The following is a review of the Credit Risk Measurement and Management principles designed to address the learning objectives set forth by GARP®. This topic is also covered in:

An Introduction to Securitization

Topic 36

Exam Focus

Securitization is the process of selling cash-flow producing assets to a third party special purpose entity (SPE), which in turn issues securities backed by the pooled assets. Mortgage-backed securities (MBSs) securitize residential mortgages where the property serves as the collateral. For the exam, be prepared to discuss the securitization process of selling cash-flow producing assets to a special purpose vehicle (SPV) and contrast the differences between amortizing, revolving, and master trust structures. Also, be familiar with the different types of credit enhancements, and be prepared to define and calculate the various performance tools for securitized structures discussed.

Securitization Process

LO 36.1: Define securitization, describe the securitization process and explain the role of participants in the process.

Securitization is the process of transforming the illiquid assets of a financial institution or corporation into a package of asset-backed securities (ABSs) or mortgage-backed securities (MBSs). A third party uses careful packaging, credit enhancements, liquidity enhancements, and structuring to issue securities backed by the pooled cash flows (i.e., principal and interest) of the same underlying assets. Cash is transferred to the selling party, and the obligation is effectively removed from the seller's balance sheet if the sale is made without recourse. Hence, securitization represents an off-balance-sheet transaction.

A wide range of assets can be securitized (e.g., mortgages, credit card receivables, auto loans, etc.). The common feature of all ABS and MBS is that the underlying assets generate cash flows. It is important to note that the third party in the securitization process is not involved in the origination of the assets underlying the securitized product.

The two key participants in the securitization process are the originator and the issuer. The **originator** is the entity that seeks to convert its credit-sensitive assets into cash. The credit risk is then transferred away from the originator. The **issuer** is a third party who stands between the originator and the eventual investor that purchases the securities. The issuer buys the assets from the originator. The issuer must be a distinct legal entity from the originator in order for the sale of the assets to be considered a *true sale*. In a true sale, the assets are transferred off the originator's balance sheet and there is no recourse. A **special purpose vehicle** (SPV) [also sometimes referred to as a special purpose entity (SPE)] is a separate legal trust or company that is set up specifically for the purpose of securitization.

The SPV separates the underlying asset pool supporting the securitized issues from the other assets of the originator. This is an important step in the process because it ensures that the securitized assets are not affected if the originator becomes insolvent. This process of securitization provides *credit enhancement* to the newly issued securities as the third party SPV guarantees the credit quality of the issues. Thus, the investors purchasing the securitized issues are not concerned about the financial strength or creditworthiness of the originator. Investors are only concerned about the credit quality of the securitized issues and the SPV guaranteeing them. Thus, in the event that the originating financial institution becomes financially insolvent, it would not impact the SPV (except for any consideration on the first-loss piece which will be discussed later).

As stated previously, the SPV may be designated as a corporation or a trust. For tax purposes, SPVs are often incorporated in offshore locations such as the Cayman Islands, Dublin, or the Netherlands, which are regions that have SPV-friendly legislation. If the SPV is set up as a *corporation*, the originator sells the assets to the SPV in exchange for cash. The SPV, in turn, issues claims directly against the assets of the SPV. In European countries, accounting regulations allow SPVs to be structured as corporations. However, this method may not distance the originator from the assets enough for accounting purposes in the United States. Therefore, in the United States, the SPV *trust* is the most common structure.

The most common application for an SPV is to set up cash flow securitization where the originator sells the assets to the SPV who funds the purchase of the assets by issuing notes to investors. However, SPVs are also used to convert the currency of underlying assets through currency swaps, issue credit-linked notes (CLNs), and transfer illiquid assets into liquid assets (e.g., accounts receivables from equipment leases).

The **structuring agent** is the *de facto* advisor for the securitization issue. This agent is largely responsible for the security design (e.g., maturity, desired credit rating, credit enhancement, etc.) and forecasting the interest and principal cash flows. The structuring agent may also be the **sponsor** as the two roles have natural overlap.

In the event of a default, a **trustee** is charged with the fiduciary responsibility to safeguard the interests of the investors who purchase the securitized products. The trustee will monitor the assets based on pre-specified conditions of the asset pool such as minimum credit quality and delinquency ratios.

An insurance company referred to as the **financial guarantor** is sometimes used to wrap the deal by providing a guarantee of financial support in the event the SPV defaults. Financial guarantors are more common in a master trust arrangement, which we will cover later in this topic.

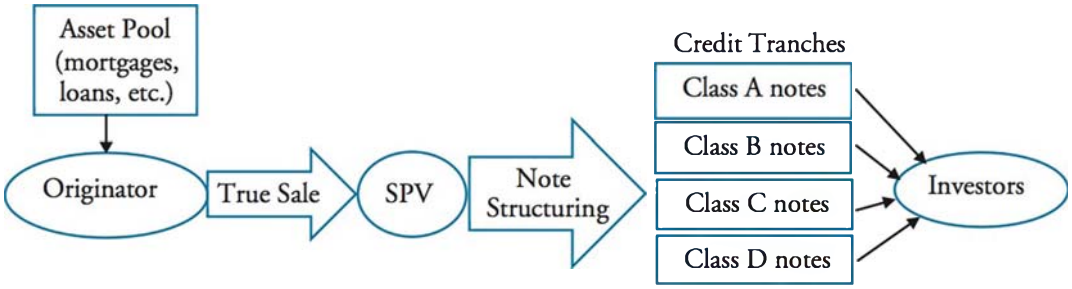
The **custodian** was initially responsible for safeguarding the physical securities. This role has evolved to also include the collection and distribution of the cash flows of assets like equities and bonds.

Credit rating agencies such as Moody's, Standard & Poor's, or Fitch also play an important role in the securitization process. The rating agencies provide formal credit ratings for each securitization. The rating agencies quantify the corporate credit quality of the originator. In addition, they provide analysis on competitors, the industry, regulatory issues, the legal

structure of the SPV, and cash flows. If the credit rating is too low, the securitization deal may be restructured by the structuring agent to offer additional credit enhancements.

Figure 1 illustrates how the SPV purchases assets from an originator. The purchase of these assets is funded by issuing notes and selling them to investors. The structure of the issues is often customized to meet the credit quality needs of the investors via tranches. As mentioned, the process of securitization allows the originator to remove credit risk and assets from their balance sheet.

Figure 1: Securitization Process



Cash Waterfall Process

LO 36.2: Explain the terms over-collateralization, first-loss piece, equity piece, and cash waterfall within the securitization process.

The securitization process issues notes that are structured to meet specific needs of investors by pooling the assets into different classes referred to as **tranches**. The quality of credit on the lowest rated assets can be enhanced by a method known as **overcollateralization**. The lowest class of notes is often overcollateralized by issuing notes with a principal value that is less than the principal value of the original underlying assets purchased from the originator. For example, assume a mortgage pool was securitized based on 100 mortgages, but the originator included 101 mortgages in the pool. This issue is overcollateralized by one mortgage. Thus, investors in the mortgage pool can absorb one default before suffering any economic losses.

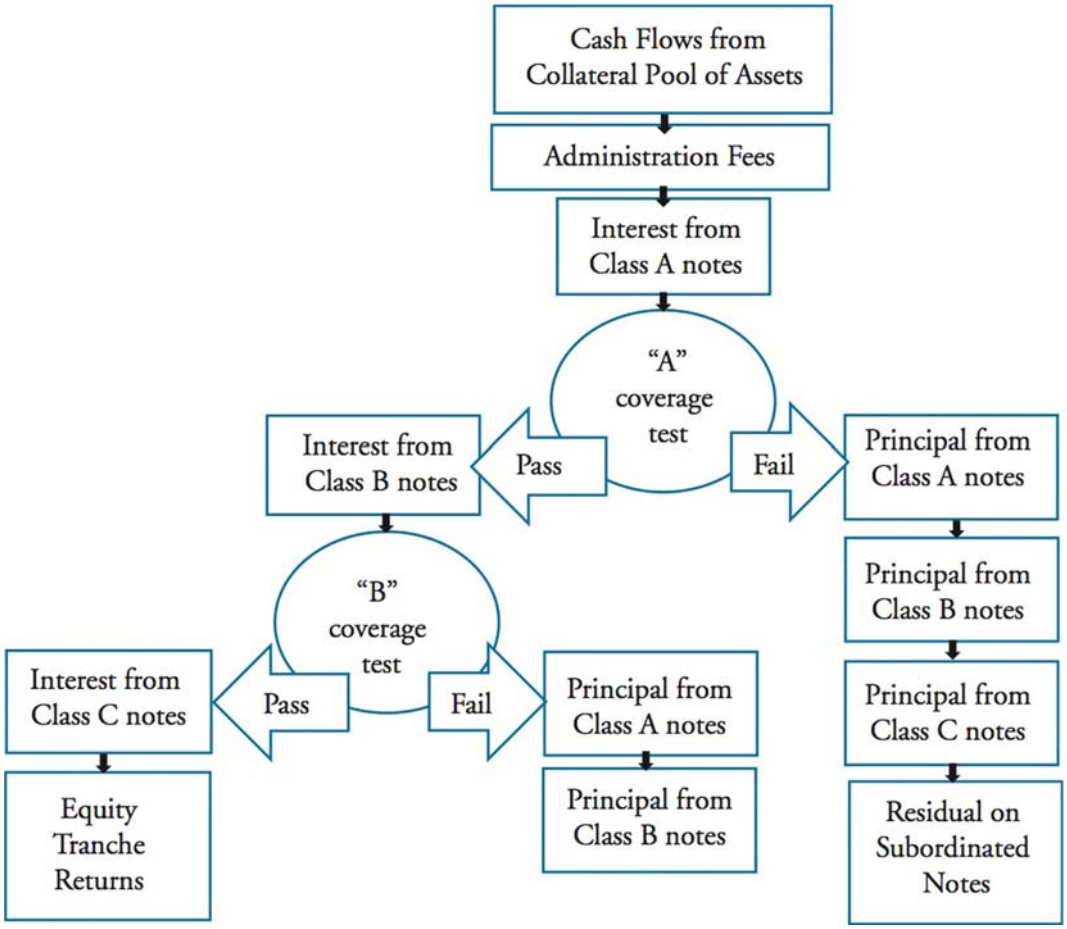
The **first-loss piece** is the class of assets with the lowest credit quality. This is the most junior level where losses are first absorbed in the event of a default. The originator often maintains ownership of the first-loss piece. Because the originator still has ownership of this first-loss piece, it is also sometimes referred to as the **equity piece** (or the **equity tranche**). The first-loss piece or equity piece is often non-rated and absorbs initial losses.

