WORLD BANK WORKING PAPER NO. 62

What Determines U.S. Swap Spreads?

Adam Kobor
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Abstract

This paper examines the evolution of the U.S. interest swap market. The authors review the theory and past empirical studies on U.S. swap spreads and estimate an error-correction model for maturities of 2, 5, and 10 years from 1994 to 2004.

Financial theory depicts swaps as contracts indexed on London interbank offered (LIBOR) rates, rendered almost free of counterparty default risk by mark-to-market and collateralization. Swap spreads reflect the LIBOR credit quality (credit component) and a liquidity convenience premium present in Treasury rates (liquidity component). Multifactor models that were estimated on observed swap rates highlighted the central role played by the liquidity component in explaining swap-spread dynamics over the past 15 years. The multifactor models also found some puzzling empirical results. Statistical models, on the other hand, based mainly on market analysis, faced technical difficulties arising from the presence of regime changes, from the nonstationarity in swap spreads, and from the coexistence of long-term and shorter-term determinants.

Against this background, the authors apply an error-correction methodology based on the concept of cointegration. They find that U.S. dollar swap spreads and the supply of U.S. Treasury bonds are cointegrated, suggesting that the Treasury supply is a key determinant on a long-term horizon. The authors estimate an error-correction model that integrates this long-term relationship with the influence of four shorter-term determinants: the AA spread, the repo rate, the difference between on-the-run and off-the-run yields, and the duration of mortgage-backed securities. The error-correction model fits observed swap spreads quite well over the sample period. The authors illustrate how the same model can be used to carry out scenario analysis.

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CHAPTER 1

Introduction

This paper studies the determinants of U.S. Dollar (US$) interest rate swap spreads from 1994 to 2004 and presents an econometric model based on this analysis.

Since they were introduced in the early 1980s as a financial innovation—the World Bank was credited with pioneering the swap contract in 1981—swaps have grown into a very mature and central market with unparalleled size and growth. Their $164 trillion outstanding notional, as reported by the International Swaps and Derivatives Association (ISDA) for the first half of 2004, dwarfs the $31 trillion aggregated principal of all world bond markets[1] taken together. The most familiar types—interest rate and currency swaps—regularly perform crucial functions for a wide array of users.

Swaps constitute the most common instrument in asset-liability management and in portfolio and debt management. They are essential for hedging, investing, and borrowing. They are also widely used as a benchmark, as an index, and as an underlying asset for options—witness the size of the swaption market. Swaps are customarily used by banks, industrial firms, institutional investors, and sovereign debt managers. Euro and dollar swap curves represent a primary source of information in developed markets.

These multiple uses and users reflect swaps' comparative advantage and provide ample evidence of their status as a valuable and nonredundant financial instrument.[2] Like other

1. 2002 estimate of all world bond markets at the end of 2001 as published by the investment bank Merrill Lynch.

2. There long has been a discussion among academics to determine whether swaps added some net value to a financial market or if they should be considered a redundant security. Turnbull (1987) contributed notably to the debate in arguing that, in a perfect and complete market, swaps merely consisted in a "zero sum game."

derivatives, swaps broaden the choices available to economic agents when borrowing money, preserving and transferring value over time, accepting or avoiding risk. However, and unlike options, the value of swaps does not derive from the price of another, underlying asset. Swaps themselves constitute an asset, a commodity, more akin to a Treasury bond than to a derivative. The swap spread, or the price of swaps relative to Treasuries, cannot be captured in a pricing formula but results instead from the joint equilibrium of bond and swap markets.

Due to their wide use, swap spreads and their fluctuations have a decisive impact on some of the most essential financial operations. For an issuer of bonds based on the London interbank offered rate (LIBOR) systematically swapping its debt into floating at issuance, the relative evolution of the swap spread versus its own spread against Treasuries will result in its final funding cost as measured against the LIBOR curve (or swap curve). A sovereign debt manager, examining whether to reduce the duration of the public debt by engaging in a series of fixed-rate-receiver swaps, will base the decision on a thorough analysis of the medium-term evolution of swap spreads. In both cases, the ability to deliver a valid assessment of the spread level and a correct forecast of its future path has very significant implications.

Swap-spread movements therefore may have serious financial consequences. As swap markets have been characterized by a much heightened volatility during the past 10 years, researchers and analysts, not surprisingly, have been paying much closer attention to swap markets' determinants. However, the available theoretical and empirical results remain rather sparse.

The term structure of interest rates—that is, of credit-risk-free rates—has been the subject of an intense research effort since the onset of modern finance. More recently, with the expansion of spread markets and the attention placed on credit risk in the 1990s, many theories have been developed for pricing corporate defaultable bonds and credit derivatives. Against this backdrop it may seem that swaps have been somewhat left aside. The very hybrid nature of swaps—neither Treasury nor corporate bond—might account for this apparent neglect, which contrasts sharply with swaps' primordial role in global markets.

Academics have focused on two fundamental factors embedded in swap spreads. One is credit risk. It is now generally recognized that the credit risk in swap rates does not originate simply from the default risk on a counterparty. But the conceptualization of the credit-risk factor and its influence on the swap rate are still largely in debate. A second factor is liquidity. Treasuries may incorporate a premium relative to swaps stemming from their multiple uses, notably the possibility of raising cash at a low cost through repos. Several articles have discussed modeling of the credit and the liquidity factors, their evolution over time, and their influence on swap spreads. But the results obtained in confronting these models to empirical data were not conclusive, and one of the most influential papers in this field stated that a deeper understanding of the dynamics of supply and demand in swap markets was necessary.[3]

3. See Duffie and Singleton (1997), a seminal article aimed at modeling the credit and liquidity components in swap spreads and at analyzing their evolution over time. Other papers pursuing the same objective with the same methodology reported puzzling results (Longstaff and Mandell [2002]).

Investment bank research took an alternative approach, abstracting from or shortcutting theory, and designing econometric models that would deliver good short-term forecasts to their clients or, more crucially, to their proprietary trading desks. Their publications reflect this very pragmatic stance. These papers first identify several potential drivers of swap spreads based on elementary economic intuition or on the close observation of market dynamics. They then apply various econometric techniques, including some of the most sophisticated, to achieve the most accurate forecast. In such a purely statistical approach, the data, the sample period, and the judicious choice of methodology and its proper implementation are obviously crucial. Some studies pointed to a series of trends that have governed swap spreads over the past 10 years. A few publications applied the methodology generally considered most appropriate in such contexts. Based on the concept of cointegration, this methodology requires that the specification and the estimation of the long-term trend and the short-run fluctuations around this trend be separated. Chapter 3 of this paper details how we modeled U.S. swap spreads by applying this methodology in its entirety—something which, to the best of our knowledge has not been done thus far.[4]

Our approach is closer to that of investment bankers, being essentially a statistical approach. But our objective is to understand the fundamental forces driving swap spreads; hence, the need to review carefully the theory on swaps and, equally, to rely on a close analysis of the actual functioning of swap markets. Our identification of a priori determinants, outlined in the following Chapter, emerges from these two angles of approach. We wish to explain the movements in swap spreads over the past 10 years based on a sound methodology and a good fit to observed data. The ability to identify swap spread drivers and to predict correctly from their projected values is certainly a key requirement to our modeling. But our priority is to highlight the economic forces driving the spread rather than to deliver highly accurate, trade-oriented forecasts that would come at the expense of a meaningful economic interpretation.

The paper is organized as follows. Chapter 2 examines potential swap spread determinants based on theory and on the retrospective analysis of swap spreads fluctuations over the past 10 years. Chapter 3 reviews the available empirical studies on swap spreads. Chapter 4 discusses the methodology and presents the error-correcting model that is estimated on the period from 1994 to 2004. Chapter 5 presents and comments on the study's empirical results, and provides an illustration of how the model can be used to conduct scenario analyses.

4. We found that the cointegration—error-correcting model—methodology has been fully applied by some papers modeling euro swap spreads. In the case of dollar swap spreads, Kurpiel (2003) makes use of the notion of cointegration, but his paper does not contain a restitution of the application of the whole method.

CHAPTER 2

A Priori Determinants

Theory

Swap spreads are defined as the difference between the yield of an interest rate swap and the yield on a Treasury note of the same maturity.

Swap spreads express a relative price. Accordingly, financial theory has been concerned with the investigation of the structural differences between swaps and government bonds taken as alternative financial assets. Swaps and bonds exhibit identical sensitivities to changes in their respective rates (a swap can be thought of as a fixed rate bond funded by the short sell of a floating rate note). They have the same type of market risk.

However, swaps and bonds differ markedly in terms of credit risk. Government bonds carry their idiosyncratic default risk (in this paper we assume the risk is nonexistent in the case of the U.S. Treasury). Swaps contain the credit risk embedded in the LIBOR index paid on the floating leg and, potentially, a counterparty default risk. The two financial instruments also differ considerably in terms of liquidity. Liquidity has separate determinants on swap and Treasuries markets. Moreover, Treasuries perform a series of unique functions in financial markets that gives them a status very close to cash.

Abstracting from the comparison with government bonds, swaps can be analyzed as a bilateral contract whose institutional features considerably matter in understanding its nature and interpreting its spread (see Box 1).

Next we review how theory moved into considering swaps as default–risk-free contracts; how the embedded liquidity and credit-risk components were conceptualized; the subsequent formulation of multifactor stochastic models of the swap-term structure; and how recent analyses shed new light on the impact of default–risk-mitigation techniques. We conclude the Chapter by presenting an alternative approach of swap rates based on the structure of the swap market.

Box 1: Institutional Features and Market Conventions in Swap Markets

The "plain vanilla" interest-rate swap (IRS) consists of exchanging at the end of every quarter a three-month LIBOR interest (with the LIBOR rate determined at the beginning of the quarter) against a fixed rate (the swap rate) interest computed on the same notional. Periodicity of payments and reference indices can vary (six-month, one-year). Most common maturities are 2-, 3-, 5- and 10-year. Swap rates or spreads are quoted on broker screens in Bloomberg, Reuters, and Telerate for various generic maturities. The usual bid offer is around four basis points, and the quotes are for the mid-rate and spread. As they are indicative, it is not possible to know the rate at which a particular swap has been actually traded.

Most swaps are between a swap dealer and a swap end-user who is not a dealer. Swap dealers play a key role, not only as brokers facilitating the transactions but also in warehousing the interest rate risk imbedded in swaps, typically hedging their risk in the futures or repo markets.

All swap contracts are documented using the standard ISDA swap legal documentation, which is updated regularly (the 2002 ISDA is currently in use).

Swaps are valued as a portfolio of LIBOR forwards with net cash flows present valued using the swap-LIBOR zero coupons. Forward rates are implied from the quotations available for LIBOR futures rates adjusted for convexity. Interest rate swaps exhibit convexity (the sensitivity of their price to changes in rate is a nonlinear curve), whereas LIBOR futures contracts have no convexity.

At inception swaps have no value. The counterparty for which the swap value becomes positive has a credit exposure on the other counterparty equal to the value of the swap.

Several contractual clauses and practices substantially mitigate default risk. Most participants in the market and dealer banks have minimum rating requirements for their counterparties. Swaps are marketed on a regular basis (monthly or even daily between swap dealers). The counterparty with a negative value has to deliver an amount in collateral (most usually cash or Treasury bonds) proportional to the value of the swap as per the Credit Support Annex of the ISDA contract. The collateral requirements are normally tightened in the event of a downgrading. Swap dealers exchange collateral daily on the basis of their netted global positions with the clearing system Swapclear.

Swaps as Contracts Free of Counterparty Default Risk

Initially, most researchers proposed to analyze swaps as financial contracts on which counterparties could potentially default. Solnik (1990), Cooper and Mello (1991), Sundaresan (1991), Sorensen and Bollier (1994), and Baz and Pascutti (1996) offer examples of such default-based theories.[5] Many researchers used the concepts elaborated for pricing credit risk in credit derivatives or defaultable bonds. However, empirical studies such as the one by Sun, Sundaresan, and Wang (1993) tended to suggest a relatively small impact of counterparties ratings on swap rates. Duffie and Huang (1996) argued that the impact of default risk tended to be overstated. They produced a model with a numerical application providing evidence of an extremely small impact of counterparty credit risk on swap rates.[6]

As swap markets matured in the 1990s, financial theory moved toward considering swaps as contracts that were virtually free of any default risk. Based on extensive first-hand

5. See also Longstaff and Schwartz (1995). Koticha (1993) and Mozumdar (1996) analyze the impact of the slope of the yield curve on the default risk in swaps.

6. Huge and Lando (1999) presented an extended version of the model of Duffie and Huang (1996) in which they applied a rating-based model borrowed from the credit–risk-pricing methodology (Jarrow and Turnbull [1995]). They could retrieve the results of Duffie and Huang (1996), but also showed how a change in the specification of the rating transition could alter the conclusion and make the rating of each party in a swap relevant again.

experience, Litzenberger (1992) examined in detail the credit–risk-mitigation techniques used in the swap industry (e.g., monthly or daily mark-to-market, collateralization, termination options for long-dated swaps). On this basis he claimed that there was no reason why swap spreads should be sensitive to counterparties' credit quality, notably because swap dealers were not considering credit risk when quoting on a swap, at least not for entities rated single A or higher. Weaker counterparties would be denied access to the swap market or experience very tight collateral requirements.

