What Constitutes a Good Model?

An Analysis of Models for Mortgage Backed Securities[*]

MASSOUD HEIDARI[†]

Chief Investment Officer, Caspian Capital Management, LLC

LIUREN WU[‡]

Associate Professor of Finance, Zicklin School of Business, Baruch College

This version: August 31, 2004

---

[*] We thank Peter Carr, William Dellal, Ayman Hindy, Gregory Klein, Karl Kolderup, John Minahan, Andy Okun, David Rowntree, and seminar participants at the 10th Annual Conference on Global Derivatives & Risk Management (2003), and the 2003 Hedge Fund Panel at the Fixed Income Analysis Society for many helpful discussions and valuable suggestions.

[†] 1251 Avenue of the Americas, 16th floor, New York, NY 10020; tel: (212) 703-0333; fax: (212) 703-0380; `Massoud.Heidari@caspiancapital.com`.

[‡] 113 West 60th Street, New York, NY 10023; tel: (212) 636-6117; fax: (212) 765-5573; `wu@fordham.edu`.

What Constitutes a Good Model?
An Analysis of Models for Mortgage Backed Securities

Abstract

The U.S. agency mortgage backed securities (MBS) market is deep and highly liquid, yet modeling MBS is extremely challenging. This paper applies market participants' desired requirements for a good pricing model to MBS pricing models provided by six of the top MBS dealers. We find that five out of the six models fall short of the desired requirements. The five models are highly correlated, but less correlated with the best model, indicating potential herding among MBS analysts. The most undesirable property of the failed models is the high correlation with the underlying interest rate and options markets.

What Constitutes a Good Model?
An Analysis of Models for Mortgage Backed Securities

The value of a good pricing model lies in its capability in explaining market prices. This is especially true in large liquid markets where one expects the full application of the Efficient Market Hypothesis (EMH). Unfortunately, many of the more interesting and complicated markets in the fixed income universe are too illiquid or lack enough publicly available data for accurate market versus model comparisons.[1] An exception is the U.S. agency mortgaged backed securities (MBS) market. This is a deep and highly liquid market that nevertheless offers researchers a serious challenge due to the homeowner's prepayment option.

Large research departments at many Wall Street firms are dedicated to developing ever more complicated models for pricing MBS. The task is complicated due to the sub-optimal monthly exercise of the homeowner's prepayment option over a 30-year maturity. Nevertheless the industry has arrived at a standard for expressing relative value in the MBS market known as Option Adjusted Spread (OAS) (See Hayre (2001)). OAS measures the difference, in basis points, between the returns of MBS and a replicating portfolio of Libor/swap and swaptions over the life of the mortgage. For example, an OAS of ten basis points is the annualized excess return that one expects over the life of the MBS compared to holding a replicating portfolio of swaps and swaptions, all at today's prices. Therefore, the larger the OAS values, the "cheaper" is the mortgage and vice versa. In their effort to win clients and to generate trading ideas, most Wall Street firms provide their clients with a daily run of OAS values on a number of more liquid mortgage securities. These values are different across firms due to the choice of the interest rate dynamics as well as the prepayment function. This provides us with a great opportunity to test and compare these models.

But what constitutes a test of a "good" pricing model? What are the most desired properties of such a model? To answer these questions, we sent a questionnaire to a number of academics and practitioners involved in the design or trading of financial pricing models. From responses to the questionnaire, we

---

[1] One example is the long dated cap and swaption market where out-of-the-money pricing data are to this date unavailable to the general public.

drew a wish list of properties that determine the goodness of a model. We then used four years of daily OAS values obtained from six of the top dealers in the U.S. MBS market to investigate their properties against our wish list. The results of our study can be summarized as follows,

1. All but one model fail against our wish list for a "good" model. The most undesirable property in most models is the high correlation of the OAS series with the underlying interest rate and interest rate option markets. In a fully hedged portfolio, this property could result in profits and losses that are market directional.
2. There does not exist one dominant principal component in the OAS time series produced by the six models, indicating that the results are not noisy variations of the same valuation model. However, we find that the five failed models are highly correlated with one another, and less correlated with the best model. The high correlation among the five failed models may indicate "herding" among the MBS research analysts, which may lead the entire flock over the proverbial cliff.
3. Assuming that the MBS market is relatively efficient, we estimate the model risk associated with the best model at ten basis points.

In related literature, Breeden (1994) analyzes the complexity inherent in the hedging of the mortgage-backed securities. Brown (1999) studies the determination of expected return on mortgage backed securities based on the OAS and shows how the expected return depends both on general market conditions and contract specific factors.

The remainder of this paper is organized as follows. Section 1 is a brief overview of the mortgage market and the OAS data set. Section 2 describes our questionnaire and summarizes the responses. Section 3 contains results on the statistical analysis of the OAS time series. Section 4 examines the question of arbitrage opportunities and model risk. Section 5 concludes.

1 Overview of the U.S. Mortgage Market

The agency mortgage market in the US has evolved into one of the largest and most liquid fixed income sectors in the world and in recent years it has outpaced even the US treasury market in size. Driven by the combination of low interest rates and a booming housing market, the size of the market is now nearly \$4 trillion with daily trading volume exceeding \$150 billion per day,[2] an amount that represents nearly half the volume of the U.S. treasury market (excluding T-bills and short-term coupon bonds). Currently, the agency mortgage market is the single largest fixed income asset class and comprises 32 percent of the Merrill Lynch US High Grade Bond Index.