The **cash waterfall** process of securitization refers to the order in which payments from the asset pool are paid to investors. Senior tranches are paid prior to making payments to junior tranches. A third party is hired to run "tests" in order to ensure cash flows are sufficient to pay all outstanding liabilities.

Figure 2 illustrates how cash flows are allocated to the different tranches in the cash waterfall process. If the first coverage test passes, then interest payments are made to

subordinate tranche levels. However, if a coverage test fails, then the principal of the notes will begin to be paid off starting with the most senior tranche.

Figure 2: Cash Flow Waterfall



SPV Structures

LO 36.3: Analyze the differences in the mechanics of issuing securitized products using a trust versus a special purpose vehicle (SPV) and distinguish between the three main SPV structures: amortizing, revolving, and master trust.

The three main special purpose vehicle (SPV) structures used in the securitization process are amortizing, revolving, and master trust. The master trust is a special type of structure that is used for frequent issuers. The difference in how payments are received over the asset-backed security's life determines whether the ABS is better suited to the amortizing or revolving structure.

In an **amortizing structure**, principal and interest payments are made on an amortizing schedule to investors over the life of the product. Because payments are made as coupons are received, this type of structure is referred to as a *pass-through structure*. Amortizing structures are very common with the securitization of products that have amortization schedules such as residential mortgages, commercial mortgages, and consumer loans. Amortizing structures

are valued based on the expected maturity and the *weighted-average life (WAL)* of the asset. The WAL is the time-weighted period that the underlying assets are outstanding. Because borrowers of mortgages and consumer loans often have the option to pay off the loans early, the WAL must include pre-payment assumptions to estimate the rate at which principal is repaid over the life of the loans.

Revolving structures are used with products that are paid back on a revolving basis. Thus, under the revolving structure, principal payments of the assets are paid in large lump sums rather than a pre-specified amortization schedule. Credit card debt and auto loans are examples of products that are securitized using a revolving structure due to their short time horizon and high rate of pre-payments. Under a revolving structure, payments are not simply passed through. Rather, principal payments are often used to purchase new receivables with criteria similar to assets already in the pool. Investors are repaid by principal payments through controlled amortization or in single lump sum payments referred to as soft bullet payments.

Professor's Note: The term revolving structure is similar in nature to a revolving loan issued by a commercial bank to a corporation. Under the terms of a revolving loan, the corporation has a line of credit and is required to pay down that line of credit to zero every year. Thus, the loan does not amortize to reduce the balance, rather the balance is reduced in large lump sum payments.

A **master trust structure** allows an SPV to make frequent issues or multiple securitizations. The originator transfers assets to the master trust SPV who in turn issues new notes from this asset pool. Master trusts are often used in the securitization of mortgages and credit card debt.

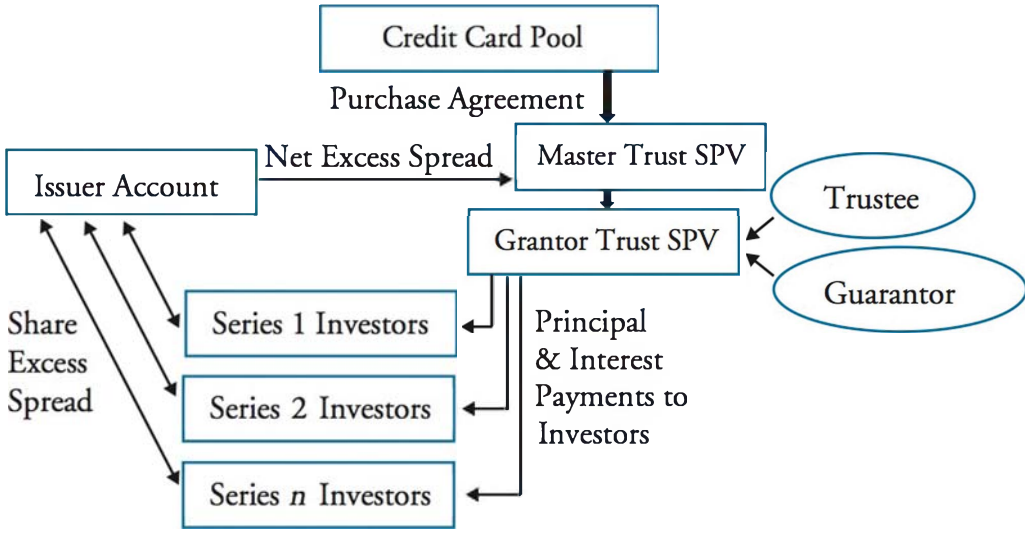
Figure 3 illustrates the securitization process for credit card asset-backed securities (ABS) using the SPV master trust structure. The pool of credit card receivables is changing over time. However, the master trust structure enables the SPV to issue multiple ABS through the single trust. Investors from different series receive payments from the entire pool of credit card ABS.

Excess spread is created from the high yield credit card debt less the cost of issuing the ABS. The excess spread is the difference between the cash inflows from the underlying assets and the cash outflows in the form of interest payments on the ABS issues. After administration expenses are covered, any remaining excess spread is held in a reserve account to protect against future losses. If there are no future losses, the remaining excess spread is returned to the originator.

As illustrated by Figure 3, under a trust arrangement two distinct SPVs are created. The additional entity is created to further distance the originator from the issuer and the underlying assets. A common arrangement will involve a master trust, or special purpose vehicle (SPV), and a grantor trust. In contrast to the previous approach (i.e., corporation), the assets do not serve directly as collateral. Under this arrangement, the originator sells the assets to the master trust (SPV 1) for cash, but the master trust in turn deposits the assets in the grantor trust (SPV 2). The master trust receives a beneficial interest in the grantor trust, which represents the same economic position as if only one SPV was employed. Now the claims of the securitized products are backed by the beneficial claim on the master trust rather than on the assets themselves.

Credit card debt is not collateralized and typically suffers from a low rate of recovery in the event of default. Therefore, a **financial guarantor** is used as a credit enhancement. If there are payment defaults for a series, the excess spread is shared to cover the losses. The ability of SPV master trust structures to sell multiple issues to investors that share excess spreads over these multiple series makes this structure very different from the amortizing and revolving structures.

Figure 3: Master Trust Structure



Securitization Benefits

LO 36.4: Explain the reasons for and the benefits of undertaking securitization.

Benefits to Financial Institutions

The three main reasons for a financial institution to use securitization are for funding assets, balance sheet management, and risk management. Typically a financial institution specializes in financing specific assets such as residential mortgages, automobile loans, commercial loans, or credit card debt. Securitization of these assets provides funding for the financial institution that helps support growth, diversifies the funding mix, and reduces maturity mismatches. The diversification of the funding mix reduces risk and the cost of funding. The originator separates the assets from its balance sheet by going through a third party (i.e., the SPV).

Asset-backed securities (ABS) issued by a SPV often have higher credit ratings than the original notes issued by the originator. If the SPV has a higher credit rating, then the originating institution benefits by lowering the cost of issuing debt when going through the SPV. ABS markets are not as liquid as bond markets, but the lower credit ratings of SPVs typically make them a more cost effective funding option. Thus, the cost savings from securitization creates a cash surplus for the originator. In addition, financial institutions often use short-term liabilities (such as savings and checking account balances) to fund long-term assets (such as residential mortgages). Securitization allows notes to be issued

by the SPV that match the time horizon of the underlying asset. At the same time, the originator is able to remove the risk of mismatched durations on the balance sheet.

Another reason financial institutions securitize assets is to manage the capital on their balance sheets. The Basel I Accord set capital requirements for banks based on the riskiness of the assets. Basel I capital requirements provided a big incentive for banks to securitize assets in order to gain regulatory capital relief. SPVs are not categorized as banks, so they are not subject to the same capital requirements as banks. For example, regulators may require banks to hold capital of 8% of the bank's total asset value. An originating bank is able to reduce capital requirements by selling assets to an SPV. As mentioned earlier, originators often keep a portion of the capital exposure by retaining the first-loss piece. Therefore, the capital requirements from the securitization are significantly reduced, but not completely eliminated. By reducing capital requirements, securitization is a form of raising capital. Banks need to issue less preferred stock and other forms of equity when they securitize assets. The reduction of capital also increases the return on equity (ROE) which is a key ratio for investors.

In addition to providing regulatory relief, securitization provides additional risk management benefits in the form of removing non-performing assets from the balance sheet. Securitization removes the credit risk as well as the negative sentiment associated with non-performing assets. Furthermore, the originator may receive surplus profit from the SPV in the event these non-performing assets start returning cash flows in the future.

Benefits to Investors

Securitization also provides benefits for investors. As a result of securitizations, investors have access to new liquid assets that were previously not available to them. This allows investors to create different risk-reward profiles and diversify into new sectors. Securitized notes often provide higher risk-reward incentives than corporate bonds with the same credit rating. The improved performance results from the originator maintaining the equity tranche. In addition, holding a securitized asset diversifies the risk exposure because the securitized asset is purchased from an SPV with a pool of assets as opposed to a corporate bond from one entity. Securitization broadens the market for buyers and sellers through diversification and customization of new liquid products. The increased liquidity reduces transaction costs, which benefits both borrowers and investors.

Credit Enhancements

LO 36.5: Describe and assess the various types of credit enhancements.

Credit enhancements play an important role in the securitization process by improving the credit rating for the asset-backed security (ABS) or mortgage-backed security (MBS) tranches. The benefits of improved credit quality are even greater for the lowest-rated assets. The different types of credit enhancements used in securitization include: overcollateralization, pool insurance, subordinating note classes, margin step-up, and excess spread.

The first two types of credit enhancements are designed to increase the ability of collateral to absorb losses associated with defaults in the underlying asset pool. The lowest class of notes often exhibit **overcollateralization** where the principal value of the notes issued are valued less than the principal value of the original underlying assets. The additional collateral of the ABS issues absorbs initial losses with no impact to investors. The credit rating can also be enhanced by offering **pool insurance**. A composite insurance company provides pool insurance on the ABS issues that covers the loss of principal in the collateral pool in the event an SPV defaults.