Credit and Liquidity Components in Swap Spreads

The Liquidity Component. Grinblatt (1995) assumes that swaps are free of default risk from the outset and develops a model to explain how swap spreads are generated by a Treasury liquidity advantage only. Treasuries include what Grinblatt refers to as a liquidity-based convenience yield stemming from two essential functions they perform. Treasuries are often the preferred instruments to hedge interest rate–sensitive products, in particular corporate bonds and swaps. In addition, Treasury bonds, when repoed, give access to the cheapest source of funds. The liquidity-based convenience yield is specified as a stochastic factor determining swap spreads, an approach used in subsequent papers such as Duffie and Singleton (1997). While Grinblatt acknowledges that his model could be improved (the question of the specialness in the repo market is not addressed), his theory has proven one of the most relevant in explaining swap spreads.

The Pricing of Swaps. Swaps can be priced as portfolios of LIBOR-forward contracts (Smith and others [1988], Sundaresan [1991]). The successive payments in an interest rate swap can be replicated by a series of LIBOR-forward rate agreements maturing on the swap payment dates. While there are no publicly available quotes for LIBOR forwards, especially for long-dated contracts, these rates can be derived from the Eurodollar future prices, available for maturities up to 10-year. Forward LIBOR rates are then computed as the value of Eurodollar futures rates minus a "convexity adjustment." A Eurodollar future contract displays a linear sensitivity to the forward rate (the payoffs in the contract are linear functions of rates). Moreover, thanks to an exchange implementing a system of margin calls, the gains and losses are settled instantaneously. The same position in a forward exhibits a convexity, similar to the purchase of a zero coupon bond to the maturity of the forward contract, as demonstrated in Cox, Ingersoll, and Ross (1981). Whereas, a future instead can be thought of as rolling over a short-term placement. Cox, Ingersoll, and Ross (1981) prove that, if there is a negative correlation between the value of the forward contracts and the price of the discount factors, then the difference in convexity places forward rates below futures rates, a relation that has been verified empirically. Taking the values of the Eurodollar futures as proxies for the forward LIBORs, therefore, leads to an overestimation of the swap rate. Gupta and Subrahmanyam (2000) report empirical evidence suggesting that swaps may have been priced with future prices (unadjusted for convexity) in the earlier part of their 1987–1996 sample period. In the latter part, market rates drifted below the swap rate implied by a portfolio of futures[7] and towards a portfolio of forwards.

7. In the empirical study of Minton (1997), observed market swap rates are not perfectly correlated with portfolio of futures.

The Conceptualization of Credit Risk in Swaps. As financial theory evolved toward considering swaps as quasi default–risk-free, more attention was devoted to the treatment of credit risk in modeling and pricing.

Valuation formulae show explicitly how the credit spread in swap rates originates from the stream of LIBOR-indexed payments on the floating leg. LIBOR is itself a short-term and default–risk-imbedded interbank lending rate, or more precisely, the average of offered rates provided by 12 banks selected to constitute a homogeneous sample representative of the banking sector credit quality. The LIBOR rate thus maintains the same LIBOR-homogeneous credit quality over time. Duffie and Singleton (1997), and several subsequent articles by other authors, treat swap rates as rates applicable to a bond issuer that would keep the same LIBOR-homogeneous credit quality over time.[8] Pointing to the fact that swap counterparties are supposed to maintain the same LIBOR credit status over time, Duffie and Singleton (1997) refer to the *refreshed* LIBOR-homogeneous credit quality in swap rates. The discount factors they apply to swap cash flows are also derived from the LIBOR rate. As a result, their paper really constitutes a theory of the LIBOR–swap curve conceived as a second-term structure parallel to the term structure of (credit–risk-free) interest rates.

Multifactor Affine Models of the Swap-Term Structure

Duffie and Singleton (1997) construct a two-factor affine model of the swap term structure based on the reduced-form credit risk methodology presented in an earlier study that was eventually published in Duffie and Singleton (1999). Exponential affine expressions for swap-zero coupons are computed from a credit and liquidity adjusted short-term rate (equal to the default–risk-free short-term rate plus a credit-and-liquidity spread), which is assumed to keep a refreshed LIBOR credit quality over time. They estimate their model on U.S. swap rates data using a maximum likelihood methodology. While their model fits the long end of the swap curve quite well, they concede that their specification should be enriched to obtain a better fit of the entire curve. The methodology outlined in Duffie and Singleton (1997) rapidly has become a standard applied by numerous subsequent studies (He [2000]; Liu, Longstaff, and Mandell [2001]; Collin-Dufresne and Solnik [2001]; Johannes and Sundaresan [2003]).

Liu, Longstaff, and Mandell (2001) estimate a five-factor affine model à la Duffie and Singleton for both the swap and the risk-free term structure on U.S. swap rates data, with the objective of measuring the credit-risk premium and explaining its evolution. Their model fits observed data quite well over their sample period. They observe the model's implication that the instantaneous credit-and-liquidity-spread is much more correlated with liquidity proxies than with credit-risk proxies. Having computed the credit-risk premium component inherent in swap rates, the authors find that this component varies quite significantly and actually exhibits negative values for six consecutive years within their sample period. In view of such puzzling results, Liu, Longstaff, and Mandell (2001) conclude that liquidity factors as described in Grinblatt (1995), as well as swap–market-specific components, should be added to the model.

8. Duffie and Singleton (1997) and subsequent papers assume that (a) credit risk is exogenous and is not related to the credit quality of the counterparties or the market value of the swap and (b) swap counterparties have the same refreshed LIBOR-homogeneous credit quality.

He (2000) designs and estimates a three-factor model along the same lines and reports evidence about changes in the shape of the swap yield curve from 1998 to 2000. He (2000) finds that those changes correlated with specific events affecting the liquidity-based convenience yield (Grinblatt [1995]), such as the announcement of a U.S. Treasury buyback program in the beginning of 2000. He (2000) thus complements Liu, Longstaff, and Mandell (2001) in underlining the importance of the liquidity component in swap spreads.

The Impact of Counterparty Default Risk Revisited

Swaps tend to form a unique category of credit–risk-embedded instruments. Although generally considered as quasi default–risk free, swap rates differ from Treasury rates. As was seen earlier, swaps traditionally have been valued as portfolios of forward LIBOR contracts or, alternatively, as par bonds issued by borrowers maintaining the same refreshed LIBOR credit quality over time (Duffie and Singleton [1997]). Collin-Dufresne and Solnik (2001) model the spread between swaps and LIBOR bonds, which are issued by borrowers having the LIBOR credit quality, yet only at inception. Contrary to swaps, LIBOR bonds have a future possible credit deterioration imbedded in their spread.[9] Collin-Dufresne and Solnik (2001) also insist on the consequences of treating swaps as default-free instruments. While swaps indexation does reflect a refreshed LIBOR credit spread, their cash flows should be discounted using the risk-free rates (He [2000] makes the same choice).

Johannes and Sundaresan (2003) argue that there is a logical contradiction in stating that the counterparty credit risk can be eliminated from swap contracts at no cost. In their swap model, they integrate the stochastic cash flows associated with the posting and receiving of collateral, assuming the costs and benefits of these cash flows are measured by a "cost-of-collateral instantaneous rate"(y). Under this assumption,[10] Johannes and Sundaresan (2003) establish that the discount factors applicable to swap cash flows are generated by an instantaneous collateral-adjusted rate $r - y$ (r minus y, r being the short-term risk-free rate).[11] The paper shows that stochastic collateral payments play a role identical to the margin calls in futures contracts, and that their impact is determined, accordingly, by the covariance between $r - y$ and LIBOR (a result reminiscent of Cox, Ingersoll, and Ross [1981]). This theory predicts that observed swap rates should stand above the rates implied by the portfolio of forward LIBORs and below the rates obtained from equating a swap with a portfolio of future contracts. Johannes and Sundaresan (2003) bring empirical evidence supporting this view.[12]

An approach taken by Bomfim(2002) tests the robustness of the credit mitigation techniques used for swaps (collateralization, mark-to-market) at times of market stress.

9. By the same argument, swap spreads should therefore capture market expectations, at the horizon of the swap maturity, of a deterioration in the LIBOR (that is, in the banking sector) credit quality.

10. Johannes and Sundaresan (2003) also model the protection offered by collateral in the event of a default. Since they assume that the swap is collateralized for its full value at all times, the possibility of a default only makes the maturity of a swap uncertain.

11. If the cost of posting and receiving collateral is measured by the instantaneous risk-free rate; then swaps become equivalent to portfolios of futures.

12. Taking data from the Eurodollar futures from 1994 to 2002, they estimate refreshed-LIBOR term structures to compute swap rates consistent with the portfolio of forward model. They verify empirically that actual swap rates stand between futures-implied and forward-implied swap rates.

Over the period from 1993 to 2002, Bomfim (2002) compares swap dealers' quotes (midmarket) with "synthetic" swap rates resulting from the traditional identity made between swaps and portfolios of forward LIBORs. Bomfim (2002) estimates forward LIBORs from quoted futures contracts relying on different models to calculate the convexity adjustment. He finds no significant difference between swap-market rates and "synthetic" rates, a result hinting at the robustness of the credit mitigation techniques currently in use.

Taken together, these two recent articles suggest that more attention should be devoted to the impact of collateralization mechanisms. As suggested in Johannes and Sundaresan (2003), further research should consider that swap spreads are impacted as much by collateral management aspects as by the traditional credit and liquidity factors.

Market–Structure-Based Approaches

Lang, Litzenberger, and Liu (1998) argue that differences in credit quality among borrowers determine the demand for swaps. Based on an idea expressed by Arak, Goodman, and Silver (1988), Flannery (1986) and Titman (1992), Lang, Litzenberger, and Liu explain why "good" and low-rated (single-A) firms owning private information on future-favorable credit prospects will prefer to borrow short-term and swap their floating rate liability with long-term fixed rate. The swap hedges their exposure to the short-term rate volatility. They can benefit from a potential future narrowing of their spread when the favorable business prospects they had awaited for materialize. "Bad" single-A firms, on the other hand, would rather lock in a long-term fixed-rate borrowing. Swaps then create a surplus for "good" firms, enabling them to signal themselves and to differentiate themselves from the "bad" firms.

This surplus will be even more needed when A spreads widen. Abstracting from the intermediation by swap dealers, Lang, Litzenberger, and Liu (1998) consider that A firms, when transacting swaps, will face directly AAA agencies with complementary needs, as they swap into floating the fixed rate bonds they issue. Lang, Litzenberger, and Liu (1998) argue that AAA agencies will attempt to widen the swap spread to capture a fraction of the surplus created by swaps, especially as their own funding spread comes in. Those authors therefore predict that both A and AAA spreads are related positively to swap spreads, a hypothesis they support with empirical data.

Swap Markets in a 10-year Retrospective

Over the period from 1994 to 2004, while reflecting a series of major events, swaps have completed their evolution toward a mature market with a central place in the global financial system. At the same time, swaps also may have turned into a generic instrument, becoming a commodity closer in status to Treasuries than to other types of derivatives. Such an evolution may have prompted a regime change in the swap market.

Swap Spreads as a Mirror of Major Events, 1994 to 2004

From 1994 to 2004, swap spreads went through a series of dramatic moves for which there exists a commonly accepted narrative (see Box 2 and Figure 1).

Box 2: Swap Spreads from 1994 to 2004: A Narrative

From 1994 to 2004, U.S. swap spreads have followed a succession of directional trends, each governed by specific economic regimes. Most commentators agree on the following synopsis.

In a first period preceding the crisis of 1997–98, swap-spreads levels and volatilities were low, manifesting a commonly shared appetite for trading and a general neglect for market and credit risks. Active proprietary desks in banks and large hedge funds kept volatility in check. The outbreak of the 1997 Asian crisis prompted investors to revise drastically their assessment of credit risk. In August 1998, at the time of the Russian crisis and the near collapse of the LTCM (Long Term Capital Management) hedge fund, as a massive flight to safe liquidity unfolded, soaring swap spreads gave a global measure of the abnormally large premium paid for holding Treasuries. Simultaneously the exit of several large players arbitraging swaps in search for relative value led to a significant and durable increase in the spread volatility (see Figure 3).

By mid-1999, as markets overcame the traumas of the financial crisis, swap spreads were kept from reverting to lower levels by alleged concerns over potential Y2K disruptions. At the beginning of 2000, after the announcement of a large U.S. Treasuries buyback program, markets became suddenly concerned with the prospects of a decline in the stock of government bonds. Accordingly, Treasuries started benefiting from a substantial scarcity premium relative to all assets. Swaps reflected the widening of all spreads beyond their 1998 levels. This widening cycle came to an end in December 2000 as the U.S. economy started slowing down.

