality Function Deployment." The Customer Driven Approach to Quality Planning and Deployment. Minato, Tokyo: Asian Productivity Organization.

Bender, Michael C. and Damian Paletta, Donald Trump Plans to Undo Dodd-Frank Law, Fiduciary Rule, Wall Street Journal, February 3, 2017.

Berrospide, Jose M. and Rochelle M. Edge, The Effects of Bank Capital on Lending: What Do We Know, and What Does it Mean?, Finance and Economics Discussion Series, Divisions of Research & Statistics and Monetary Affairs, Federal Reserve Board, Washington, DC, 2010.

Board of Governors of the Federal Reserve Systems, Minutes of the Federal Open Market Committee, December 13–14, 2016.

Board of Governors of the Federal Reserve System, October 2016 Senior Loan Officer Opinion Survey on Bank Lending Practices, p. 10.

Brena Swanson, "OCC terminates JPMorgan and EverBank mortgage servicing consent orders," HousingWire, January 5, 2016.

Bureau of Consumer Financial Protection, Ability-to-Repay and Qualified Mortgage Standards under the Truth in Lending Act, 12 CFR Part 1026, January 10, 2014.

Consumer Financial Protection Bureau, Semi-annual report of the Consumer Financial Protection Bureau, 2016.

Curran, Teresa "Considerations When Introducing A New Product or Service at a Community Bank," Community Banking Connections, 1st Quarter 2013.

Deng, Yongheng, John M. Quigley and Robert Van Order, Mortgage Termination, Heterogeneity and the Exercise of Mortgage Options, Working Paper No. W99-002, Program on Housing and Urban Policy, University of California, Berkeley, 1999.

DiMasi, Joseph A., Ronald W. Hansen, and Henry G. Grabowski. 2003. The Price of Innovation: New Estimates of Drug Development Costs. Journal of Health Economics 22: 151–85.

Dunsky, Robert M., Xiaoming Zhou, Michael Kane, Ming Chow, Charles Hu, Andrew Varrieur, FHFA Mortgage Analytics Platform, Federal Housing Finance Agency, July 10, 2014.

Flannery, Mark J., Paul Glasserman, David K.A. Mordecai, and Cliff Rossi, Forging Best Practices in Risk Management, Office of Financial Research, Working Paper #2, 2012. NASA, Risk Management Handbook, 2011.

Golden West 10-K report, 2005, p. 55.

Grind, Kirsten, The Lost Bank, Simon & Schuster, 2012.

Joint Center for Housing Studies at Harvard University, The State of the Nation's Housing 2016, pp.13–17.

NASA Systems Engineering Handbook. NASA. 1995.

Office of the Comptroller of the Currency, Comptroller's Handbook, Mortgage Banking, 2014.

Office of the Comptroller of the Currency, A Common Sense Approach to Community Banking, 2013.

Pyburn, Allison, Wachovia embraces Golden West's option arms, Asset Securitization report, May 15, 2006.

Robertson, Douglas, So That's Operational Risk! (How operational risk in mortgage backed securities almost destroyed the world's financial markets and what we can do about it), Office of the Comptroller of the Currency, OCC Economics Working Paper 2011-1, March 2011.

Rossi, Clifford V., Mortgage Banking Cost Structure: Resolving an Enigma, Journal of Economics and Business, 50(2):219–234, March 1998.

Serlo, Mark, Janis Frenchak, and Jason Lew, "Managing Risk Throughout the Product Life Cycle," Consumer Compliance Outlook, 2nd Quarter 2015.

US Department of the Treasury and FDIC, Offices of Inspector General, Evaluation of Federal Regulatory Oversight of Washington Mutual Bank Report No. EVAL-10-002 April 2010.

The Financial Crisis Inquiry Commission Report, The Final Report of the National Commission on the Causes of the Financial and Economic Crisis in the United States, pp. 83–102., January 2011.

U.S. Senate Permanent Subcommittee on Investigations, Wall Street and the Financial Crisis: The Role of High Risk Home Loans, Hearing, April 13, 2010.

Yoon, Al, Total Global Losses From Financial Crisis: $15 Trillion, Wall Street Journal, October 1, 2012.

MBa®

MORTGAGE BANKERS ASSOCIATION

1919 M STREET NW, 5th FLOOR
WASHINGTON, DC 20036