Other types of credit enhancements are designed to control the cash flows from the collateral pool. **Subordinating note classes** of a collateral pool into different tranches is another type of credit enhancement. Junior or class B notes are subordinate to more senior class A notes. Therefore, investors in class B do not receive payments of principal until the class A notes are fully redeemed or until rating agency requirements are met. The collateral pool is required to pass certain performance tests over a period of time before making principal payments on subordinate notes.

Two other cash flow related credit enhancements are margin step-up and excess spread. ABS issues sometimes use a **margin step-up** that increases the coupon structure after a call date. The issuer has the option to redeem the notes after this call date. The margin step-up provides investors with an extra incentive to invest in the issues. However, the issuer may refinance if the increased coupons are greater than market rates.

The **excess spread** is the difference between the cash inflows from the underlying assets and the cash outflows in the form of interest payments on the ABS issues. The securitization is structured such that the liability side of the SPV (issued notes) has a lower cost than the asset side of the SPV (receivables from mortgages, loans, or credit card debt). After administration expenses are covered, any remaining excess spread is held in a reserve account to protect against future losses. If there are no future losses, the remaining excess spread is returned to the originator.

Performance Measures for Securitized Structures

LO 36.6: Explain the various performance analysis tools for securitized structures and identify the asset classes they are most applicable to.

There are a number of performance tools designed to analyze the collateral pool of asset-backed security (ABS) and mortgage-backed security (MBS) products. MBS products were first created to provide cheaper financing for residential homes by issuing pass-through securities. Investors benefited from a new liquid asset class and lenders benefited by removing interest rate risk off the balance sheet. In addition, MBS were backed by a government-sponsored entity with "Ginnie Mae" issues. Auto loans and credit card ABS products also became more popular with investors during the low interest rate environment of 2002–2007. Investor demand grew for ABSs because they provided diversification benefits and offered higher returns than the corporate bond market.

The portfolio performance of ABS and MBS products is largely dependent on the ability of individuals to pay off their obligations in the form of consumer debt and mortgages. Performance measures serve as trigger methods to accelerate amortization. ABS structures

also have reserve accounts to protect against losses resulting from interest shortfalls. A key difference between the collateralized debt obligations (CDOs) and ABS structures is the number of underlying loans. A CDO portfolio typically consists of less than 200 loans, while ABS or MBS structures often have much greater diversity with thousands of obligors.

Auto Loan Performance Tools

There are specific performance measures that are used for different asset class types. *Auto loans* have features that are very favorable for investors in this ABS product. Auto loans are collateralized with assets that are highly liquid in the event of default. In addition, most loans have a short three to five year horizon. Thus, there is virtually no prepayment risk and losses are relatively low compared to other ABS.

A good measure of performance for auto loan ABS is the **loss curve.** The loss curve shows the expected cumulative loss for the life of the collateral pool. The expected losses based on the loss curve are compared to actual losses. Originators of prime loans typically have evenly distributed losses. Subprime or non-prime loan originators have higher initial losses resulting in a steeper loss curve. Losses for all types of loans typically decline in later years of the curve.

Another important performance tool for the auto loan ABS is the **absolute prepayment speed** (APS), which indicates the expected maturity of the issued ABS. The APS measures prepayment by comparing the actual period payments as a percentage of the total collateral pool balance. The APS is an important measure that is used to determine the value of the implicit call option of the ABS issue at any time.

Credit Card Performance Tools

Another type of ABS product is collateralized by pools of *credit card debt*. The fact that credit cards have no predetermined term for outstanding balances differentiates this class from other ABS products. Despite having no predetermined term, most credit card debt is repaid within six months. The repayment speed of a credit card ABS is controlled by scheduled amortization or a revolving period under a master trust framework. Recall that the master trust allows multiple issues and principal collections to be used to purchase new receivables.

Three important performance tools for credit card receivables of ABS are the delinquency ratio, default ratio, and monthly payment rate (MPR). These three ratios serve as triggers to signal early amortization of the receivable pool. The delinquency ratio and default ratio measure the credit loss on credit card receivables pools. An early indication of the overall quality of the credit card ABS collateral pool is the delinquency ratio. The **delinquency ratio** is computed by dividing the value of credit card receivables that are 90 days past due by the total value of the credit card receivables pool. The **default ratio** is calculated by dividing the amount of written off credit card receivables by the total credit card receivables pool. The **monthly payment rate** (MPR) is calculated as the percentage of monthly principal and interest payments divided by the total credit card receivables pool. Rating agencies require every non-amortizing ABS (such as credit cards) to set a minimum MPR as a trigger for early amortization.

LO 36.7: Define and calculate the delinquency ratio, default ratio, monthly payment rate (MPR), debt service coverage ratio (DSCR), the weighted average coupon (WAC), the weighted average maturity (WAM), and the weighted average life (WAL) for relevant securitized structures.

As described above, the delinquency ratio, default ratio, and monthly payment rate (MPR) serve as triggers to signal early amortization of the receivables pool for an ABS.

Example: Delinquency ratio, default ratio, monthly payment rate

Suppose an ABS has a total outstanding balance of credit card receivables of $57,800,000. $49,900,000 of the total receivables are current, $5,750,000 of the receivables are over 30 days past due, $1,270,000 of the receivables are over 60 days past due, and $880,000 are over 90 days past due. In addition, $1,100,000 of receivables were written off. Total monthly principal and interest payments per month are $1,560,000. **Calculate** the delinquency ratio, default ratio, and monthly payment rate for this ABS.

Answer:

The delinquency ratio 1.522%, computed by dividing the value of credit card receivables over 90 days past due by the total credit card receivables pool ($880,000 / $57,800,000).

The default ratio is 1.903%, calculated by dividing the amount of written off credit card receivables by the total credit card receivables pool ($1,100,000 / $57,800,000).

The monthly payment rate (MPR) is 2.699%, calculated as the percentage of monthly principal and interest payments divided by the total credit card receivables pool ($1,560,000 / $57,800,000).

MBS Performance Tools

The debt service coverage ratio (DSCR), weighted average coupon (WAC), weighted average maturity (WAM), and weighted average life (WAL) are performance tools used to analyze MBS. The **debt service coverage ratio** (DSCR) is calculated by dividing net operating income (NOI) by the total amount of debt payments. Net operating income is the income or cash flows that are left over after all of the operating expenses have been paid. The DSCR is a performance tool that measures the ability of a borrower to repay the outstanding debt associated with commercial mortgages. A DSCR less than one indicates that the underlying asset pool of commercial mortgages do not generate sufficient cash flows to cover the total debt payment. Total debt service refers to all costs related to servicing a company's debt. This often includes interest payments, principal payments, and other obligations. As investors' confidence levels in the securitization increase, the required DSCR decreases, and vice versa. For residential mortgages, this ratio is typically between 2.5 and 3.0. However, higher DSCR are needed with more risky receivables where the value of the receivables is highly discounted in the event of a default.

Example: Debt service coverage ratio

Suppose an MBS has net operating income from commercial mortgaged properties equal to $89,572,500. The total debt payments for notes issued against these mortgages is equal to $87,958,000. **Calculate** the debt service coverage ratio (DSCR).

Answer:

The DSCR is equal to 1.02, calculated as $89,572,500 / $87,958,000. A DSCR greater than one implies that there is sufficient cash flows generated from the underlying mortgage pool to meet debt payments. However, this is a very low DSCR for mortgages.

The **weighted average coupon** (WAC) is calculated by multiplying the mortgage rate for each pool of loans by its loan balance and then dividing by the total outstanding loan balance for all pools. Thus, it measures the weighted coupon of the entire mortgage pool. The WAC is compared to the net coupon payable to investors as an indication of the mortgage pool's ability to pay over the outstanding life of the MBS.

Example: Weighted average coupon

Suppose an MBS is composed of three different pools of mortgages: $6 million of mortgages that yield 7.8%, $10 million of mortgages that yield 6.0%, and $4 million of mortgages that yield 5%. **Calculate** the weighted average coupon (WAC).

Answer:

The WAC is calculated as follows:

WAC = [0.078(6 million) + 0.06(10 million) + 0.05(4 million)] / (6 million + 10 million + 4 million)

= (0.468 million + 0.6 million + 0.2 million) / 20 million

= 1.268 million / 20 million

= 0.0634 or 6.34%

If notes issued by the SPV are for 5.5%, for example, then an excess spread will be generated if there are no defaults on the original mortgages.

The **weighted average maturity** (WAM) is the weighted average months remaining to maturity for the pool of mortgages in the MBS. To calculate the WAM, the weight of each MBS pool is multiplied by the time until maturity of each MBS pool, and then all the values are added together. (Note that the weight is determined by taking the total value of the pool for one maturity and dividing that by the total value of all loans.)

The volatility of an MBS is directly related to the length of maturity of the underlying securities. The WAM is calculated based on stated maturity dates or reset dates. A WAM calculated based on stated maturity dates includes the liquidity risk of all mortgage securities in the portfolio by using the actual maturity date. A WAM calculated based on reset dates captures the effect of prepayments on the maturity of the loans.

Example: Weighted average maturity

Suppose an MBS is composed of three different pools of mortgages: $6 million of mortgages that have a maturity of 180 days, $10 million of mortgages that have a maturity of 360 days, and $4 million of mortgages that have a maturity of 90 days. **Calculate** the weighted average maturity (WAM).

Answer:

The WAM is calculated as follows:

WAC = [180(6 million) + 360(10 million) + 90(4 million)] / (6 million + 10 million + 4 million)

= (1,080 million + 3,600 million + 360 million) / 20 million

= 5,040 million / 20 million

= 252 days

The **weighted average life** (WAL) of the mortgage notes issued is calculated by summing the time to maturity multiplied by a pool factor using the following formula:

$$WAL = \sum (a / 365) \times PF(t)$$

Figure 4 illustrates how WAL is calculated for an MBS with an initial outstanding balance for the entire pool of $89,530,000. The pool factor, *PF(t)*, is the outstanding notional value adjusted by the repayment weighting. The actual days, *a*, until the next payment are stated in column B. This amount in column B is then divided by 365 in column F to calculate the time to maturity. The amount in column F is multiplied by column C to compute each individual note's weighted life and this is recorded in column G. WAL is then determined as the summation of column G.