The associated structural reversal in the U.S. policy mix marked the starting point of a sustained tightening phase that lasted until June 2003, hardly interrupted by the September 11, 2001 attack. Two major facts led to the compression of the swap spread: the Federal Funds rate moving down rapidly from 6.5 percent in December 2000 to a low of 1 percent in June 2003; the swiftly reactivated fiscal policy turning the four-year 1998–2001 era of fiscal surpluses ($237 billion in 2000) into three consecutive years of deficit ($158 billion in 2002, $400 billion on average in 2003–2004).

In summer 2003 another major determinant appeared. The increase in the 10-year Treasury yield forced mortgage investors to unfold their convexity hedges rapidly. As they asked dealers en masse for fixed-rate payer swaps, the 10-year spread jumped from 42 to 65 basis points in a few days.

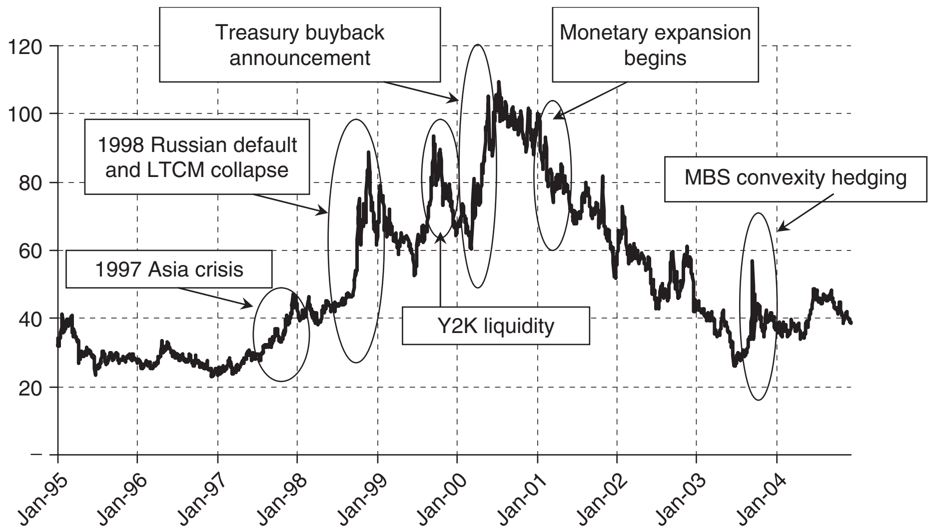
We are now at the onset of a new cycle, with an economic policy geared toward monetary tightening and heightened concern for the fiscal deficit. One can observe that the current low levels in spreads and volatility, against the backdrop of a relentless search for yield, resemble the pre-1997 period described at the beginning of this narrative. This similarity highlights the need for a deeper understanding of swap-spread determinants.

Toward a Mature Swap Market

Throughout the decade from 1994 to 2004, along with a very noticeable heightened price volatility, the swap market experienced a sustained 30 percent annual growth rate. The total outstanding swap notional was estimated by the ISDA[13] to be $164.4 trillion in the first half of 2004, towering above both the U.S. Treasury market and the global bond market (around $31 trillion bonds outstanding).

13. The ISDA promotes the development of swap markets mainly through the adoption of market conventions benefiting their participants, be they dealers or end-users.

Figure 1. Evolution of Swap Spreads and Major Events, 1994 to 2004



During this time, more participants joined in, including new classes of end-users. Industrial firms and banks had long hedged their interest rate and currency risks with swaps. Toward the end of the 1990s an increasing fraction of portfolio managers came to consider swaps as an asset class in its own right. Several governments—in the euro area notably—started to engage in swaps, seeking to achieve a more efficient management of their public debt. In the U.S., mortgage investors and the federal agencies ("Fannie Mae," "Freddie Mac") invested in Treasuries or swaps without differentiating, to hedge the negative convexity of their mortgage portfolios.[14]

Swap markets became more attractive to more participants as swaps increasingly were regarded as safer, more transparent, and more standardized after the latter half of the 1990s. Several facts signaled such a change.

First, the constant effort to streamline the standard ISDA legal documentation led to a stable and robust definition of the swap contract. After 1995, the ISDA introduced general rules for the use of collateral in the form of a standard annex to the swap "ISDA" master agreement between counterparties (the Credit Support Annex). A majority of swap users now customarily rely on collateral management, whose practical effect is to eliminate counterparty default risk. At the same time, market risk management has been considerably improved by swap dealers. Following notably the publication of the Bank for International Settlements (BIS) "Supervisory framework for derivatives activities" in 1995, swap dealers

14. The prepayment option given to the mortgage borrower means that the mortgage lender has written an option on the purchase of the mortgage loan.

scaled up significantly their internal control systems and built up robust in-house risk-management capabilities. This risk management technology then spread among a large number of end-users. Finally, the competitive derivatives sector has gone through a selection process, eliminating weaker firms and concentrating swap trading among larger firms having adequate capital and resources.

The maturity of the swap market is also, to a large extent, a matter of perception. As swaps have been perceived as less risky and more friendly instruments, market participants have focused on their advantages and have extended their use. Swaps have become demanded as a commodity.

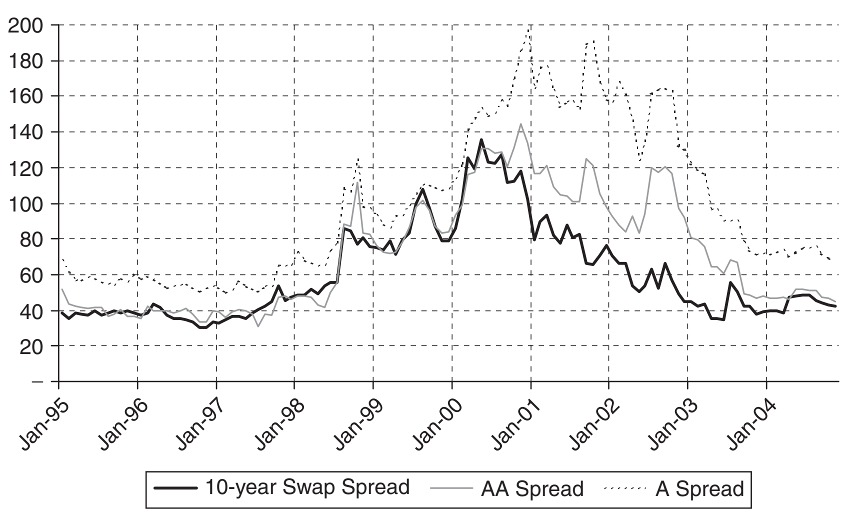
Swaps as a Commodity

Swaps do indeed have interesting and unique features: while being almost immune to default risk, their rate is tied to LIBOR, a credit-risky rate. As a result, swaps are both representative of investment-grade spread instruments and correlated with them (Figure 2).

This correlation makes swaps a very convenient and effective hedging tool. Many investors in credit-risky bond portfolios, funded and hedged by the short selling of Treasury bonds, suffered quite severe losses during the 1998 crisis: as their credit-risky bonds were losing value because of the increase in spreads, the flight to quality was pushing up the market prices of Treasury bonds. Those investors who had been losing on both sides (Haubrich [2004]) elected swaps as the appropriate instrument for hedging investment-grade portfolios.

Some observers pointed out that Treasury yields could go below their natural risk-free rate levels (Cooper and Scholtes 2001) in times of crisis or because of an alleged scarcity of Treasury bonds in times of fiscal surplus, as in 2000. The supply of swaps, alternatively,

Figure 2. Swap Spreads, AA Spreads, and A Spreads



could be assumed to be unaffected by such idiosyncrasies. The same study also showed that spreads of high quality issuers such as the World Bank or the European Investment Bank were much more consistent when measured against swaps than when measured against Treasuries. The swap curve has since become the natural benchmark for issuers, including European sovereign issuers, and for investors in spread products.

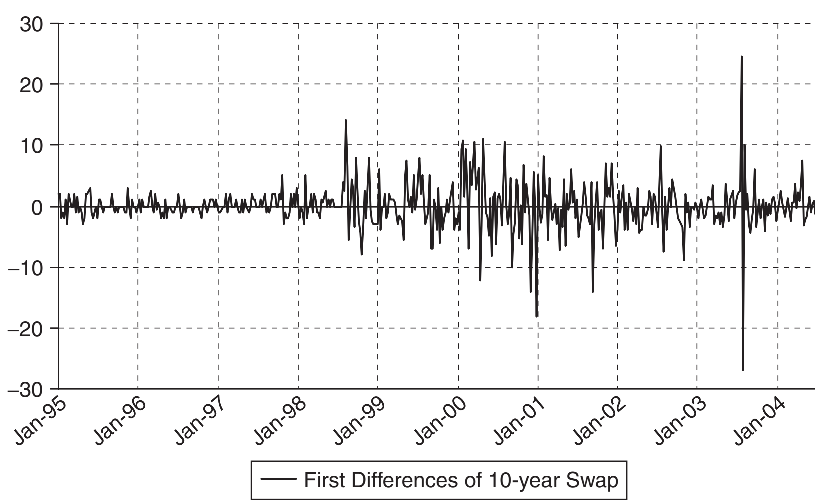
In summary, swaps, as a generic default-free credit-risk instrument, have become used as a commodity by market participants, a commodity whose price (*i.e.,* the swap spread) tends to be more affected by supply and demand consideration than by the price of an underlying instrument (as would be the case for a normal derivative). However, in at least one important aspect—electronic trading—recent developments in government bond markets have not been matched by a similar evolution for swaps. There has not been, thus far, a swap equivalent to the success of the two celebrated electronic platforms in government bond trading[15], MTS (the European sovereign bond platform, MTS stands for the Italian Mercato dei Titoli di Stato) and Trade Web.

These transformations in swap and Treasury markets seem to accompany a regime change, in the narrow sense given to this phrase in econometrics (Box 3).

Structural Changes in Swap Markets

Many observers believe that swap markets have undergone a regime change following the 1997–1998 crisis whereby the volatility of swap spreads increased remarkably. Figure 3

Figure 3. Post–1998 Increase in Swap Spread Volatility



15. Consistent with its traditional role as a catalyst for innovation in capital markets, the World Bank has developed its own proprietary platform, eswaps, on which it has started to trade all its stand-alone swaps since 2003.

Box 3: Regime-Switching Models

When analyzing an economic time series, the data-generating process often can be described by shifting regimes characterized by different parameters. For example, we often speak about *expansion* versus *recession* in the economy, or *bullish* versus *bearish* periods in the market. Regime-switching models enable us to separate these periods statistically and estimate the probability of an observation belonging to a given regime. Regime-switching models were first applied to macroeconomic analyses (Hamilton, 1989 and 1990), and now have become popular tools for risk analysis and asset pricing.

There is a methodological difficulty. Regime changes in financial markets cannot be observed directly. From a modeling point of view, the regime change itself is described as a stochastic process. In estimating a regime switching model, therefore, we have to estimate the conditional parameters of the distributions in different regimes, as well as those of the regime change process, simultaneously. If we assume that financial factor changes follow an *m*-dimensional normal distribution with expected values μ_i and covariance matrices Ω_i conditional on the regimes, the density function of series y_t is given by

$$f(y_t \mid s_t = i) = \frac{1}{(2\pi)^{m/2}\det(\Omega_t)^{1/2}} \exp\left\{-\frac{1}{2}(y_t-\mu_i)'\Omega_i^{-1}(y_t-\mu_i)\right\},$$

where s_t denotes the state or regime in period *t*. In the simplest way the switching of the regime s_t can be expressed as Markov-chain: let s_t be a random variable, which takes its values from the set of integer numbers of $\{1, 2,\ldots, N\}$, assuming an *N*-state Markov-chain. The probability of $s_t = j$ is assumed to depend only on the previous observation:

$$P\{s_t = j \mid s_{t-1} = i, s_{t-2} = k, \ldots\} = P\{s_t = j \mid s_{t-1} = i\} = P_{ij}$$

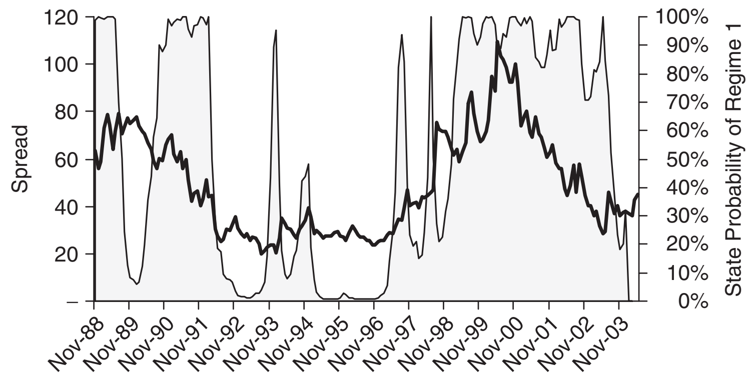
To describe the potentially distinct behavior of the swap spreads, we have estimated the parameters of a two-regime models based on monthly swap spread changes over the past 16 years. To estimate the parameters we have applied the maximum likelihood or *expectation maximization* technique described by Diebold, Joon-Haeng, and Weinbach (1994). In our analysis we assume that the monthly swap-spread changes ($y_t = S_t - S_{t-1}$) are not auto-correlated, and the conditional volatilities are time-independent. Figure 4 and the accompanying comments summarize our findings.

plots the volatility of swap spread changes from 1995 to 2004. While there is evidence of at least one structural change in market conditions after the 1997–98 crisis, it was important to submit this hypothesis to more robust tests taken from the regime-switching field (see Box 3).