Figure 4: Calculation of WAL

A	B	C	D	E	F	G
Payment Date	Actual Days (a)	PF(t)	Paid Principal	Outstanding Balance (000s)	a / 365	(a/ 365) × PF(t)
11/21/2008	66	1.00		89,530	0.1808	0.1808
1/26/2009	90	0.94	5,059	84,471	0.2466	0.2318
4/26/2009	91	0.89	4,941	79,530	0.2493	0.2219
7/26/2009	91	0.83	4,824	74,706	0.2493	0.2069
10/25/2009	91	0.75	4,706	70,000	0.2493	0.1870
1/24/2010	91	0.73	4,588	65,412	0.2493	0.1820
4/25/2010	91	0.68	4,471	60,941	0.2493	0.1695
7/25/2010	91	0.63	4,353	56,588	0.2493	0.1571
10/24/2010	92	0.58	4,235	52,353	0.2521	0.1462
1/24/2011	90	0.54	4,118	48,235	0.2466	0.1332
4/24/2011	91	0.49	4,000	44,235	0.2493	0.1222
7/24/2011	92	0.45	3,882	40,353	0.2521	0.1134
10/24/2011	92	0.41	3,765	36,588	0.2521	0.1033
1/24/2012	91	0.37	3,647	32,941	0.2493	0.0922
4/24/2012	91	0.33	3,529	29,412	0.2493	0.0823
7/24/2012	92	0.29	3,412	26,000	0.2521	0.0731
10/24/2012	92	0.25	3,294	22,706	0.2521	0.0630
1/24/2013	90	0.22	3,176	19,530	0.2466	0.0542
4/24/2013	91	0.18	3,058	16,472	0.2493	0.0449
7/24/2013		0	16,472	0	0	0
					WAL =	2.565

Prepayment Forecasting

LO 36.8: Explain the prepayment forecasting methodologies and calculate the constant prepayment rate (CPR) and the Public Securities Association (PSA) rate.

Common methodologies used to estimate prepayments for an MBS or ABS collateralized by mortgages or student loans are the **constant prepayment rate** (CPR) and the **Public Securities Association** (PSA) method. Assumptions regarding the rate of prepayment are required to estimate the cash flows for an MBS. Prepayments will reduce the yield of an MBS, assuming principal payments remain unchanged.

The CPR is calculated as: $CPR = 1 - (1-SMM)^{12}$. The **single monthly mortality** (SMM) is the single-month proportional prepayment. Factors that influence the CPR are market environment, characteristics of the underlying mortgage pool, and the outstanding balance of the pool.

Example: Constant prepayment rate

Suppose an ABS has an SMM of 1.5%. This implies that the approximate prepayment for the month is equal to 1.5% of the remaining mortgage balance for the month less the scheduled principal repayment. **Calculate** the CPR for this MBS.

Answer:

The CPR for this MBS equals 16.59%, calculated as: $CPR = 1 - (1 - 0.015)^{12} = 0.1659$.

The PSA typically assumes that prepayments will increase as a pool approaches maturity. The MBS pool of mortgages has a 100% PSA if its CPR begins at 0 and increases 0.2% each month for the first 30 months. A graph of the CPR for an ABS as it approaches maturity is illustrated in Figure 5.

Note that the middle line in Figure 5 represents 100% PSA where the prepayments are assumed to start at 0 and increase 0.2% each month up until month 30. After 30 months, the 100% PSA is assumed to be at a constant 6% (calculated as 0.2 times 30 months) until maturity. Other prepayment scenarios are then calculated as a percentage of this 100% base case. Thus, a 50% PSA assumes 50% of the initial increase for the first 30 months. In Figure 5, the bottom line represents the 50% PSA scenario where prepayments are assumed to increase 0.1% each month for the first 30 months, before reaching a constant prepayment rate of 3%. Similarly, the top line represents the 150% PSA scenario where prepayments are assumed to increase 0.3% each month for the first 30 months, before reaching a constant prepayment rate of 9%.

Figure 5: Different Prepayment Scenarios

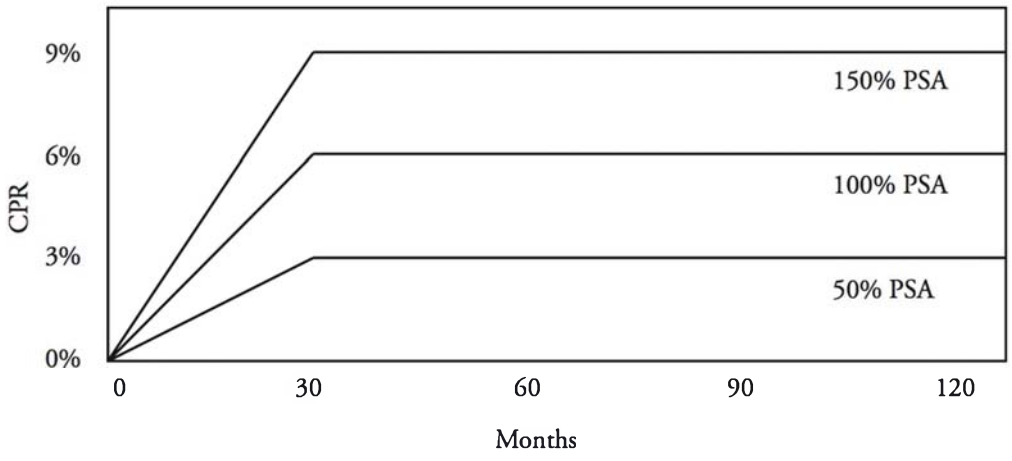


Figure 6 summarizes performance tools discussed in this topic based on the type of ABS or MBS.

Figure 6: ABS and MBS Performance Tools

Performance Analysis Tools	*Asset Type*	*Calculation*
loss curves	auto loans	expected cumulative losses
absolute prepayment speed (APS)	auto loans	prepayments / pool balance
delinquency ratio	credit cards	past due receivables / pool balance
default ratio	credit cards	defaults / pool balance
monthly payment rate (MPR)	credit cards	receivables collected / pool balance
debt service coverage ratio (DSCR)	commercial mortgages	NOI / debt payments
weighted average coupon (WAC)	mortgages	weighted pool coupon payments
weighted average maturity (WAM)	mortgages	weighted pool maturity
weighted average life (WAL)	mortgages	$\sum(a / 365) \times PF(t)$
single monthly mortality (SMM)	mortgages, home-equity, student loans	prepayment / pool balance
constant prepayment rate (CPR)	mortgages, home-equity, student loans	$1 - (1\text{-SMM})^{12}$
Public Securities Association (PSA)	mortgages, home-equity, student loans	[CPR / (0.2)(months)] × 100

Securitization after the Credit Crunch

LO 36.9: Explain the decline in demand in the new-issue securitized finance products market following the 2007 financial crisis.

The financial crisis of 2007–2009 was a direct result of the subprime mortgage problems that led to an asset-backed commercial paper standstill. The liquidity crisis faced by large financial institutions led to a worldwide recession. U.S. mortgage defaults quickly rippled worldwide through the globally integrated banking system and global investments in structured credit products backed by U.S. mortgages. Collateralized debt obligations (CDOs) and other ABS were key contributors in poor lending decisions in the U.S. mortgage market.

Key factors that led to the loss in market confidence and the 2007–2009 financial crisis were the impact of the credit crunch, shadow banking system, leverage, lack of transparency, credit rating agencies' practices, accounting rules, and liquidity. These factors led to negative sentiment among investors and a sharp decline in the new-issue securitization market.

The widespread use of securitization to remove assets from the balance sheet of financial institutions eventually led to the **credit crunch**. Subprime lenders made excessive amounts of low quality loans and then removed these loans from their balance sheets through ABS. Investors were overconfident in buying these ABS and unaware of the risks in this market.

The securitization structure is designed to break the link between loan originators and borrowers. Loans are carefully grouped and packaged into tranches and sold to investors who have no knowledge of the credit quality of the original borrowers. A **shadow banking system** was created where entities are not bound by the same regulatory requirements of normal banks. These entities in the shadow banking system were referred to as special investment vehicles (SIVs). SIVs funded loans through commercial paper and did not rely on the central bank's discount window as a backup source of funding. This worked until the shadow bank was no longer able to find investors in this market. The inability to refinance the securitized products led to a liquidity crisis.

SIVs were **highly leveraged** just prior to the market collapse in 2007. Leverage ratios of 1:15 were common at this time. Some SIVs had leverage ratios as high as 1:50 as they increased their borrowing in an attempt to compensate for the shrinking credit spreads during the bull market. The use of leverage was even more problematic for CDOs that invested in other CDOs.

The **lack of transparency** resulted in increasingly complex products. Valuing products with no transparency is extremely difficult. As the credit crisis progressed, the wide variety of ABS tranches that existed in the market became very difficult to mark-to-market due to the widening of credit spreads for tranches and the changing correlation risk for ABS portfolios. To complicate matters even further, the changes in correlations had different impacts for different seniority levels of tranches.

Credit rating agencies (CRAs) were overly optimistic in their ratings due to poor credit quality models and a lack of understanding of the degree of correlation risk for ABSs. High ratings were justified for lenders on the assumption that the residential real estate market would continue to increase in value. The models used by rating agencies did not correctly incorporate the impact of correlations or sharp declines in real estate values.

Investors viewed securitized products as AAA rated with high liquidity. Unfortunately, the **liquidity** of ABS was overestimated. As the first losses were realized in the subprime lending market, SPVs needed to unwind or sell off investments in securitized paper. The SPVs mispriced the securities initially by failing to include a liquidity premium.

The impact of the liquidity crisis was even greater due to mark-to-market **accounting rules**. As investments were marked-to-market, it created a downward spiral effect in asset prices of securitized products. In the flight-to-quality environment of a liquidity crisis, financial institutions were required to mark down asset values based on highly stressed prices in the secondary market. To complicate things further, securitized products were more negatively impacted than plain vanilla commercial paper, which is characteristic of markets where participants are attempting to shed risky assets for safer ones.

Key Concepts

LO 36.1

Securitization is the process of issuing securities against an asset pool. The proceeds of the security sale collateralize the purchase of the assets from the originator, thereby removing the liability and involvement of the originator. A special purpose vehicle (SPV) is used to separate the assets from the originator and customize the products for investors.

LO 36.2

A common credit enhancement of securitized assets is overcollateralization where the principal value of the notes issued by the SPV are valued less than the principal value of the original underlying assets. The first-loss piece or equity piece absorbs initial losses. This non-rated junior tranche is often held by the originator.

LO 36.3

The master trust is a special type of structure that is used for frequent issuers. The difference in how payments are received from the underlying collateral over the asset-backed security's life determines whether the ABS is better suited to the amortizing or revolving structure.

LO 36.4

Financial institutions benefit from securitization by funding assets, balance sheet management, and risk management. Securitization benefits investors by providing access to liquid assets that were previously not available to them.

LO 36.5

Credit enhancements such as overcollateralization, pool insurance, subordinating note classes, margin step-up, and excess spread enable originators to lower costs while providing investors customized products that meet their needs.

LO 36.6

The portfolio performance of ABS and MBS products is largely dependent on the ability of individuals to pay off their obligations in the form of consumer debt and mortgages. Performance measures serve as trigger methods to accelerate amortization.

The loss curve shows the expected cumulative loss for the life of the collateral pool. The absolute prepayment speed (APS) measures prepayment by comparing the actual period payments as a percentage of the total collateral pool balance.

LO 36.7

The delinquency ratio is computed by dividing the value of credit card receivables more than 90 days past due by the total credit card receivables pool. The default ratio is calculated by dividing the amount of written off credit card receivables by the total credit card receivables pool. The monthly payment rate (MPR) is calculated as the percentage of monthly principal and interest payments divided by the total credit card receivables pool.

The debt service coverage ratio (DSCR) is calculated by dividing net operating income (NOI) by the total amount of debt payments. The weighted average coupon (WAC) is calculated by multiplying the mortgage rate for each pool of loans by its loan balance and then dividing by the total outstanding loan balance for all pools. The weighted average maturity (WAM) is the weighted average months remaining to maturity for the pool of mortgages in the MBS. The weighted average life (WAL) of the mortgage notes issued is calculated by summing the time to maturity multiplied by a pool factor, which is the outstanding notional value adjusted by the repayment weighting.

LO 36.8

Common methodologies used to estimate prepayments for securitized products collateralized by mortgages or student loans are the constant prepayment rate (CPR) and the Public Securities Association (PSA) method.

The CPR is calculated as: $CPR = 1 - (1\text{-}SMM)^{12}$

The PSA typically assumes that prepayments will increase as a pool approaches maturity. The MBS pool of mortgages has a 100% PSA if its CPR begins at 0 and increases 0.2% each month for the first 30 months.

LO 36.9

Key factors that led to the loss in market confidence and the financial crisis of 2007–2009 include: the impact of the credit crunch, shadow banking system, leverage, lack of transparency, credit rating agencies' practices, accounting rules, and liquidity.

Concept Checkers

1. A major benefit of securitization for a financial institution is the ability to remove assets from the balance sheet, which lowers risk and the required regulatory capital. While a large portion of the risk is removed from the balance sheet the originating financial institution often maintains a portion of the risk. Which of the following terms best identify the risk that is maintained by the originator?
   A. Correlation.
   B. Excess spread.
   C. First-loss piece.
   D. Guarantor of collateral value.

2. Securitized products are often customized to meet the needs of the investor as well as the originator. What type of asset-backed securities (ABSs) typically uses a revolving structure?
   A. Residential mortgage.
   B. Credit card debt.
   C. Commercial mortgage.
   D. Commercial paper.

3. Which of the following statements regarding credit enhancements in the process of structuring a securitization through a special purpose vehicle (SPV) is correct?
   A. The securitization process is structured such that the asset side of the SPV has a lower cost than the liability side of the SPV.
   B. Credit enhancements are typically only associated with mortgage-backed securities (MBS) and are not used in other types of asset-backed securities (ABS).
   C. The most senior class of notes is often overcollateralized in order to reduce the risk of the asset-backed security (ABS).
   D. A margin step-up is sometimes used by an asset-backed securities (ABS) where the coupon structure increases after a call date.

4. Which of the following measures are most likely to be used by a securitized product backed by student loans?
   A. Single monthly mortality (SMM), constant prepayment rate (CPR), and Public Securities Association (PSA).
   B. Loss curves and absolute prepayment speed (APS).
   C. Weighted average life (WAL), weighted average maturity (WAM), and weighted average coupon (WAC).
   D. Debt service coverage ratio (DSCR) and monthly payment rate (MPR).

5. Assume an MBS is composed of the following four different pools of mortgages:
   - $2 million of mortgages that have a maturity of 90 days.
   - $3 million of mortgages that have a maturity of 180 days.
   - $5 million of mortgages that have a maturity of 270 days.
   - $10 million of mortgages that have a maturity of 360 days.

   What is the weighted average maturity (WAM) of these mortgage pools?
   A. 167 days.
   B. 225 days.
   C. 252 days.
   D. 284 days.

Concept Checker Answers

1. **C** The originator often maintains ownership of the first-loss piece, which is the class of assets with the lowest credit quality and is the most junior level where losses are first absorbed in the event of a default.

2. **B** Revolving structures are used with products that are paid back on a revolving basis, such as credit card debt or auto loans. Credit card debt does not have a pre-specified amortization schedule; therefore the principal paid back to investors is in large lump sums rather than amortizing schedules.

3. **D** ABS issues may use a margin step-up that increases the coupon structure after a call date. Credit enhancements play an important role in the securitization process for both the asset-backed security (ABS) and mortgage-backed security (MBS) issues. The liability side of the SPV has a lower cost than the asset side of the SPV to create an excess spread prior to administration costs. The lowest class of notes are often overcollateralized where the principal value of the notes issued are valued less than the principal value of the original underlying assets.

4. **A** The constant prepayment rate (CPR) and the Public Securities Association (PSA) method are common methodologies used to estimate prepayments for student loans and mortgages.

5. **D** The WAM is calculated as follows:

   WAC = [90(2 million) + 180(3 million) + 270(5 million) + 360(10 million)] / (2 million + 3 million + 5 million + 10 million)

   = (180 million + 540 million + 1,350 million + 3,600 million) / 20 million

   = 5,670 million / 20 million

   = 284 days

The following is a review of the Credit Risk Measurement and Management principles designed to address the learning objectives set forth by GARP®. This topic is also covered in:

Understanding the Securitization of Subprime Mortgage Credit

Topic 37

Exam Focus

This topic describes many important aspects of the subprime markets. Seven frictions between market participants are discussed involving mortgagors, originators, arrangers, rating agencies, asset managers, and investors. You should understand the information problem (moral hazard or adverse selection) for each friction. Characteristics of subprime mortgages are also discussed including loan terms, performance, and subordination. For the exam, be familiar with subprime mortgage securitization, the frictions in the subprime market, and the process of rating subprime securities.

The Subprime Securitization Process

LO 37.1: Explain the subprime mortgage credit securitization process in the United States.

The subprime securitization process in the United States involves several different parties beginning with the borrowing needs of the home buyer. The borrower (mortgagor) applies for a mortgage and, conditional on the due diligence of the lender, is extended a loan with the residence serving as collateral. Borrowers range in quality from prime (i.e., strong credit history) to Alt-A (i.e., borrowers with good credit but more aggressive underwriting standards) to subprime (i.e., borrowers with poor credit history). Lenders sell a significant portion of their loans to a third-party (special purpose vehicle) and receive cash in return. Prime loans that meet conforming standards are sold to government sponsored enterprises (GSEs). The remaining loans are increasingly being sold and taken off the originators' balance sheet. Approximately 75% of newly originated subprime mortgages were securitized in 2005 and 2006.

Frictions in Subprime Mortgage Securitization

LO 37.2: Identify and describe key frictions in subprime mortgage securitization, and assess the relative contribution of each factor to the subprime mortgage problems.

In general, when two parties do not have the same information (which is usually the case), a sub-optimal outcome results. The two broad classes of information problems we will discuss here are moral hazard and adverse selection. **Moral hazard** denotes the actions one party may take to the detriment of the other. A classic example is the shareholder-manager relationship where the managers may use their position for personal gain rather than for

the shareholders to whom they owe a fiduciary duty. On the other hand, **adverse selection** is when one party possesses important hidden information. For example, a person's driving ability is private knowledge and a potential buyer of auto insurance will have the incentive to represent themselves as good drivers even if they are not. Mechanisms are designed to minimize these information problems such as board oversight for the managers and examination of driving records for those seeking auto insurance.

There are seven frictions in the mortgage securitization process. Each friction is discussed as follows.

Friction 1: *Mortgagor and originator*. The typical subprime borrower is typically financially unsophisticated. As a result, the borrower may not select the best borrowing alternative for themselves. In fact, the borrower may not even be aware of the financing options available. On the other hand, the lender may steer the borrower to products that are not suitable.

Friction 2: *Originator and arranger*. The arranger (issuer) purchases the loans from the originators for the purpose of resale through securitized products. The arranger will perform due diligence but still operates at an information disadvantage to the originator. That is, the originator has superior knowledge about the borrower (adverse selection problem). In addition, the originator may falsify or stretch the bounds of the application resulting in larger than optimal lending (predatory lending or predatory borrowing as discussed in LO 37.8).

Friction 3: *Arranger and third-parties*. The arranger of the pool of mortgages will possess better information about the borrower than third parties including rating agencies, asset managers, and warehouse lenders. The adverse selection problem gives the arranger the opportunity to retain the higher quality mortgages and securitize the lower quality mortgages (i.e., lemons).

The warehouse lender temporarily holds and finances the underlying purchases. As a precaution, the warehouse will fund less than 100% of its estimated collateral value forcing the arranger to retain a equity position on its balance sheet.

The asset portfolio manager purchases the assets for the pool from the arranger. Once again, the arranger has superior information about the creditworthiness of the mortgage pool. To minimize the potential adverse selection problem, the asset manager must use adequate due diligence, use reputable arrangers, and force credit enhancements from the arranger.

Similarly, the rating agencies determine the amount of credit enhancement necessary to achieve the desired credit rating. Thus, the rating agency is dependent on the information provided by the arranger. Typically, the due diligence on the arranger and originator is rushed.

Friction 4: *Servicer and mortgagor*. The servicer's role is to manage the cash flows of the pool and follow up on delinquencies and foreclosures. A conflict of interest arises for delinquent loans. The homeowner in financial difficulty does not have the incentive to upkeep tax payments, insurance, or maintenance on the

property. Escrowed funds can minimize this problem but ultimately efficient foreclosure must comply with federal regulations.