The results suggest that the main distinctive parameter across different regimes is the volatility of the spread changes. Swap spreads in the mid-1990s and in some shorter periods from 1997 to 1999 changed smoothly, with lower volatility. On the other hand, spreads exhibited much higher volatility over the crisis periods of 1997–98 and most of the past five years. Figure 4 shows that swap spreads can belong to either one of two estimated regimes, one associated with high volatility (represented in grey) and one with low volatility.

Similarly, Apedjinou (2003) applies specific econometric techniques to detect structural breaks and formally identifies not only, as expected, the summer of 1998 as a regime change date, but also the months of February–March 2000. Reinhart and Sack (2002)

Figure 4. Regime-Switching Estimate



decompose the dynamics of the swap into four synthetic factors: 10-year risk-free rate, liquidity, credit, and idiosyncratic. Reinhart and Sack report that the influence of the idiosyncratic factor becomes much larger after 2001 without any specific reason but the fact that swaps become more widely used as hedging instruments.

A First Look at Potential Swap-Spread Determinants

Our study focuses on the potential determinants listed in Box 4.

All potential determinants in box 4 display some correlation with the swap spread. The Treasury supply appears to be a long-term driver, setting unambiguously directional trends either during the 1997–2000 (upward) or the 2000–2004 period (downward), rather than a factor in short run fluctuations (see Figure 5). Several studies[16] have made this assertion, which corresponds to the econometric concept of cointegration (Box 5). Chapter 4 reports on tests accrediting the swap spreads—Treasury supply cointegration hypothesis to support this conjecture with more rigorous evidence.

Among the a priori determinants in Box 4, the AA spread is the other variable yielding positive results in cointegration tests. The strong correlation with swap spreads, apparent in Figure 2, reflects a narrow influence over the medium long run.

Over shorter horizons, other factors, such as the slope of the yield curve, the repo rate, and the MBS duration display a very narrow correlation with the swap spread, apparently becoming at times the main driver.

16. Kocic and Quintos (2001), Kurpiel (2003).

Box 4: Swap-Spread Determinants

1. *Treasury Supply*. Since swap spreads measure the relative price between government bonds and swaps, the basic supply-and-demand–based rationale tells us that swap spreads should widen when the volume of outstanding Treasury bonds diminishes. Swap spreads should thus be influenced by the dynamics of fiscal deficit and government debt.

2. *AA Credit Spreads*. By virtue of the swap contract definition, the credit spread contained in LIBOR rates is also present in the swap spread. While swaps now tend to be considered as default–risk-free instruments, there is agreement about the fact that swap spreads are affected by the changing perception of credit risk over the long term, particularly in the AA-rated sector, as the majority of banks quoting LIBOR rates are AA rated. Alternatively the average spread on bonds issued by banks or the performance of banks stocks relative to the index can be considered.

3. *On-Off-the-Run Treasury Bond Yield Differential*. The difference in yield between on-the-run and off-the-run Treasuries constitutes a good indication of the "liquidity convenience yield" conceptualized in Grinblatt (1995). As evidenced in many empirical studies, this liquidity premium should remain as influential factor.

4. *The Slope of the Yield Curve.* Several econometric studies have identified the slope of the yield curve as one of the variables potentially driving swap spreads. In a steep curve environment the demand to be the fixed-rate receiver in a swap increases: fixed rate bond issuers are more inclined to swap new issues into floating; sovereign debt managers tend to reduce the duration of their outstanding debt (both ask to receive the fixed rate in a swap); institutional investors wish to benefit from the carry gain by entering in swaps; commercial banks are less inclined to hedge their short-term variable rate deposits (thus reducing the demand to be fixed-rate payers). All these modifications explain why a tightening of swap spreads can be expected as the yield curve gets steeper (see Kurpiel, 2003).

5. *The Repo Rate.* The repo rate influences the swap spread in two ways. One is the way swap dealers hedge the swaps they are entering in with counterparties by buying (or selling) a Treasury, and repo (or reverse repo) it over time. If the swap dealer is a net fixed-rate payer, then the carry cost of its hedged swap book is the difference between the LIBOR and the repo rate. The lower the repo rate the easier it becomes for the swap dealer to pay the fixed rate. But this supposes that swap dealers are net fixed-rate payers. The repo rate also represents the short-term rate, and changes in the repo rate tend to be correlated with changes in the slope of the yield curve, *i.e.,* a low repo rate means a steep yield curve and the impact on the demand for swaps is similar to the impact of the slope of the term structure. For example, Brown, Harlow, and Smith (1994) use overnight bond repurchase rate (repo) and the new issues of corporate bonds (as a measure of hedging demand).

6. *The Duration of Mortgage Backed Securities (MBS).* Mortgage borrowers have the right to prepay (and refinance) their loans, thereby holding an option. As the refinancing activity becomes more intensive as yields decrease, the duration of the MBS sector is therefore sensitive to changes in interest rates. Agencies and mortgage investors, which are therefore sellers of options, usually hedge against the convexity—the fluctuating duration—of their assets by holding assets which can be Treasury bonds or swaps. When rates decrease and refinancing occurs, investors counter the fall in MBS duration by entering swaps as fixed-rate receivers, thus tending to tighten spreads. An increase in rates and MBS duration tends to widen swap spreads. Due to the size of mortgage portfolios and of the MBS market, the effect of this hedging activity is expected to be significant.

7. *The Volatility of the Stock Index.* As in previous studies we used the VIX index, the implied volatility index for equity markets. A high stock market volatility reflects a more uncertain economic environment, which in turn affects credit spreads. Stock market volatility are also generally seen as a good indicator of the overall risk aversion in capital markets. Through both channels the VIX can be expected to determine swap spreads.

Figure 5. Ten-year Swap Spread and Treasury Supply

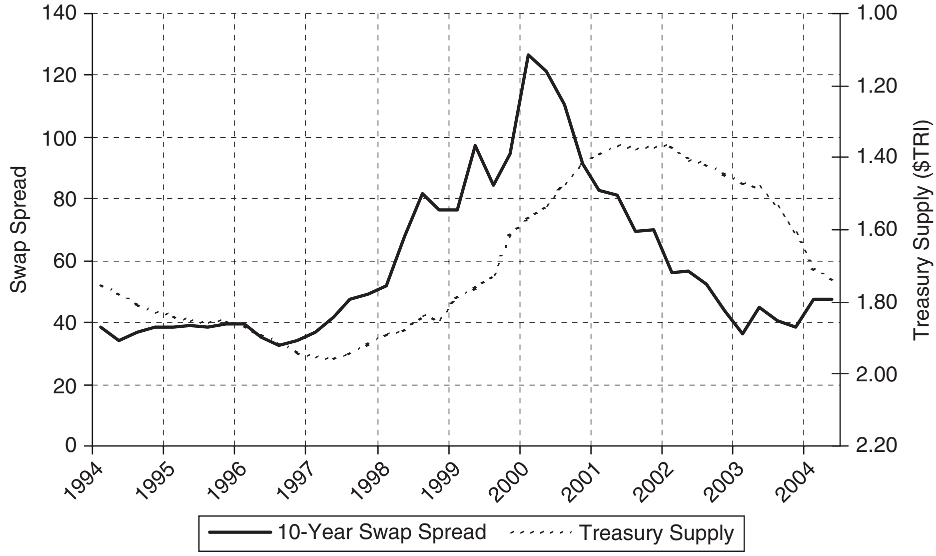
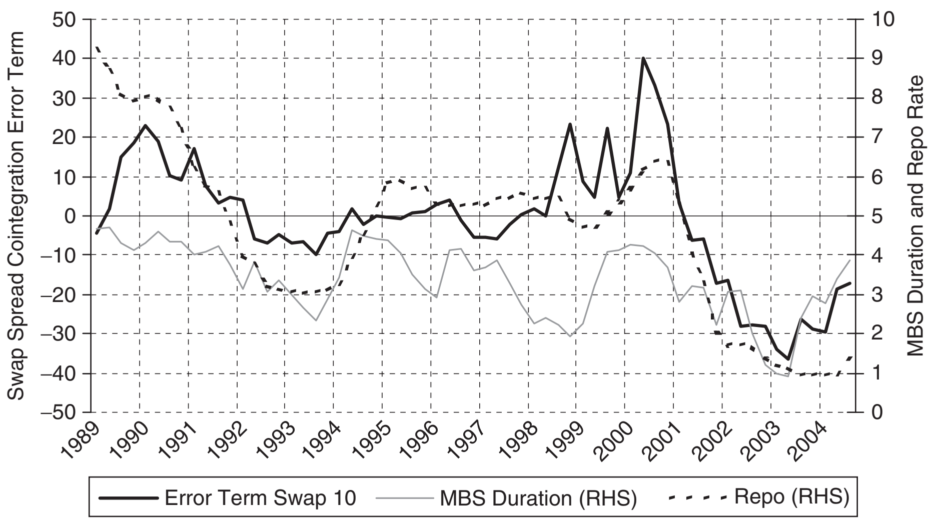


Figure 6 plots the 10-year swap-spread evolution once the influence of the government debt supply has been removed. This "de-trended" 10-year swap spread, computed as the residual term in a regression over the Treasury supply, corresponds to the first step of the implementation of the cointegration methodology outlined in later chapters (see also Box 6).

Figure 6. Detrended 10-year Swap Spread, Repo Rate, and MBS Duration



Box 5: How Much of the Swap Spread is Determined by the LIBOR-to-Repo Spread ?

There are many reasons to see the LIBOR to repo spread as a major force driving swap spreads. The LIBOR-repo spread reflects, in the short term, the two essential components in the swap spread: the LIBOR credit spread and the liquidity premium stemming from the possibility to fund in the repo market, at a cheap rate, the holding of a Treasury bond, particularly if it goes on special. In U.S. swap markets, it is common to hedge a swap with a Treasury bond either repoed or reverse repoed. The relation is not trivial, however, and crucially depends on assumptions made about credit risk.

A common assumption—call it Assumption A—is to consider that the credit risk in a swap always remains homogeneous to the credit risk of the LIBOR rate and that all cash flows should be discounted using discount factors derived from the LIBOR rate. Hence the formula (I) giving the swap rate at time $t = 0$.

$$E^*\left[\sum_{i=1}^{n}(S_n - L_{i-1})\exp\left(-\int_0^i R_s ds\right)\right] = 0 \qquad \text{(I)}$$

with the notations: E^* is the expectation under the risk neutral probability, L_{i-1} is the one-period (that is, 3-month or 6-month) LIBOR, R_s is the instantaneous LIBOR rate, L^*_{i-1} and N^*_{i-1}, are the forward value at time 0 of the one-period LIBOR and repo rates prevailing at time $i - 1$, S_n, T_n, are the par rate for the swap and the Treasury bond with maturity n, B_i and Z_i, are, respectively, the value at time 0 of a swap and a Treasury zero coupon with maturity i.

Replacing the LIBOR rates by their expression as functions of the instantaneous LIBOR rate, it can be shown that, under Assumption A, the swap rate is a weighted average of forward LIBORs, formula (II). The same relation in formula (III) relates the n-period Treasury rate to the forward values of the instantaneous risk-free rate (which we identify here with the repo rate).

$$S_n = \sum_{i=1}^{n} w_i L^*_{t-1} \quad \text{with} \quad w_i = \frac{B_i}{\sum_{i=1}^{n} B_i}, \qquad \text{(II)}$$

$$T_n = \sum_{i=1}^{n} w_i N^*_{i-1} \quad \text{with} \quad w_i = \frac{Z_i}{\sum_{i=1}^{n} Z_i} \qquad \text{(III)}$$

From (II) and (III) it is clear that the swap spread, $S_n - T_n$, cannot be expressed as a weighted average of forward LIBOR to repo spreads.

An alternative assumption—Assumption B—which has been analyzed by several researchers (He [2000], Collin-Dufresne and Solnik [2001], Johannes and Sundaresan [2003]) leads to discounting swap cash flows with the risk-free interest rate. Under Assumption B it becomes possible to relate the swap spread to the future values of the LIBOR to repo spread (He [2000]).

We did not find any evidence of a correlation between LIBOR–repo and swap spreads. Many studies reviewed in this paper made the same empirical observation. The LIBOR-to-repo spread typically remains very stable over time, periodically showing spikes which are rather technical by nature (see, for instance, He [2000]). Baz and others (1999) and Lehman (1999) also find that the LIBOR-to-repo spread is not significant in their regression models. Most models do not retain the LIBOR-to-repo spread as an explanatory variable.

One potential determinant, absent from our list in box 4, has a special status; it is generally supposed to strongly influence swap-spread dynamics, based on sound theoretical grounds, while in reality it does not play any role. It is the LIBOR-to-repo spread (see Box 5).