Friction 5: *Servicer and third-parties*. The servicer faces a moral hazard problem because their (lack of) effort can impact the asset manager and credit rating agencies without directly affecting their own cash flow distribution. In delinquency, the servicer is responsible for the property taxes and insurance premiums. These funds are reimbursable upon foreclosure so there is a temptation to exaggerate the fees and expenses particularly with high recovery rates.

The servicer also has an incentive to keep the problem loan on its books by modifying loan terms rather than foreclose (investor preference). Since most of the costs are unrecoverable (escrow analysis, payment set up, etc.) the property needs to be active to generate any additional funds to the servicer.

It is apparent that the quality of the servicer can directly impact the cash flows of the pool which in turn affects the credit rating. Changes in credit ratings reflect poorly on the agency. Therefore, the credit rating agencies must use due diligence in analyzing the servicer as well as the underlying collateral.

Friction 6: *Asset manager and investor*. The investor relies on the asset manager's expertise to identify and analyze potential investments. It is difficult for the investor to comprehend the investment strategy and the investor will not be able to observe the effort of the management team (same moral hazard problem as shareholder-manager). Investment mandates and proper benchmarking can mitigate some of the distortion.

Friction 7: *Investor and credit rating agencies*. Rating agencies are compensated by the arranger and not the end user, the investor. To the extent that the rating agencies are beholden to the fee structure of the arranger, a conflict of interest arises. In addition, it is very difficult to judge the accuracy of their models particularly with complex products and rapid financial innovation.

Five of the above factors are direct contributors to the recent subprime crisis. First, the complexity of the product and naïve nature of the borrower led to inappropriate loans (friction 1). Second, managers sought the additional yield from structured mortgage products without fully assessing the associated risks (friction 6). Third, the problem became more expansive as underperforming managers made similar investments with less due diligence on the arranger and originator (friction 3). Fourth, as the asset managers reduced their oversight, it was natural that the arranger would follow suit (friction 2). This left the credit rating agencies as the last line of defense but they operated at a significant informational disadvantage. Finally, the assigned ratings were hopelessly misguided (friction 7).

Characteristics of the Subprime Mortgage Market

LO 37.3: Describe the characteristics of the subprime mortgage market, including the creditworthiness of the typical borrower and the features and performance of a subprime loan.

Subprime borrowers have a history of either default or strong indicators of possible future default. Past incidents include 30- or 60-day delinquencies, judgments, foreclosures, repossessions, charge-offs, or bankruptcy filings. Low FICO scores (660 or below) or a high debt service ratio of 50% or more are likely indicators of future default.

The vast majority of subprime loans are adjustable rate mortgages. The loan offers a teaser rate for a short period of time, and then adjusts each year relative to a floating rate index (usually LIBOR). The 2- and 3-year teaser rates are called 2/28 and 3/27 hybrid arms denoting the fixed and floating terms, respectively (e.g., fixed term is 2 years, floating term is 28 years). Since the majority of the term of the mortgage is floating, the borrower is bearing the interest rate risk in contrast to a traditional fixed rate mortgage where the lender bears the interest rate risk.

The performance of subprime pools indicates defaults and foreclosures way above historical levels. As a point of reference, the authors of the assigned reading analyze a New Century pool originating in May 2006 and estimate a 23% cumulative default rate through August 2007.

Securitized pools incorporate structures to provide protection to investors from losses in the collateral including subordination, excess spread, shifting interest, performance triggers, and interest rate swaps.

Subordination involves creating tranches of differing priority levels. Losses are applied first to the most subordinated tranche, the equity tranche. The equity tranche is usually created from overcollateralization (i.e., assets in excess of face value). If the losses exceed the size of this tranche then losses will reach the next highest subordinated level called the mezzanine. Credit ratings on mezzanine debt typically vary from AA to B. In this fashion, the most senior tranche is protected by all the junior tranches and offers the lowest return.

Mortgages pools are typically constructed so that the weighted average coupon (less servicing, hedging, and other expenses) exceeds the weighted average payout. The difference is called the **excess spread** which is paid to equity tranche investors when available. Thus, the excess spread protects all tranches.

Under **shifting interest**, the senior investors receive all principal in the pool while the mezzanine investors receive only interest. The senior holders may receive the principal for a set period of time ("lockout period") or until a cutoff ratio is reached.

Performance triggers denote the release of overcollateralizion which is applied from the bottom of the capital structure up.

Since the first few years of the pool are fixed, the pool faces interest rate risk. As protection, **interest rate swaps** are used where the pool will pay a fixed rate and receive a floating rate.

The Credit Ratings Process

LO 37.4: Describe the credit ratings process with respect to subprime mortgage backed securities.

A credit rating is defined as an opinion on the creditworthiness of the specific bond issue. Note that the assigned rating is specific to the security and in no way a reflection on the originator. The ratings represent an unconditional view of the rating agency as they rate "**through-the-cycle.**"

The rating process involves two steps: (1) estimation of loss distribution and (2) simulation of the cash flows. Once the estimates are obtained, the agency indicates the level of credit enhancement necessary to achieve the desired rating. If the projected rating is too low, the originator can provide additional enhancement to raise the rating.

LO 37.5: Explain the implications of credit ratings on the emergence of subprime related mortgage backed securities.

Assigning credit ratings for securitized assets presents additional challenges. Credit ratings for subprime securities, and more generally asset-backed securities (ABS), differ from corporate ratings in several important ways. First, corporate bond ratings are based on the firm-specific characteristics of the issuer where as ABS is a claim on a portfolio. Hence, systematic risk and degree of correlation between assets is important in the latter but not the former. ABS represents claims on a static pool and cannot infuse additional capital or restructure as a corporation can. In addition, the forecasts for ABS incorporate future economic conditions since the cash flow stream is tied to the macro environment. Finally, while corporates and ABSs with the same rating may indicate similar default probabilities, the ABS will exhibit much wider variation in losses.

LO 37.6: Describe the relationship between the credit ratings cycle and the housing cycle.

The goal of the rating system is to rate through-the-cycle, meaning that there should not be excessive upgrades (downgrades) if the housing market heats up (slows down). A problem may arise if the agency assigns, say, an AAA rating during a boom period. As the housing market slows down, the probability of default increases and the security has migrated to AA even though the agency has not made a public pronouncement. The problem is further exacerbated if new deals are based on the credit enhancements from the AAA rating in the boom period.

As economic conditions change, it is expected to see some upgrades or downgrades in mortgage-backed securities. However, the effect may amplify up and down markets. For example, in a downward trending market, additional enhancements are needed to maintain the highest ratings. This "crowds out" the credit available for lower rated borrowers increasing the required loan rate or raising qualification standards. The opposite is true for housing upturns freeing up credit for lower rated borrowers.

Cash Flow Analysis of Excess Spread

In the ratings process it is necessary to simulate the cash flows of the structure to forecast the degree of excess spread used for credit enhancement. As you can imagine, the forecasts are complex and depend on several interrelated factors including credit enhancement, timing of losses, prepayment rates, interest rates, trigger events, weighted average loan rate decrease, prepayment penalties, pre-funding accounts, and hedging instruments. The more important factors are discussed as follows.

First, the credit enhancement identifies the amount of collateral that can be impaired before the tranche suffers an economic loss. The timing of losses is also important because as losses accumulate, less excess spread will be available. A more conservative approach would front-load the losses. Prepayments will directly impact the excess spread. Prepayments may be voluntary (refinance, sales) or involuntary (default) so the prepayment assumption directly impacts the cash flow analysis. Prepayments typically follow the CPR (conditional prepayment rate) convention. However, it is important to note that hybrids will have higher than predicted defaults on or about the reset date due to the sudden change in rates and financial condition of the subprime borrower. A more conservative view would accelerate prepayments reducing further interest collections. Finally, the path of interest rates introduces uncertainty into the projected cash flow stream. Interest rates determine the adjustments (i.e., cash inflows), and influence refinancing.

LO 37.7: Explain the implications of the subprime mortgage meltdown on portfolio management.

Currently, the rating agencies collectively monitor approximately 10,000 mortgage pools. It would be impractical to monitor each pool on a monthly basis in detail. It is current practice to annually review each individual pool. An important performance measure used during this review is the **loss coverage ratio** (LCR), defined as: (current credit enhancement for tranche) / (estimated unrealized losses). An example of a credit enhancement is excess spread. If the LCR is breached (i.e., falls below what is acceptable), a full review is warranted.

Predatory Lending and Borrowing

LO 37.8: Compare predatory lending and borrowing.

Predatory lending results in the borrower becoming worse off after the loan than before. This may happen because the rates are deceptively high, the appraisals are inflated allowing the borrower to extract equity and then cannot refinance, and prepayment penalties are extreme, steering borrowers unnecessarily to subprime products and similar ruses. Predatory lending may also include outright fraudulent activity in addition to deception.

Predatory borrowing is misrepresentation in the mortgage application from the borrower side. The temptation is driven by increasing housing prices whereby the borrower feels that he cannot catch up with housing prices. Therefore, lying on the mortgage application allows the borrower to the buy the house with the expectation that continued appreciation will allow a favorable refinancing. The fraud may be perpetrated by the buyer alone or in concert with lawyers, broker, and appraisers.

Key Concepts

LO 37.1

The recent past has witnessed about 75% of subprime mortgages securitized.

LO 37.2

Frictions involve the borrower, originator, arranger, asset manager, investor, and rating agency. The frictions are based on adverse selection and moral hazard problems.

Ultimately, the lack of due diligence on the asset manager and arranger led to even looser underwriting standards. The credit rating agencies issued ratings that lacked this key information.

LO 37.3

Subprime mortgages are mainly hybrid arms (2/28 and 3/27) where the term denotes fixed and floating, respectively. Hence, the borrower retains the vast majority of the interest rate risk.

The capital structure of a pool places the safest securities on top (senior notes), junior securities in the middle (mezzanine) and riskiest on the bottom (equity).

Subordination, excess spread, and shifting interest provide protection for the senior tranches.

LO 37.4

Credit ratings are determined by the amount of collateralization in the structure. If the projected cash flows are insufficient to warrant a desired rating, the originator can supply additional enhancement.

LO 37.5

Credit ratings for ABSs are more complex than corporate ratings because of the underlying portfolio nature and correlation between assets, dependence on economic forecasts, and static nature of the collateral pool.

LO 37.6

Credit ratings are designed to rate through-the-cycle so that there are not excessive upgrades (downgrades) during housing booms (busts). However, changing required enhancements amplify the impact on housing markets by reducing credit in down markets and increasing credit in up markets for the lowest rated borrowers.

LO 37.7

Rating agencies collectively monitor approximately 10,000 mortgage pools. It's impractical to monitor each pool on a monthly basis in detail, so annual reviews are preferred.

LO 37.8

Predatory lending is when the borrower's welfare is reduced after undertaking the loan. The key characteristic is that the borrower has entered into an agreement with unfavorable terms. Predatory borrowing is when the borrower knowingly misrepresents his financial condition to secure a loan that he otherwise would not qualify for.

Concept Checkers

1. Which of the following is not a friction in the subprime securitization market?
   A. Investor and rating agency.
   B. Servicer and mortgagor.
   C. Mortgagor and arranger.
   D. Asset manager and investor.

2. Which of the following frictions represents an adverse selection problem?
   A. Investor and mortgagor.
   B. Originator and arranger.
   C. Servicer and rating agency.
   D. Servicer and mortgagor.

3. Which of the following statements about subprime mortgages is true? Subprime mortgages:
   A. are typically fixed rate obligations.
   B. often use the 2/28 or 3/27 hybrid structure.
   C. force the lender to bear most of the interest rate risk.
   D. are simpler to analyze than corporate bonds.

4. Which of the following is true about predatory lending and predatory borrowing?
   A. Both underprovide credit.
   B. Both overprovide credit.
   C. Predatory lending underprovides credit and predatory borrowing overprovides credit.
   D. Predatory lending overprovides credit and predatory borrowing underprovides credit.

5. Which of the following subprime characteristics provide direct protection for senior tranches?
   A. Subordination, excess spread, and shifting interest.
   B. Subordination, prepayments, and shifting interest.
   C. Overcollateralization, excess spread, and timing of losses.
   D. Overcollateralization, excess spread, and prepayments.

Concept Checker Answers

1. **C** The mortgagor and arranger have no direct contact so there is no friction.

2. **B** The originator has better information about the quality of the borrowers so the arranger is subject to an adverse selection problem. That is, if the originator keeps the high quality mortgages, the arranger will receive lemons.

3. **B** Most subprimes are 2/28 or 3/27 structures where the fixed component is for two or three years. Hence, the remainder of the term (27 or 28 years) is variable and bears the majority of the interest rate risk.

4. **B** Predatory borrowing is when the borrower misrepresents themselves to obtain credit they otherwise would be denied. Predatory lending is providing credit that is welfare decreasing and should not be provided.

5. **A** Subordination, excess spread, and shifting interest provide protection for senior tranches. Overcollateralization also provides protection for senior tranches. Timing of losses impacts excess spreads. Prepayments can accelerate or decelerate the cash flows to senior tranches.

Self-Test: Credit Risk Measurement and Management

10 Questions: 30 Minutes

1. A firm is experiencing financial difficulties. Using a contingent claims approach, which of the following best describes the valuation of their senior and subordinated debt?
   A. Both the senior debt and subordinated debt have positive exposures to debt maturity, firm volatility, and interest rates (i.e., the debt value increases as these factors increase).
   B. The senior debt has negative exposures to debt maturity, firm volatility, and interest rates (i.e., the senior debt value decreases as these factors increase). The subordinated debt has positive exposures to debt maturity, firm volatility, and interest rates (i.e., the subordinated debt value increases as these factors increase).
   C. The senior debt has positive exposures to debt maturity, firm volatility, and interest rates (i.e., the senior debt value increases as these factors increase). The subordinated debt has negative exposures to debt maturity, firm volatility, and interest rates (i.e., the subordinated debt value decreases as these factors increase).
   D. Both the senior debt and subordinated debt have negative exposures to debt maturity, firm volatility, and interest rates (i.e., the debt value decreases as these factors increase).

2. Suppose a portfolio has a value of $1,000,000 with 50 independent credit positions. Each of the credits has a default probability of 2% and a recovery rate of 0%. The credit portfolio has a default correlation equal to 0. The number of defaults is binomially distributed and the 95th percentile of the number of defaults is 3. What is the credit value at risk at the 95% confidence level for this credit portfolio?
   A. $20,000.
   B. $40,000.
   C. $60,000.
   D. $980,000.

3. Continuously increasing default probability (while holding default correlation constant) will most likely have what effect on the credit VaR of mezzanine and equity tranches?

	Equity VaR	Mezzanine VaR
A.	Increase	Increase then decrease
B.	Increase	Decrease then increase
C.	Decrease	Increase then decrease
D.	Decrease	Decrease then increase

4. Which of the following statements regarding counterparty risk and lending risk is correct?
   A. For an interest-rate swap, counterparty risk exists because default may occur at the end of the contract term.
   B. With counterparty risk, there is uncertainty as to which counterparty will have a negative mark-to-market value.
   C. Lending risk involves bilateral risks.
   D. With lending risk, the principal amount at risk is known with absolute certainty at the outset.

5. Netting refers to the combining of cash flows from different contracts with a counterparty into a single net amount. This method of mitigating counterparty risk has enabled explosive growth in credit exposures. Which of the following statements is incorrect regarding the advantages and disadvantages of netting?
   A. Netted exposures can be volatile, which may result in difficulty in controlling exposure.
   B. Netting removes risks by executing a reverse position with a counterparty, removing both default and operational risk, but not market risk.
   C. Without netting, entities trading with insolvent or troubled counterparties would be motivated to cease trading and terminate existing contracts.
   D. By offsetting exposures with parties managing net positions only, netting reduces risk and improves operational efficiency.

6. Counterparty Y is attempting to transfer posted collateral to another counterparty as collateral through a process of rehypothecation. Assuming that Counterparty X pledges collateral to Counterparty Y, and then Counterparty Y rehypothecates this collateral to Counterparty Z, what will happen if Counterparty Z defaults?
   A. Counterparty X will receive its original collateral back from Counterparty Z.
   B. Counterparty Y will have a liability to Counterparty X for not returning its collateral.
   C. Counterparty Y will profit from not receiving the collateral from Counterparty Z given that a credit event has occurred.
   D. Counterparty Y will accept a haircut on the value of the pledged collateral in order to reclaim a portion of the collateral.

7. Teresa Harrison, a junior portfolio manager, is considering the purchase of super senior tranches for her client portfolios. The typical client is fairly conservative and concerned more with downside risk than upside potential. Harrison based her recommendation on the following observations:
   - Senior tranches have large attachment points and hence a low probability of credit losses.
   - Mezzanine tranches represent the first loss piece of the capital structure.
   - Synthetic CDOs have standardized tranche widths similar to index tranches.

   How many of these observations support Harrison's view of tranches?
   A. 0.
   B. 1.
   C. 2.
   D. 3.

8. A portfolio consists of two bonds, Bonds A and B. The credit VaR for the portfolio is defined as the maximum loss due to defaults at a confidence level of 98% over a one-year horizon. The probability of joint default of the two bonds is 1.32%, and the default correlation is 35%. The bond value, default probability, and recovery rate are USD 1.2 million, 4%, and 60%, respectively for Bond A, and USD $800,000, 5%, and 35%, respectively for Bond B. What is the expected credit loss for the portfolio?
A. $45,200.
B. $15,820.
C. $42,800.
D. $26,400.

9. High Flying Hedge Fund will enter into a $100 million total return swap on the S&P 500 Index as the index receiver (i.e., total return receiver). The counterparty (i.e., total return payer) will receive 1-year LIBOR + 400bp. The contract will last two years and will exchange cash flows annually.
- Current LIBOR = 3%.
- Current S&P 500 value = 2,000.
- S&P 500 in one year = 2,200.
- S&P 500 in two years = 1,760.

Given the above information, what are the cash flows to High Flying in one year and in two years, respectively? Assume LIBOR remains flat.

	1 Year	2 Years
A.	+3 million	–13 million
B.	+3 million	–27 million
C.	+13 million	–13 million
D.	+13 million	–27 million

10. Five tranches of auto loan asset-backed securities (ABSs) are issued with a face value of $6,000,000 and pay an average coupon of 5.2%. The value of the auto loans is $6,800,000, and they have an average interest rate of 5.4%. The fee for servicing the ABS is 0.2%. Which of the following credit enhancements are involved with this transaction?
A. Excess spread.
B. Margin step-up.
C. Subordinating note classes.
D. Overcollateralization.

Self-Test Answers: Credit Risk Measurement and Management

1. **B** If a firm is in financial distress, the subordinated debt behaves more like equity and a call option. It will increase in value as time to maturity increases, volatility increases, and interest rates increase. The senior debt will have negative exposures to these factors.

   If the firm is not in distress, both the senior debt and subordinated debt have negative exposures to these factors because the subordinated debt behaves more like senior debt than equity. In this case, choice D would be correct.

   (See Topic 21)

2. **B** The loss given default is $60,000 [3 × ($1,000,000 / 50)]. The expected loss is equal to the portfolio value times π and is $20,000 (0.02 × $1,000,000). The credit VaR is defined as the quantile of the credit loss less the expected loss of the portfolio. At the 95% confidence level, the credit VaR is equal to $40,000 ($60,000 minus the expected loss of $20,000).

   (See Topic 23)

3. **C** Increasing the probability of default decreases equity VaR as defaults are more likely, and the equity tranche will suffer writedowns. However, the writedowns are bounded by the thin level of subordination so the variation in losses becomes smaller. Mezzanine tranches behave more like senior bonds at low default levels (increasing VaR) but more like the equity tranche at higher default levels (decreasing VaR).

   (See Topic 24)

4. **B** With counterparty risk, there is uncertainty regarding which counterparty will have a negative MtM value. For an interest-rate swap, there is no counterparty risk at the end of the contract term because all payments required by the contract would have been made by then. With lending risk, only one party (unilateral) takes on risk. In addition, the principal amount at risk is known only with reasonable certainty at the outset because changes in interest rates, for example, will lead to some uncertainty.

   (See Topic 25)

5. **B** If an entity wishes to exit a less liquid OTC trade with one counterparty by entering into an offsetting position with another counterparty, the entity will remove market risk; however, it will be exposed to counterparty and operational risk. Netting removes these risks through executing a reverse position with the initial counterparty, removing both market and counterparty risk.