CHAPTER 3

Previous Empirical Works

This chapter reviews several econometric models designed to identify the economic variables driving swap spreads.

Diverse economic forces have been at play in succession over the past 15 years, each engendering a characteristic cycle. To identify the economic drivers of swap rates or swap spreads in a comprehensive and robust manner, it is important to work on a sample covering a sufficiently long period. In reviewing the existing studies we have tended focus on those covering 1990 to 2004 and spanning most of the major events.

Academic publications generally provide evidence of a particular hypothesis, such as a theoretical component present in swap rates or spreads (specifically, the credit risk or the liquidity premium). Investment banks tend to focus more on trading and forecasting performances of their models.

We first review models presented by academic researchers, then those made public by the dealer banks research teams.

Econometric Models Based on Financial Theory

The Duffie and Singleton (1997) model of the term structure of swap rates was fitted on U.S. weekly data covering the period from January 1988 to October 1994. In the same paper those authors proceed further and estimate an econometric model of the 10-year swap-zero spread computed as the difference between their model-implied 10-year zero swap rate and the 10-year zero coupon Treasury obtained with a statistical spline model. Consistent with their search for evidence of theoretical determinants, Duffie and Singleton (1997) run a four-variable Vector Auto-Regression (VAR) model including, along with the 10-year swap-zero spread, proxies for the credit risk and liquidity components present in swap rates. These are: the six-month Treasury bill yield (the economic cycle being closely related to the credit quality of firms); the spread between the repo on the on-the-run and the GC-repo, the repo on the generic Treasury note (the liquidity premium proxy); and the spread between AAA- and BBB-rated commercial paper rates. The authors find that the lagged values of the 10-year swap zero spread and of the on-the-run versus off-the-run repo spreads are the variables with the most significant explanatory power. The influence of the repo spreads is entirely consistent with Grinblatt (1995)'s theory of the liquidity convenience yield. Besides, a widening of the AAA-BBB commercial paper spread has a weak immediate impact but exerts a significant effect toward narrowing swap spreads after two years. The authors note, however, that the zero swap spread's own lagged values alone explain almost half of its variations. For Duffie and Singleton (1997), this autocorrelation calls for a deeper investigation of swap-specific supply and demand factors.

Liu, Longstaff, and Mandell (2002) apply Duffie and Singleton's methodology and fit a five-factor affine model on swap and Treasury U.S. rates over the sample period of January 1988 to February 2002. While their specification enables them to fit observed data quite well, they obtain a puzzling evolution of the model-implied credit spread present in swaps, which turns out to be negative during the 1990s. They conclude therefore that the liquidity premium inherent in swap rates might have had the most determinant influence on swap spreads over the observation period.

Liu, Longstaff, and Mandell (2002) also bring some evidence to support this contention. In fitting their model, the authors obtain a model-implied instantaneous short-term risk-free rate as well as an instantaneous swap spread. In the latter, they distinguish two elements: an instantaneous credit spread (three-month LIBOR minus the GC repo rate) and an instantaneous liquidity spread (GC repo rate minus the model-implied short-term risk-free rate). They argue that since their model was fitted on the three-month LIBOR rates and on a number of on-the-run Treasury rates with constant maturities, the model-implied short-term risk-free rate should correspond to an "on-the-run repo rate" (repo using on-the-run Treasuries as collateral). They conclude that the variation in the instantaneous swap spread over the sample period was primarily influenced by its liquidity component.

Lang, Litzenberger, and Liu (1998) test the hypothesis that A-rated bond and Agency bond spreads should both correlate positively with swap spreads. They run regressions for the 10-year and the 5-year U.S. swap spreads with month-end data from March 1986 to June 1992. These regression are one-lag autocorrelation-corrected and include, as explanatory variables, A-rated spreads, Agency spreads, and the level and the variation in the unemployment rate (these two variables are added to control for the alleged procyclicality of swap spreads). In line with the hypothesis tested, both A spreads and Agency spreads are found to be statistically significant drivers, with the best regressions accounting for 75 percent and 48 percent of the variations in 10-year and 5-year swap spreads, respectively.

Huang and Nefti (2002) estimate a VAR model on a sample of daily data from January 1999 to March 2002 with five variables: the 10-year U.S. swap spread, the 10- to 2-year slope of the yield curve, the six-month LIBOR, the market capitalization of the CSFB Liquid

Corporate Bond Index—over 500 high grade U.S. corporate bonds (a credit factor)—and the duration of this index.

In their VAR model, the slope, the credit and the duration factors each explain 18 percent to 25 percent of the variance in swap spreads while 25 percent of this variance is attributable to the swap spreads' own shocks. Similar to Duffie and Singleton (1997), Huang and Nefti find that the influence of the credit factor is stronger over longer horizons and that a widening of credit spreads tends to narrow swap spreads.

Kambhu (2004) examines whether the presumed intensive convergence trading on swap spreads (entering fixed rate receiver swaps while shorting Treasuries if swap spreads are believed to be above their long run level) has a stabilizing or a destabilizing impact on the dynamics of swap rates. Kambhu (2004) defines the long-run level of the five-year swap spread as the estimated values of a regression on the variables selected by Lang, Litzenberger, and Liu (1998) over the 1996 to 2002 period. Kambhu then regresses the deviation of the swap spread from this long-run level on its own one-period lag and on a number of variables reflecting potential convergence trading (like the volume of repo contract). He reports that adding the repo-related variables improves the quality of fit, tending to indicate that convergence trading exerts an effect. However the R-squared only reaches 20 percent.

Econometric Models Based on a Statistical Approach

The statistical approach consists of identifying a priori a number of potential drivers of swap spread, derived from theory or from a practitioner's understanding of swap market dynamics. The key issue then becomes the most appropriate econometric method to obtain a good fit to data, a robust model, and, ultimately, good predictors of swap rates or spreads.

One of the main difficulties in such statistical modeling lies in what is referred to in econometric terms as the nonstationarity of swap spreads (see Box 6). Stationarity—broadly speaking, the absence of trends—is a crucial requirement for a time series to lend itself to traditional econometric methods. In particular, the traditional linear regression model that explains an economic variable by its linear sensitivities to a list of other independent drivers, becomes nonapplicable. Over the past 20 years and, in particular, from 1994 to 2004, swap rates and spreads have displayed a strong nonstationarity. Moreover, most of the variables, retained as potential a priori drivers of swap spreads, present the same characteristic.

The Presence of Long-Term Determinants

Kocic and Quintos (2001) as well as Kurpiel (2003) expressly identify the supply of Treasury bonds or, alternatively, the U.S. fiscal deficit, as a structural factor driving swap spreads over the long run. While both studies report a long-term correlation between the supply of U.S. government bonds and dollar swap spreads, they fall short of establishing a cointegration relation, given the proxies, the data, and the sample period they use (1995–2001 and 1992–2002 respectively). In their search for a long-term relation, Kocic and Quintos (2001)

Box 6: Nonstationarity, Cointegration Theory, and Error-Correction Models

Stationary Processes

A stochastic process $(X_t)_{t \in N}$ is stationary if its mean, variance, and covariances are independent of time, that is for every $t, h \in N$: $EX_t = m$ and $Cov(X_t, X_{t+h}) = \gamma_h$.

Any stochastic process $(X_t)_{t \in N}$ that is stationary admits an Auto Regressive Moving Average (ARMA) representation. If L is the lag operator, $LX_t = X_{t-1}$, then $P(L)X_t = Q(L)\varepsilon_t$ with P and Q polynomials of degree p and q and ε_t white noise (a series of independent identically distributed Gaussian variables, also the most common stationary series). A scalar stochastic process $(X_t)_{t \in N}$ is stationary if and only if the root modules of the polynomial P are strictly greater than 1. In that case P can be inverted and X_t can be represented by an infinite stationary Moving Average

$$X_t = M(L)\varepsilon_t = \sum_{i=0}^{\infty} m_i \varepsilon_{t-i}$$

The Dickey-Fuller test *for stationarity*

Given n observations $(X_i)_{i=1\ldots n}$ it consists in testing the hypothesis $\rho = 1$ in the regression $X_i = \rho X_{i-1} + \varepsilon_i$. If the hypothesis can be rejected (at a given significance level), then the hypothesis that $(X_t)_{t \in N}$ is not stationary can be rejected.

Nonstationary Series, Cointegration

Conventional econometrics cannot apply to nonstationary series. It can notably be shown that a regression model might falsely indicate a correlation between two nonstationary independent processes. Such regressions are commonly referred to as "spurious regressions".

A nonstationary series is *integrated of order 1*, $I(1)$, if the series of its first differences is stationary, as in the random walk model ($X_t = X_{t-1} + \varepsilon_t$). The n $I(1)$ scalar processes are said to be *cointegrated* if they admit a linear combination that is stationary.

Error-Correction Model

The representation theorem of Engle and Granger (1987) enables the application of conventional econometrics to a nonstationary AR model, provided this model is cointegrated.

If $(X_t)_{t \in N}$ is a multivariate AR with n components $I(1)$, and if it is cointegrated, *i.e.,* there exists a n-vector α such that $\alpha' X_t$ is stationary, then $(X_t)_{t \in N}$ admits an error-correction model (ECM) representation: $D\alpha' X_{t-1} + P(L)[X_t - X_{t-1}] + \varepsilon_t$ where $P(0) = I$ (matrix identity) and D is a n-vector.

The ECM can be interpreted as an optimisation problem of minimizing the deviation and the adjustments from the long-term equilibrium $\alpha' X_t = 0$. The ECM can also be seen as a standard linear regression model since $\alpha' X_{t-1}$ and $X_t - X_{t-1}$ are stationary.

There is a two-step procedure leading to the ECM model. (1) Identify and estimate the cointegration vector in the long-term model by running the regression $\alpha' X_t = \varepsilon_t$, ensuring that the residuals are generated by a stationary series (ε_t). (2) Estimate the short-term (or error-correction) equation $D\alpha' X_{t-1} + [X_t - X_{t-1}] = \varepsilon_t$ where both the explained and the explanatory variables are stationary.

always find nonstationary residuals when regressing U.S. dollar swap spreads on Treasury supply. They see in this nonstationarity the presence of structural changes and, in order to reflect them, opt for a nonlinear regression model. Their explanatory variables include the Treasury supply multiplied by other factors, such as the slope of the yield curve. Their nonlinear econometric model thus enables them to obtain a long-term relation displaying stationary residuals.

Kurpiel (2003) identifies a cointegration relation between EUR 10-year swap spreads and the German Treasury deficit, which he cannot verify in the U.S. dollar market.[17] For U.S. dollar swap spreads though, Kurpiel finds evidence of a cointegration relation with U.S. Treasuries when adding another long-term factor, the outperformance of banks stocks relative to the S&P index.[18] However, Kurpiel (2003) does not report on the implementation of an error correction model based on this long-term cointegration equation.

Specification Issues and Results

Even when not concerned with the existence of a structural long-run relation, all the econometric models designed after 2001 include proxies of the outstanding public debt as one of the a priori swap spread determinants. These models are linear regression models (as opposed to Kocic and Quintos). There tends to be agreement on a number of explanatory variables. The slope of the yield curve is always present in all papers reviewed, sometimes justified as a credit-risk proxy (see Box 4). One variable represents the overall perception of risk, traced by the stock volatility index VIX or by other ad hoc indices. Another variable attempts to measure the liquidity premium incorporated in Treasuries through the differential in yield between on-the-run and off-the-run Treasury bonds (consistent in that with the *liquidity convenience yield* put forward by Grinblatt (1995). There is unanimity among researchers, on the other hand, that a very intuitive and tempting variable—the spread between the LIBOR rate and the General Collateral Repo rate—does not show any correlation with the variations in swap rates or spreads. It is not always possible to check the quality of fit of these models, as the traditional indicators are not always disclosed. A paper reporting a good R-square might, on the other hand, raise concern for methodology reasons: the observation period was too short and witnessed a single strong directional move in swap spreads, or the R-square was for a regression run with levels instead of first differences (something problematic because of the nonstationarity: see Box 6).

The Lessons Learned

This paper stands very close to these statistical approaches. Our objective is to bring empirical evidence that swap-spread variations are caused by movements in well-identified factors. Specifically, we aim to verify empirically the intuition that public debt dynamics

17. Examining the drivers of EUR swap spreads, Baraton and Cuilliere (2001) do not find the same “natural” cointegration relation between the supply of government bonds and swap spreads. They fall back on a cointegration–error-correcting model where the long-run relation relates euro swap spreads to five factors which are not so obviously “long-term:” two indicators of the economic activity in the US (the NAPM Manufacturing and Services indices), the stock market volatility, the French government long term yield, and the slope of the yield curve.

18. Lefeuvre and others (2001) can exhibit a cointegration relation for swap markets in dollar. They verify with the Dickey Fuller statistic (see box 6) that the residuals are stationary in a regression of U.S. dollar swap spreads with the Treasury supply and four other factors as explanatory variables. However the estimation period (1998–2001) looks a little short in order to validate a long-term relation.

are the major long-term determinant, with the most appropriate methodology based on the concept of cointegration. Our overview of existing empirical works tells us that this methodology has not been applied entirely to U.S. dollar swap spreads. We wish to obtain a good explanation of the past, based on a good fit to real data. Our review also tells us that the performance of econometric models in terms of goodness of fit remains an issue; all the factors accounting for shorter term fluctuations have not been identified in full. The modeling effort presented in the next chapter is geared toward achieving these objectives.

CHAPTER 4

Methodology and Modeling

Data

We examine the 2-, 5-, and 10-year U.S. dollar swap spreads using a comprehensive dataset from January 1994 to June 2004. The sources of daily data, outlined in Table 1, are taken directly from Bloomberg, except for the spread between on-the-run and off-the-run Treasuries (data provided by Goldman Sachs), the supply of Treasury bonds (measured by the value of the Lehman U.S. Treasury Index divided by its price) and the MBS Duration (data obtained from Lehman Brothers). Weekly data were obtained from the daily data by picking up every end-of-week observation (observation day is Friday). We then compute monthly and quarterly averages were computed from the weekly data.

Table 2 summarizes descriptive statistics for the 2-, 5- and 10-year swap spreads from January 1994 to June 2004. The data show several interesting features. On average, swap spreads increase with maturity (a feature already documented several times (see Chapter 2). Table 2 also shows that the distribution of swap-spread changes is not symmetrical, as the skewness of spread changes is different from zero. Third, the distribution of swap spread changes is characterized by excess kurtosis, something which can be attributed to heteroscedasticity or change in variance levels over time. Excess kurtosis is more evident for higher frequency data (higher numbers for kurtosis of weekly swap spread), consistent with the fat-tailed stylized facts observed in high-frequency financial time series.

Table 1. Sources of Daily Data

Variable	Description	Source
*swapsp*10*y*	10-year swap spread	Bloomberg
swapsp5y	5-year swap spread	Bloomberg
swapsp2y	2-year swap spread	Bloomberg
treassup	Treasury supply	Lehman Brothers
aasp10y	10-year AA spread	Bloomberg
aasp5y	5-year AA spread	Bloomberg
aasp2y	2-year AA spread	Bloomberg
MBS	Mortgage backed securities duration	Lehman Brothers
VIX	Index of implied volatilities for options on S&P stocks	Bloomberg
repo	Repo rate	Bloomberg
slope	US Treasury 10-year minus 20-year yield	Bloomberg
onoff	US Treasury 10-year off-the-run minus on-the-run yield	Goldman Sachs

Table 2. Summary Statistics of Swap Spreads, January 1994–June 2004

	Spread Levels		Spread Changes	
	Mean (in basis points)	Variance (in basis points)	Skewness	Kurtosis
Weekly data				
2y swap spread	38.34	3.75	0.342	6.78
5y swap spread	50.64	3.92	–0.179	14.61
10y swap spread	60.92	3.76	–0.336	13.87
Monthly data				
2y swap spread	38.33	4.25	0.3	3.37
5y swap spread	50.64	5.43	0.18	3.45
10y swap spread	60.86	6.02	0.54	4.53
Quarterly data				
2y swap spread	38.07	7.05	0.59	3.23
5y swap spread	50.20	8.62	0.78	3.79
10y spread	60.44	9.92	0.85	4.43

Nonstationarity in Swap Spreads

Figures 1, 2, and 5 indicate that the 10-year swap spread, the 10-year AA spread, and the Treasury supply time series are not stationary. Most empirical studies consider swap spreads as a nonstationary process.

Figure 3 indicates, on the other hand, that swap spreads are stationary in their first differences; that is they are integrated of order 1 or I(1) (see Box 6).

This nonstationarity is confirmed from a strict statistical point of view by the results of the Augmented Dickey Fuller test (ADF test). The null hypothesis of the ADF test is that the variable under consideration has a unit root (nonstationary). The alternative hypothesis is that the variable does not have a unit root. The test statistics are summarized in Table 3. To test whether a given variable in the first column of table 3 is stationary, we use the model that includes a constant but no time trend (this is because the variables in the study have a non-zero mean); the corresponding test statistic is given in the second column of Table 3. Test whether a given variable in first difference is stationary, we use a model that includes neither a constant nor a time trend (this is because the first differences of the variables have a mean that is not significantly different from zero); the corresponding test statistic is given in the last column of Table 3.

Table 3 shows that the nonstationarity hypothesis cannot be rejected for the levels while the nonstationarity hypothesis in first differences can be rejected for all variables at the 1 percent confidence level. Hence, we can consider that all those variables are integrated of order 1.

One can view the cause of nonstationarity as the time necessary for swap spreads to revert toward their long-term or unconditional average, which may be long compared to the chosen observation period. Over a sample period too short relative to their mean-reversion speed, swap spreads would exhibit an artificial trend, *i.e.,* would appear to be a unit root process (see Box 6). The presence of one or several structural breaks over the whole sample period would also presumably produce nonstationarity.

The $I(1)$ property of all the variables in our study is an important and necessary precondition to implementating the cointegration methodology.

Table 3. ADF Unit Root Test

	Test Statistics	
Variable	Level (Constant, no time trend)	First difference (No constant, no time trend)
swapsp10y	–1.23	–5.04***
swapsp5y	–1.61	–2.41**
swapsp2y	–1.51	–6.26**
treassup	–2.13	–2.25**
aasp10y	–1.17	–5.51***
aasp5y	–1.33	–5.84***
aasp2y	–2.11	–7.00***
onoff	–1.85	–7.45***
VIX	–2.27	–6.32***
repo	–1.19	–3.03***
MBS	–2.08	–3.85***
slope	–0.98	–3.98***

Notes:
1. Length of the lags based on Schwartz Information Criterion.
2. *, **, and *** stand for significance at 10%, 5% and 1% level respectively.

Presence of a Cointegration Relation

The nonstationarity of the variables makes traditional econometrics techniques such as the ordinary least square (linear) model invalid as explained above (see Box 6 on page 24). One way around the nonstationarity problem is to apply the usual linear model after having taken the first differences of the variables. The presence of a co-integration or long-term relationship would authorize the implementation of a more powerful method.

There is at least one variable, the Treasury supply, for which there are good reasons to presume that a long-term relationship with swap spreads exists. Moreover, the Treasury supply and other a priori determinants are integrated of order 1. It is therefore worth trying to apply the cointegration methodology introduced by Engle and Granger (1987) as a superior form of dealing with nonstationarity.

The first step is to identify a cointegration relation potentially existing among the selected variables. Our preference goes naturally to a cointegration relation that involves the presumed long-term driver, the Treasury supply.

For this purpose we use Johansen's cointegration test (1988) to test whether a long-run relationship exists involving the swap spread and the explanatory variables. Applying the Johansen cointegration test to the swap spread and all possible subsets of the explanatory variable shows that two cointegration relations exist.

The first is, as we expected, a cointegration relation between swap spreads and the Treasury supply.[19]

The second is a cointegration relation between swap spreads and AA spreads. However, we do not find a cointegration relation between the three variables (swap spread, Treasury supply, and AA spreads). In view of the most obvious long-term feature of the Treasury supply (AA spreads also display shorter term correlations), we build our error-correction model on the cointegration relation between swap spreads and Treasury supply.

The error-correction model (ECM) is therefore specified in the following way. For each of the series—10-year, 5-year, and 2-year swap spreads—a long-term relation with the Treasury supply is first estimated, using quarterly data. We then estimate a second regression reflecting short-term fluctuations around this long-term trend. The first differences of swap spreads are the explained variable. The residuals of the long-term regression (which are, hence, stationary) are one of the explanatory variables, along with the first differences of other variables. Given our objective, to achieve a better understanding of the economic determinants from 1994 to 2004, we implement this ECM with quarterly data, for which we obtain a good fit, while keeping the number of variables and lags in control.

We now detail the process by which we selected and minimized the number of explanatory variables and time lags.

19. As noted, Kurpiel (2003) finds a similar cointegration relation over the last ten years between the German swap spreads and the public deficit but fails to exhibit one in U.S. dollar given the proxy he has chosen.

Specification of the Error-Correction Model

The Relation between AA and Swap Spreads

All indicators in financial markets are, to a certain extent, simultaneously determined, and any assumptions about exogeneity or endogeneity of particular variables may be questioned. The short-term regression in our error-correction model is a univariate linear model for 10-, 5- and 2-year swap spreads (the dependent variables) where the potential explanatory variables (Treasury supply, slope, and so forth) are assumed to be exogenous. We validated this assumption by running Granger causality tests (see Box 7) to determine whether the dependent variables also exert a significant influence on the explanatory variables. If this were the case, our model's specification would have to be amended to take into account this retroaction of explained variables on explanatory variables.[20]

The Granger causality test is particularly important in the case of the AA spread. As discussed earlier, this variable displays a high degree of correlation and is also cointegrated with the swap spread (for the three maturities under consideration). At the same time, one of the strongest conclusions on swaps reached by the financial theory is that their credit risk differs fundamentally from the credit risk of AA-rated bonds. Contrary to LIBOR bonds, whose credit spread incorporates the likelihood of a degradation in credit quality,

Box 7: Granger Causality Test

The presence of a correlation between two variables does not provide any information about the direction of causality. Even if the relation is strong, does it mean that one economic factor causes the other or are they just simultaneously moved by a third variable? The Granger causality test enables us to verify formally whether a variable causes another one. Let us note that the Granger causality, which measures the information content from a statistical point of view, should be treated as a statistical test and not as a strict causality in elaborating an economic interpretation.

Considering variables x and y, variable x is said to Granger cause y, if the prediction of y obtained by regressing y on its own lags can be improved by adding the lagged variables of x to the linear regression model. Considering the following Vector Auto Regressive model:

$$x_t = c_1 + \sum_{i=1}^{p} \alpha_{1i} x_{t-i} + \sum_{i=1}^{p} \beta_{1i} y_{t-i} + \varepsilon_{1t}$$

$$y_t = c_2 + \sum_{i=1}^{p} \alpha_{2i} x_{t-i} + \sum_{i=1}^{p} \beta_{2i} y_{t-i} + \varepsilon_{2t}$$

To test for Granger causality from x to y, we test the joint significance of $\alpha_{21}, \ldots, \alpha_{2p}$. This can be done by completing a F-test for the null hypothesis of $\alpha_{21}, \ldots, \alpha_{2p} = 0$. Similarly, to test for Granger causality from y to x, in fact we test the joint significance of $\beta_{11}, \ldots, \beta_{1p}$.

20. In such cases, Vector Autoregressive models (VAR models) are generally used. They can be thought of as simultaneous regressions (multivariate regressions) of a each component variable of a vector on the other component variables.

swap spreads reflect the LIBOR credit quality, which is continuously refreshed on every reset date.[21] We retained the AA spread as a potential driver of swap spreads because it is also an indicator of an expected systemic deterioration of the banking sector (the majority of the banks participating in the swap market or quoting on U.S. dollar LIBOR are AA-rated), a deterioration which also should be reflected in swap spreads (but not necessarily in the LIBOR). On this ground, there is no reason why the swap spread would determine the AA spread.

As could be expected, the results of the Granger causality test confirm this view and shows that, in effect, the swap spread does not Granger-cause the AA-spread nor any of our explanatory variables. Because our regression model does not suffer from any potential endogeneity bias, we can proceed with the estimation on solid ground.

The Selection Process for Variables and Lags

The selection process applied to the set of a priori determinants listed in Box 4, and also to their time lags.

Some variables, including the swap spread, showed some autocorrelation in their first differences. Because of the nonstationarity, there was an obvious positive autoregressive dependence in levels: the swap spread today is partially determined by the spread one quarter ago. Yet, a negative autocorrelation also can be observed in first differences, indicating that swap spreads are unlikely to be a random walk process.[22] This persistence in variations has been documented.[23] The influence of lagged values of the first differences, present in several explanatory variables, leads to questioning the optimal number of lags to retain in the regression.

There are no theoretical recommendations regarding the number of lags in autoregressive dependence, and different authors used different lag structures. Different numbers of lags may result in substantially different parameter estimates and even different conclusions about the existence of long-run relationships between variables. As a consequence, the robustness of all results to different choices of lag structure had to be checked.

Explanatory variables and their first lags were included one by one. Since there were potentially about a dozen explanatory variables of interest and only 40 quarterly observations, further lags were not included to preserve the degrees of freedom. Further lags were generally insignificant when included in regression equations, with the exception of the fourth lag of the Treasury supply (which makes sense, as we use quarterly data here), which retains high significance in different specifications. This suggests that 1-year lagged Treasury supply may be a good proxy for seasonal effects. Having introduced a number of lagged values, we checked the absence of autocorrelation using the Lagrange

21. See section 2.1 and notably the paper by Collin-Dufresne and Solnik (2001).

22. By definition, the first differences of a pure random walk process $y_t = y_{t-1} + \varepsilon t)(\Delta_{yt})$ are uncorrelated.