   (See Topic 26)

6. **B** In rehypothecation, party X may pledge collateral to party Y and party Y may rehypothecate this collateral to party Z. If party Z defaults, then party Y will not only have a loss from not receiving the collateral from party Z, it will also have a liability to party X for not returning its collateral.

   (See Topic 27)

7. **B** Only recommendation 1 is correct. Senior tranches have a low probability of default because their attachment points are much higher in the capital structure. Equity tranches represent the first loss position. Index tranches, not synthetic CDOs, have standardized tranche widths.

   (See Topic 30)

8. **A** The joint expected credit loss is the sum of the two individual expected credit losses.

   EL = PD × exposure × LGD

   $EL_{Bond\ A}$ = $1,200,000 × 0.04 × 0.40 = $19,200

   $EL_{Bond\ B}$ = $800,000 × 0.05 × 0.65 = $26,000

   Total EL = $45,200

   Note that expected credit loss does not depend on the correlation between the bonds.

   (See Topic 33)

9. **B** Over the next year, the S&P 500 Index will increase by 10%. Hence, the index receiver (High Flying) will receive $10 million from the index payer and will pay $7 million (LIBOR = 3% + 400bp) to the counterparty. Therefore, the net cash flow will be +$3 million to High Flying.

   Between years 1 and 2, the S&P 500 Index will drop 20%. Now, High Flying as the total return receiver must *pay* 20% to the counterparty in addition to the 7% floating rate. Hence, the total outflow from High Flying to the counterparty is $27 million.

   (See Topic 35)

10. **D** This ABS is supported by overcollateralization because the value of the asset pool is greater than the value of the securities. There is no excess spread involved because there is no difference between the cash inflows from the underlying assets and the cash outflows in the form of interest payments on the ABS issues.

    (See Topic 36)

FORMULAS

Topic 17

expected loss: PD × LGD × EAD

Topic 19

exposure at default: EAD = drawn amount + (limit – drawn amount) × loan equivalency factor

marginal risk contribution: $\beta_i = \frac{ULC_i / w_i}{UL_{portfolio}}$

economic value added: EVA = (RARORAC – K_e) × economic capital

risk-adjusted return on risk-adjusted capital:

$$RARORAC = \frac{\text{spread} + \text{fees} - \text{EL} - \text{cost of capital} - \text{cost of operations}}{\text{economic capital}}$$

Topic 20

probability of default: $PD_k = \frac{\text{defaulted}_t^{t+k}}{\text{names}_t}$

where:
PD = probability of default
defaulted = number of issuer names that have defaulted in the applicable time horizon
names = number of issuers
k = time horizon

cumulative probability of default: $PD_k^{cumulative} = \frac{\sum_{i=t}^{i=t+k} \text{defaulted}_i}{\text{names}_t}$

marginal probability of default: $PD_k^{marginal} = PD_{t+k}^{cumulative} - PD_t^{cumulative}$

annualized default rate: discrete: $ADR_t = 1 - \sqrt[t]{\left(1 - PD_t^{cumulative}\right)}$

continuous: $ADR_t = -\frac{\ln\left(1 - PD_t^{cumulative}\right)}{t}$

Merton model PD: $PD = N\left(\frac{\ln(F) - \ln(V_A) - \mu T + \frac{1}{2}\sigma_A^2 T}{\sigma_A \sqrt{T}}\right)$

where:
ln = the natural logarithm
F = debt face value
V_A = firm asset value (market value of equity and net debt)
μ = expected return in the "risky world"
T = time to maturity remaining
σ_A = volatility (standard deviation of asset values)
N = cumulated normal distribution operator

distance to default: $DtD = \frac{\ln(V_A) - \ln(F) + \left(\mu_{risky} - \frac{\sigma_A^2}{2}\right) - \text{"other payouts"}}{\sigma_A} \cong \frac{\ln V - \ln F}{\sigma_A}$

Altman's Z-score: $Z = 1.21x_1 + 1.40x_2 + 3.30x_3 + 0.6x_4 + 0.999x_5$

where:
x_1 = working capital / total assets
x_2 = accrued capital reserves / total assets
x_3 = EBIT / total assets
x_4 = equity market value / face value of term debt
x_5 = sales / total assets

LOGIT model: $LOGIT(\pi_i) = \log\frac{\pi_i}{1 - \pi_i}$

Topic 21

credit spread $= -\left[\frac{1}{(T - t)}\right] \times \ln\left(\frac{D}{F}\right) - R_F$

where:
(T – t) = remaining maturity
D = current value of debt
F = face value of debt
R_F = risk-free rate

vulnerable option = [(1 – PD) × c] + (PD × RR × c)

where:
c = value of the option without default
PD = probability of default
RR = recovery rate

Topic 22

cumulative PD: $1 - e^{-\lambda t}$

default probability: $\lambda_\tau^* \approx \frac{z_\tau}{1 - RR}$

Topic 23

correlation with default probabilities: $\rho_{12} = \dfrac{\pi_{12} - \pi_1\pi_2}{\sqrt{\pi_1(1-\pi_1)}\sqrt{\pi_2(1-\pi_2)}}$

Topic 29

$$\text{netting factor} = \frac{\sqrt{n + n(n-1)\bar{\rho}}}{n}$$

where:
n = number of exposures
$\bar{\rho}$ = average correlation

Topic 30

risk-neutral default probability = liquidity premium + default risk premium + real-world default probability

$$\text{cumulative default probability: } F(u) = 1 - \exp\left[-\frac{\text{spread}}{1-\text{recovery}} \times u\right]$$

$$\text{number of defaults} = n\left(\frac{X\%}{1-\text{recovery}}\right)$$

Topic 33

$$\text{loan portfolio expected loss: } EL = \sum_{i=1}^{N} PD_i \times EAD_i \times LGD_i$$

$$\text{deriatives portfolio expected loss: } EL = \sum_{i=1}^{N} PD_i \times (EPE_i \times \alpha) \times LGD_i$$

$$\text{credit valuation adjustment: } CVA_n = LGD_n^* \times \sum_{j=1}^{T} EE_n^*(t_j) \times q_n^*(t_{j-1}, t_j)$$

where:
LGD_n^* = risk-neutral loss given default
$EE_n^*(t_j)$ = risk-neutral discounted expected exposure
$q_n^*(t_{j-1}, t_j)$ = risk-neutral marginal default probability

$$\text{bilateral CVA: } BCVA = +\sum_{n=1}^{N} LGD_n^* \times \sum_{j=1}^{T} EE_n^*(t_j) \times q_n^*(t_{j-1}, t_j) \times S_I^*(t_{j-1}) - \sum_{n=1}^{N} LGD_I^* \times \sum_{j=1}^{T} NEE_n^*(t_j) \times q_I^*(t_{j-1}, t_j) \times S_n^*(t_{j-1})$$

Topic 36

$$\text{weighted average life (WAL): } WAL = \sum (a / 365) \times PF(t)$$

$$\text{constant prepayment rate: } CPR = 1 - (1 - SMM)^{12}$$

Using the Cumulative Z-Table

Probability Example

Assume that the annual earnings per share (EPS) for a large sample of firms is normally distributed with a mean of $5.00 and a standard deviation of $1.50. What is the approximate probability of an observed EPS value falling between $3.00 and $7.25?

If EPS = x = $7.25, then z = (x – μ)/σ = ($7.25 – $5.00)/$1.50 = +1.50

If EPS = x = $3.00, then z = (x – μ)/σ = ($3.00 – $5.00)/$1.50 = –1.33

For z-value of 1.50: Use the row headed 1.5 and the column headed 0 to find the value 0.9332. This represents the area under the curve to the left of the critical value 1.50.

For z-value of –1.33: Use the row headed 1.3 and the column headed 3 to find the value 0.9082. This represents the area under the curve to the left of the critical value +1.33. The area to the left of –1.33 is 1 – 0.9082 = 0.0918.

The area between these critical values is 0.9332 – 0.0918 = 0.8414, or 84.14%.

Hypothesis Testing – One-Tailed Test Example

A sample of a stock's returns on 36 non-consecutive days results in a mean return of 2.0%. Assume the population standard deviation is 20.0%. Can we say with 95% confidence that the mean return is greater than 0%?

H_0: $\mu \leq 0.0\%$, H_A: $\mu > 0.0\%$. The test statistic = *z*-statistic = $\frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}}$ = (2.0 – 0.0) / (20.0 / 6) = 0.60.

The significance level = 1.0 – 0.95 = 0.05, or 5%.

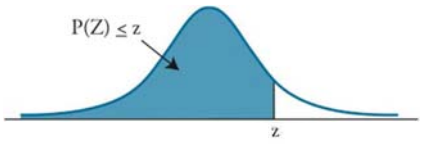
Since this is a one-tailed test with an alpha of 0.05, we need to find the value 0.95 in the cumulative *z*-table. The closest value is 0.9505, with a corresponding critical *z*-value of 1.65. Since the test statistic is less than the critical value, we fail to reject H_0.

Hypothesis Testing – Two-Tailed Test Example

Using the same assumptions as before, suppose that the analyst now wants to determine if he can say with 99% confidence that the stock's return is not equal to 0.0%.

H_0: $\mu = 0.0\%$, H_A: $\mu \neq 0.0\%$. The test statistic (*z*-value) = (2.0 – 0.0) / (20.0 / 6) = 0.60. The significance level = 1.0 – 0.99 = 0.01, or 1%.

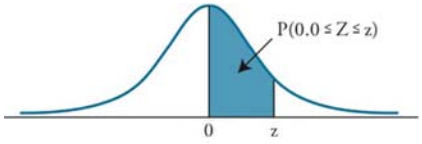
Since this is a two-tailed test with an alpha of 0.01, there is a 0.005 rejection region in both tails. Thus, we need to find the value 0.995 (1.0 – 0.005) in the table. The closest value is 0.9951, which corresponds to a critical *z*-value of 2.58. Since the test statistic is less than the critical value, we fail to reject H_0 and conclude that the stock's return equals 0.0%.



Cumulative *Z*-Table

$P(Z \leq z) = N(z)$ for $z \geq 0$
$P(Z \leq -z) = 1 - N(z)$

z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.937	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.983	0.9834	0.9838	0.9842	0.9846	0.985	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.989
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.994	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990



Alternative *Z*-Table

$P(Z \leq z) = N(z)$ for $z \geq 0$
$P(Z \leq -z) = 1 - N(z)$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3356	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4939	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990

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