23. Eom, Subrahmanyam, and Uno (2002) note that the standard deviations of swap spreads typically decline with maturity. Kurpiel (2003) argues that the fluctuations of swap spread first differences are identifiable in an ARMA framework.

Multipliers (LM) test (which tests for the null hypothesis of no serial autocorrelation in residuals). When the LM test indicated no specification problems, we stopped including further lags for the variable. Based on the conventional approach, the LM test for quarterly data includes four lags.

Concerning the variables themselves we ran successive regressions, adding potential drivers (variables) one after the other. If the inclusion of a new explanatory variable improved the fit, then it continued to be included in further tries. Otherwise, it was excluded. We made use notably of the Akaike Information Criterion (AIC). If the value of AIC substantially increased after adding a new potential variable (an increase in the AIC meant that the quality of fit is actually reduced), then the explanatory variable was dropped in the following specifications to preserve degrees of freedom. One a priori determinant, the VIX, thus disappeared in the final model. The AIC values reported by EViews 4.1[24] were such monotonic transformations of the initial statistic suggested by Akaike (1973) that lower AIC values correspond to a better fit. AIC values were not comparable across specifications estimated using different numbers of observations, hence AIC for specifications with larger number of observations were computed based on the appropriately restricted subsample.

Structural Stability

Apedjinou (2003) reconciled some of the contradictory findings reported by empirical studies on swaps by pointing out that the relative (and absolute) importance of the determinants of swap spreads possibly changed over time. Apedjinou designed a test to identify the presence of regime changes over the period from 1987 to 2002. He found at least three different regimes.

Regime-switching models provide only a partial solution to the problem however, because regime switches are exogenous. These techniques allow for a better fit of the model, but primarily and essentially an in-sample fit. Should some events trigger a regime switch in the future, the estimated model would no longer be valid and would be characterized by a poorer out-of-sample performance. Our objective in this paper is to build up a model suitable for explaining swap spreads through various future cycles, *i.e.,* out-of-sample.

For the same reason, the in-sample estimates of goodness-of-fit of swap spread models might overstate its explanatory power. We employ, therefore, in-sample as well as out-of-sample testing of the goodness of fit.

Two techniques to out-of-sample testing were used: standard out-of-sample forecasting, an estimated model applied to a series of observations following the base sample; and continuous update of the base model, an estimated model applied to the first out-of-sample observation. Then the estimates were updated using the sample that included this new observation, and the updated version of the model was used to forecast the second out-of-sample observation, and so on. For every Nth out-of-sample observation, the model is estimated on the basis of in-sample observations and $N - 1$ out-of-sample observations.

24. EViews 4.1 is the econometric software used in this study.

The Error-Correction Model

As a result of the specification work and the selection of variables and lags described above, two ECM models (model A and B as detailed below) were estimated for each of the 2-, 5- and 10-year maturity, using quarterly data.

$$Swapsp_t = \alpha + \beta Treas\ \mathrm{sup}_t + \varepsilon_t$$

is the long-term relation. The error-correcting term is defined as the estimation error of this ordinary least square equation, depicted as ECT_t.

$$ECT_t = Swapsp_t - (\hat{\alpha} + \hat{\beta}\ Treas\ \mathrm{sup}_t)$$

ECT_t is one of the explanatory variables in the second equation of the model, the short-term relation involving the first differences of other nonstationary variables

$$\Delta Swapsp_t = C + \beta_0 ECT_{t-1} + \beta_1 \Delta Swapsp_{t-1} + \sum_{i=2}^{8} \beta_i \Delta Det_i$$

where the Det_i are the 7 following determinants that were identified for model B:

$$\Delta Treas\ \mathrm{sup}_{t-1}, \Delta Treas\ \mathrm{sup}_{t-4}, \Delta aasp_t, \Delta aasp_{t-1}, \Delta onoff_t, \Delta repo_t, \Delta MBS_t$$

In model A, the explanatory variable repo is excluded and replaced by the first differences of the 2-year-to-10-year slope both in current and one-period lagged values.

CHAPTER 5

Results

The Long-Term Relation

The estimation of the ordinary least square (OLS) equation representing the long-term relation gave estimated values $\hat{\alpha}$ and $\hat{\beta}$ that are significant. Table 4 gives the estimated values of both parameters as well as the T-test statistics.

The error-correction term captures the long-run dynamics in that it measures at every time *t* the distance of the current swap spread from its long-term equilibrium.

Table 4. Estimation of the Long-Term Relation

	Swap Spread		
	10-year (*swapsp*10*y*)	**5-year** (*swapsp*5*y*)	**2-year** (*swapsp*2*y*)
$\hat{\alpha}$	145.2953	157.8858	105.0356
	4.7	*6.49*	*5.49*
$\hat{\beta}$	–0.00005	–0.00006	–0.00004
	–2.77	*–4.46*	*–3.53*

The numbers in italics are the *T*-test statistics.

The Error-Correction Model

The estimated results for the ECM are reported in Table 5. We also estimated the OLS regressions using the first differences, but without the error correction term, the results showed that the ECM regressions fit the data better, as expected. This is because the ECM captures both the short-run and long-run dynamics, whereas the regressions using first differences capture the short-run dynamics only.

Inclusion of AA spread as one of the explanatory variables improved the regression dramatically. This is consistent with Figure 2, which shows that 10-year swap spread and 10-year AA spread move generally in the same direction. The comovement in investment

Table 5. Determinants of U.S. Dollar Swap Spreads—Error Correction Model
(*Cointegration relation swap spread-Treasury supply*)

Dependent Variable	Δswapsp10y		Δswapsp5y		Δswapsp2y	
Model	A	B	A	B	A	B
Constant	0.866 (*0.917*)	0.992 (*0.890*)	1.077 (*0.860*)	1.206 (*0.847*)	0.714 (*0.649*)	0.776 (*0.767*)
Error correction term	–0.210 (*0.08*)**	–0.260 (*0.077*)***	–0.143 (*0.113*)	–0.177 (*0.109*)	–0.148 (*0.100*)	–0.204 (*0.111*)*
Δswapsp-lag 1	–0.363 (*0.149*)**	–0.329 (*0.137*)**	–0.21 (*0.169*)	–0.187 (*0.159*)	0.0158 (*0.133*)	–0.022 (*0.143*)
Δtreassup-lag 1	–0.00011 (*0.00004*)**	–0.00010 (*0.00004*)***	–0.00009 (*0.00004*)**	–0.00009 (*0.00004*)**	–0.00005 (*0.00003*)	–0.00005 (*0.00004*)
Δtreassup-lag 4	0.00004 (*0.00004*)	0.00001 (*0.00003*)	0.00004 (*0.00004*)	0.00003 (*0.00004*)	–0.00003 (*0.00004*)	–0.00006 (*0.00003*)*
Δaasp	0.563 (*0.073*)***	0.572 (*0.068*)***	0.584 (*0.073*)***	0.584 (*0.071*)***	0.4915 (*0.0678*)***	0.475 (*0.079*)***
Δaasp-lag1	0.339 (*0.106*)***	0.317 (*0.099*)***	0.078 (*0.499*)	0.079 (*0.109*)	0.0095 (*0.078*)	0.044 (*0.086*)
Δonoff	–0.392 (*38.233*)	24.779 (*32.599*)	6.353 (*40.281*)	20.171 (*36.051*)	23.6055 (*31.489*)	56.563 (*34.317*)*
Δslope	–11.321 (*5.42*)**		–6.403 (*4.955*)		–15.8246 (*3.557*)***	
Δslope-lag 1	1.5 (*5.749*)		0.834 (*5.104*)		4.2416 (*4.526*)	
Δrepo		6.072 (*2.572*)**		3.63 (*2.333*)		5.833 (*2.223*)**
ΔMBS	5.618 (*1.539*)***	5.74 (*1.429*)***	4.167 (*1.657*)**	4.433 (*1.511*)***	6.082 (*1.232*)***	6.595 (*1.386*)***
Number of obs	36	36	37	37	37	37
Het.cons. s.e.?	no	no	no	no	no	no
R-squared	0.83	0.83	0.78	0.79	0.8	0.72
Adj R-squared	0.76	0.78	0.7	0.71	0.72	0.63
Information	6.28	6.19	6.27	6.19	5.71	5.9
LM autocorrelation test	0.19 (OK)	0.05*	0.20 (OK)	0.13 (OK)	0.77 (OK)	0.50 (OK)
LR test for break	0.23 (OK)	0.75 (OK)	0.36 (OK)	0.43 (OK)	0.02**	0.015**

Values significant at 10% are marked with *; at 5% with **; at 1% with ***.
Information is the Akaike Information Criteria (AIC).

grade credit spreads and swap spreads has been previously documented and theorized (Lang, Litzenberger, and Liu [1998], Baz and others [1999], Collin-Dufresne and Solnik [2001]). This paper assumed that AA spreads were influencing the credit risk factor in swap spreads, being a proxy for the credit risk of the overall banking sector (thereby affecting the credit quality of swap dealers in particular).

Other interactions can be envisaged. Credit spreads capture potential shifts in supply and demand of bonds, shifts which will, in turn, affect the supply and demand of swaps and the swap spread. Excessive divergence between credit spreads and swap spreads is limited by issuer arbitrage. Corporate, sovereign, and supranational issuers of debt securities have incentives to time their debt issues when the difference between credit spreads and swap spreads becomes wide. Because of these strong connections between the two markets we took the precaution of checking that while swap spreads were Granger-causing AA-spreads, the reverse was not true.

The expected (in theory) and realized signs (empirical results) for the explanatory variables are summarized in Table 6. The effects of various factors are generally in line with those suggested by the theory discussed in Chapter 2.

Although the coefficients of the explanatory variables in 10-, 5-, and 2-year swap spread regressions generally have the same sign, there is an asymmetry in the significance level for some explanatory variables. For instance, the coefficients for the first lag of the first difference of swap spreads are negative and less then 1 in absolute value for 10-, 5-, and 2-year swap spreads, due to mean reversion. However, while the coefficient is significantly negative for the 10-year swap spread at the 5 percent level, it is not significantly negative for 5- and 2-year swap spreads. Similarly, the coefficients for the first lag of treasury supply are negative for 10-, 5-, and 2-year swap spreads, but significant only for 10- and 5-year swap spreads.

Table 6. Expected and Realized Signs of Explanatory Variables

Explanatory Variable	Expected Sign	Realized Sign
Δ*swapsp*	Negative	Negative
Δ*treassup*	Negative	Negative
Δ*aasp*	Positive	Positive
Δ*onoff*	Positive	Mainly/Positive
Δ*slope*	Negative	Negative
Δ*repo*	Positive	Positive
Δ*MBS*	Positive	Positive

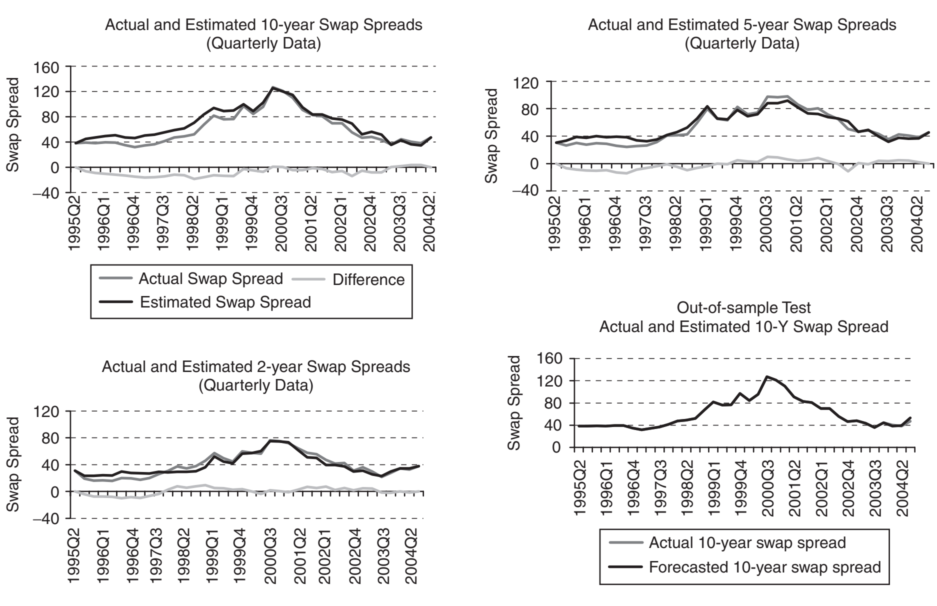
For other explanatory variables, such as offonrun, AA spread, slope and MBS duration etc, the asymmetry in the significance level is less evident. The coefficient for the offonrun 10-year in the 10-year swap spread regression does not have the expected sign, but it is not significant. The coefficients of AA spread in the 10-, 5-, and 2-year swap spread regressions are significantly positive and less than 1. In other words, an increase in AA spread by 10 basis point leads to an increase in 10-year swap spread by 5.6 basis point, other things being equal. This implies that while movements in swap spreads and credit spreads are positively correlated, the moves in swap spreads are more muted than those in credit spreads. This may be because the corporate bond market is much less liquid than the swap market. Finally, the MBS duration has significantly positive impact on swap spreads.

As discussed above, the behavior of interest rate swap spreads seemed to undergo a structural change in the middle of 1998. Apedjinou (2003) identified the date of structural break as August 14, 1998, the Friday before the Russian default. Though the Likelihood Ratio (LR) test in Table 5 does not reject the null hypothesis of no structural break even at 10 percent level for 10- and 5-year swap spreads, this does not dismiss concerns about possible structural changes in the laws determining interest rate swap spreads, since the LR test is not very high-powered in this instance.

Quality of Fit and Model Performance

How well do our ECM regressions fit the actual quarterly swap spreads? Table 5 shows that the R-square summary indicator of goodess of fit shows values close to 80 percent in all regressions, except for model B when applied to the two-year swap spread (R-square is only 72 percent). The actual swap spreads, estimated swap spreads from model A for the 10-, 5-, and 2-year swap spread in Table 5, and the differences between actual and estimated swap spreads[25] are plotted in Figure 7. From Figure 7, 10-, 5-, and 2-year estimated swap spreads move closely with the actual swap spreads, and the differences between the actual and estimated swap spreads are close to zero. Therefore, we conclude that our quarterly models explain the fluctuations in the actual swap spreads.

Figure 7. Ten-, 5-, and 2-year Swap Spreads: Actual versus Estimated



25. The estimated swap spreads are constructed as follows: at time $t = 0$ (initial period), estimated swap spread = actual swap spread; at time $t = 1$, estimated swap spread ($t = 1$) = estimated swap spread ($t = 0$) + Δ*swapspread* ($t = 1$) based on model A in Table 5 and so on.

These models also perform well in forecasting swap spreads. In the out-of-sample test we used the quarterly observations from 1994 quarter 1 to 2003 quarter 2 were used to estimate the swap spread, and then used the estimated model to estimate swap spreads from 2003 quarter 3 to 2004 quarter 2 (out-of-sample).[26] The actual and estimated swap spreads, plotted in Figure 7, hardly can be distinguished from one another.

In summary, our quarterly models closely estimate and predict the actual 10-, 5-, and 2-year U.S. dollar swap spreads from 1994 to 2004. Swap spreads are influenced by different types of factors. Consistent with several empirical studies (Kocic and Quintos [2001], Fransolet and Langeland [2001], Kurpiel [2003]), we find that the Treasury supply has the status of a structural factor (in the words of Kurpiel 2003), being a key determinant of swap spreads over a long-term horizon (e.g., several years). Moreover, on the basis of this long-term relation, we have implemented in full an error-correction model with some success, obtaining a better fit to real data than a linear model applied to first differences. We know of no complete implementation of the cointegration/error correction methodology to U.S. swap spreads.

Scenario and Sensitivity Analysis

We apply our 10-year quarterly swap spread model to illustrates how the ECM models can be used in forward-looking scenario analyses. The model coefficients are extracted from the estimated values of the error correction model displayed in Table 5 and are shown in Table 7. Bold indicators are considered to be significant at least at a 10 percent significance level.

Table 7. Estimated Parameters of the ECM Model

Constant	0.866
Error correction term	*–0.21*
Δswapsp-lag 1	*–0.363*
Δtreassup-lag 1	*–0.00011*
Δtreassup-lag 4	0.00004
Δaasp	*0.563*
Δaasp-lag 1	*0.339*
Δonoff	–0.392
Δslope	*–11.321*
Δslope-lag 1	1.5
ΔMBS	*5.618*

The error correction terms are given by the equation: *swapsp*10*Y*(*t* –*1*) + 0.00005. *treassup*(*t* –*1*)–*145.2953*.

First, we applied the swap spread model was applied to analyze different scenarios over the next one-year horizon. For illustration, we set arbitrary scenarios were set for the following three variables: Treasury Supply, Yield Curve Slope, and MBS duration. The four scenarios are

- ***Base Case Scenario***—No View scenario. In this case we assume that all of the underlying variables remain unchanged over the next 12 months. (We consider this scenario to be “no view” from the quantitative, and not from the fundamental economic aspect. In fact, an unchanged treasury supply scenario would reflect the view that the budget deficit is not increasing, and probably most of the economists would not consider this scenario to be neutral).

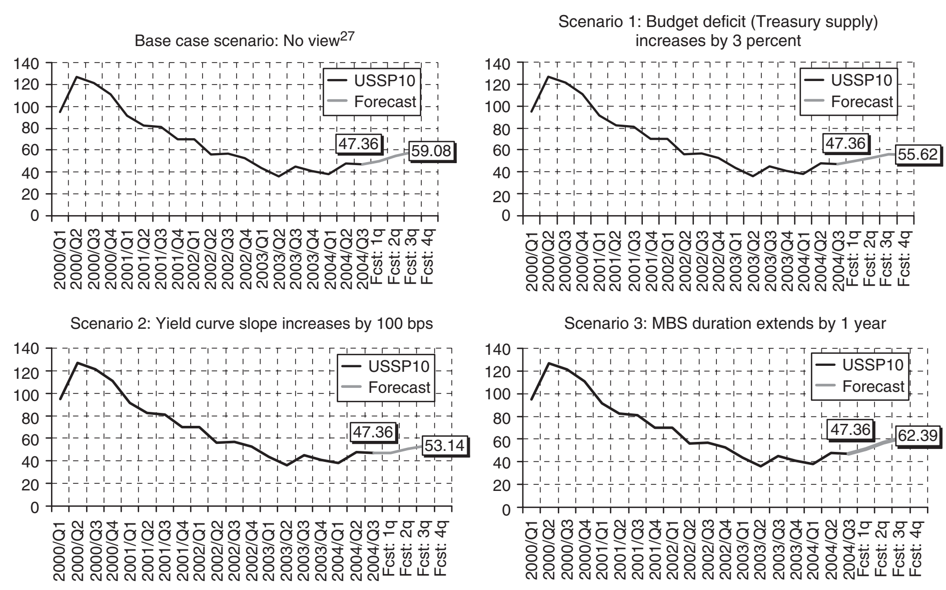
26. We also run the out-of-sample test using the continuous update of the base model in chapter 4. The results are similar.

- *Scenario 1*—Increasing Treasury Supply. We assume that the supply will increase by 10 percent over the next year.
- *Scenario 2*—Yield Curve Slope steepens by 100 basis points.
- *Scenario 3*—MBS sector duration gradually extends by one year. This scenario is useful in terms of analyzing the impact of the convexity hedging, but a slow, gradual duration expansion is not really typical: MBS duration fluctuates more rapidly, and in fact, we consider the convexity hedging as a short term explanatory variable.

Figure 8 illustrates the forecasted 10-year swap-spread paths over the next 12 months.

We have to make two important comments on these scenario analyses are needed. First, the "no-view" scenario does not result in an unchanged swap-spread path for two reasons: (1) the model is based on some lagged variables, so the previous changes in the treasury supply or the AA spread still have an impact on the spread forecast, and even more importantly, and (2) the error term of the cointegration relation plays a significant role in the spread model. The error term is currently negative (see Figure 6), which means that there is a gap between the current swap spread level and its "fair value" based on it's long-term relationship with the Treasury supply. In other words, the swap spread is too low relative to the current level of Treasury supply: if the supply does not change, the spread is expected to revert to a higher level.

Figure 8. Scenario Analyses



27. Note that swap spread does not remain flat under the no-view scenario either. The reason is that we work with several lagged variables, and the VEC is also assumed to remain in effect.

It is also interesting that in scenario 1 a 10 percent increase in the Treasury supply is required to keep the 10-year swap spread unchanged, if everything else remains unchanged. (One could say that this is, in fact, the scenario that we should be considered neutral or "no-view," as opposed to the first one.)

Table 8. Sensitivity Analysis

	Over 1 Quarter	Over 1 Year
AA Spread	1.8 bp	2.0 bp
Yield curve slope	–8.8 bp	–16.8 bp
MBS duration	0.18	0.3
Treasury supply	–0.50%	–0.90%

bp = basis points.

We did not set any scenarios for the liquidity spread were set because it did not turn out to be a significant variable. We also ignored setting scenarios for the AA spread were also not set because swap-spread estimation would follow almost the same path as the AA spread (note that the sum of the AA spread loadings is 0.902).

Another way of using the swap spread model is to apply the scenario analyses in the opposite way. Instead of showing the forecasted swap spreads under specific scenarios we try to answer the following question: What change in the selected underlying variable is required to explain a 1 basis point change in the swap spread on a pre-specified time horizon? This approach can be considered a sensitivity analysis. Table 8 illustrates such sensitivity analyses applied to the estimation results as of July 2004.

CHAPTER 6

Conclusion

This paper examined the determinants of U.S. swap spreads and estimated an econometric model for 2-, 5-, and 10-year U.S. dollar interest swap spreads using quarterly data from 1994 to 2004.

We selected a set of a priori determinants taking several complementary approaches. We first reviewed the available theory on swaps. Then, looking retrospectively at the evolution of the swap market, we noted how swap-rates dynamics apparently had been influenced by a succession of shocks over the past 10 years. We ran a regime-switching estimate and identified the presence of two regimes, each characterized by a high or low volatility. We eventually identified a number of potential drivers. Some variables were selected on theoretical grounds as proxies for the credit and liquidity components present in swap spreads (the AA spread, the on-off-the-run spread). Others resulted from the analysis of the dynamics of the swap and Treasury markets (Treasury supply, repo rate, slope of the yield curve, duration of Mortgage Backed Securities). All showed strong correlations with swap spreads. We reviewed empirical studies testing formal theories of swap spreads and concluded that, as suggested by Duffie and Singleton (1997), "a deeper investigation of the swap market activity" was needed. We also reviewed statistical models built by swap dealers.

To capture the apparent presence of long-term or structural trends governing swap spreads over the period, we opted for an error-correcting model. The time series properties of the 2-, 5-, and 10-year U.S. swap spreads and of our potential explanatory variables authorized the application of this methodology, as all were nonstationary time series that showed stationarity in their first differences (all variables were integrated of order 1). Given these features, we tested the cointegrating relationship between swap spreads and the explanatory variables and found that the 2-, 5-, and 10-year quarterly swap spreads were cointegrated with Treasury supply over the period from 1994 to 2004. In other words, we found evidence of a long-run relationship between swap spreads and Treasury supply, a finding consistent with some of the swap dealer research literature. By incorporating the long-run relationship, we then estimated an error-correcting model for 2-, 5-, and 10-year swap spreads.

The results of the ecm show that changes in swap spreads depend on the following variables: the error-correcting term (intuitively the term describing the reversion towards the long term relation); its own lagged values; the lagged value of the treasury supply; the AA-spreads; the off-on-the-run yields; the slope of the yield curve (or alternatively the repo rate); the duration of Mortgage Backed Securities. The realized signs for these explanatory variables are generally consistent with those implied by the theory.

The models obtain a good quality of fit in the three maturities (for both alternative models using either the slope of the yield curve or the repo rate) with R-squared between 0.72 and 0.83. We found that the error-correcting model performed better than a linear model using the first differences of all variables. This results comforts us with the fact that the application of an error-correcting model is needed to separate clearly the long-term relation from the short-term fluctuations around this trend.

Our empirical results suggest that the Treasury supply, as a structural factor, is a key determinant of swap spreads on a long-term horizon. The AA spreads are positively correlated with swap spreads and are highly significant in explaining the variations in 2-, 5-, and 10-year swap spreads. This conclusion is consistent with findings of previous studies. In view of the strong influence exerted by the AA spread variable (we also found that the AA spread time series was cointegrated with swap spreads), and because of the theoretical justifications to this influence (because many banks are AA-rated, the AA spread reflects the market expectations over the credit risk of the banking sector), we ensured that there was an unequivocal causality relation between the two variables. The results of a Granger causality test showed us that the AA spread was indeed Granger-causing the swap spread, while the reverse was not true. An increase in AA spread by 10 basis point leads to an increase in 10-year swap spread by 5.6 basis points, other things being equal. The moves in swap spreads therefore tend to be more muted than those in credit spreads. Finally, the MBS duration has significantly positive impact on 2-, 5-, and 10-year swap spreads. Given the good quality of fit, we believe that econometric models built on the cointegration relation between Treasury supply and the swap spread provide the right methodology for explaining the dynamics of swap spreads. Our model, which should be used, ideally, to run scenarios, can be implemented and replicated easily. A natural extension would be to model jointly dollar and euro swap spreads.

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Against the background of financial theory and statistical models, this study presents the error-correction methodology based on the concept of cointegraton. It finds that the U.S. dollar swap spreads and the supply of U.S. Treasury bonds are cointegrated, suggesting that the Treasury supply is a key determinant on a long-term horizon. The paper then estimates an error-correction model which integrates this long-term relationship with the influence of four shorter-term determinants: the AA spread, the repo rate, the difference between on-the-run and off-the-run yields, and the duration of mortgage-backed securities. The model fits observed swap spreads quite well over the sample period. The paper ends with an illustration of how the same model can be used to carry out scenario analysis.

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