The size and efficiency of the mortgage market is a result of the collective effort of a team of specialized government sponsored enterprises (GSE's) and Wall Street dealers. Through specific charters to encourage mortgage lending, the GSE's, better known as Ginnie Mae, Fannie Mae, and Freddie MAC, guarantee the borrowers' interest and principal, thereby eliminating the credit risk embedded in each mortgage. By pooling together individual mortgages and guaranteeing the loans, they allow mortgages to trade almost homogenously to the investing public through the brokerage community, thus creating a deep and liquid secondary market.

While mortgages are originated in varying maturities ranging from five to 30 years with both fixed and floating-rate coupons, the predominant choice by borrowers is the 30-year fixed rate mortgage, which represents nearly half of all outstanding mortgages. Furthermore, at any given time, the most liquid and heavily traded 30-year mortgage usually has a coupon rate that makes the mortgage value closest to par. Such a mortgage is known as the *current coupon* mortgage. The reason for the liquidity of the current coupon mortgage is a steady, but technical, supply-demand balance. The supply originates from mortgage bankers who are refinancing existing mortgage holders or creating new mortgages for first time home buyers. The demand arises from a gamut of investors most notably, Fannie Mae and Freddie MAC who, in addition to guaranteeing mortgages, also maintain a portfolio for investment

---

[2] Federal Reserve Bank of New York, January 2003, "Total Primary Dealer Transactions Volume in US Government and Federal Agency Securities Market Share."

purposes. The two GSE's reinvestment needs and portfolio growth targets help fuel the largest demand for mortgages. Combined, the two agencies control nearly 40 percent of all outstanding mortgages. MBS demand also comes from index managers, pension funds, banks, and hedge funds. With the natural balance of supply and demand, current coupon mortgage trading represents nearly half of all daily trading volume. In normal trading days, the current coupon mortgage generally trades on a 1/64th bid-offer spread for up to a $100 million block.

Because of the liquidity and price transparency, we choose the 30-year current coupon mortgage as our benchmark security to test Wall Street's OAS models. Our data set consists of daily current coupon mortgage OAS from April 29, 1999 through April 14, 2003 (989 business days), contributed from six of the largest dealers in mortgage securities.[3] The reported OAS are calculated from each dealer's proprietary interest rate and prepayment models.

2 What is a good model?

To determine what characterizes a good model, we sent the following questionnaire to a number of people involved in either design of financial pricing models or model-based trading of financial instruments (model-based arbitrage).

> *Let p denote the market price of a security, and v to be the true value of that security derived from a model proposed by the* God of Finance. *Furthermore, define the residual as the difference between the market price and the true value of the security and denote it by r, namely $r = p - v$.*
>
> 1. *Does EMH require $r = 0$ at all time? Under what conditions do we have non-zero r?*
> 2. *In markets in which you are involved, is $r = 0$? If not, why?*

---

[3] The ranking of the dealers is compiled by Greenwich Associates for year 2002.

3. *Suppose that the God of Finance has a number of not-so-talented but otherwise identical siblings. How do we choose among models proposed by this group? What is your wish list of properties that characterize an ideal pricing model?*

Most participants agree that under EMH $r = 0$ should hold. Nevertheless, they acknowledge the potential existence of temporal non-zero r due either to market frictions or short-term supply/demand imbalances. In answering the second question, all participants agree that r is non-zero at their respective market based on their respective model. Furthermore, the magnitudes of r are often larger than the transaction costs for their particular markets. However, the reasons are clearly divided along the academic/practictioner lines. The academics believe that large non-zero r's are signs of model deficiency; whereas the practitioners believe that, even in highly liquid markets, large r can exists and points to a potentially profitable trading opportunity. In retrospect, the dichotomy of responses is not surprising. They are both economically based and self-serving: The first group makes a living explaining arbitrages away whereas the second group makes a living trading arbitrages away. Interestingly enough, both groups have more or less similar answers to the last question. The following is a consensus set of the wish list for the ideal model,

1. *The time series of r should not exhibit a time trend or regime change. Furthermore, in an increasingly efficient market, the rolling variance estimate of r should be a non-increasing function of time.*
2. *The probability distribution of r should be symmetric around its mean. The autocorrelation of r should be small and should show rapid decay. All things equal, all respondents prefer a model that produces a higher number of mean-crossings.*
3. *The residual r should be independent of true value v, or any systematic movement of the underlying market.*

   In addition, one practitioner (a true Cartesian) considered the possibility of a malicious identical sibling who provides him with a devious money-losing model and added the following condition,
4. *Residuals from all competing models should be highly positively correlated. Any lack of correlation or negative correlation should raise a flag.*

In what follows, we apply the above criteria to compare the competing models in the US MBS market. For that purpose, we treat the current-coupon MBS as a derivative instrument on the US swap and swaption market, and the OAS value as the residual r defined above, but measured in terms of annual returns.

3 Statistical Analysis of the OAS Time Series

This section measures the statistical properties of the six OAS series and compares them along the criteria obtained from the survey. We assume that these six OAS series are from six different models, henceforth labelled as model 1, 2, 3, 4, 5, and 6, respectively. By so doing, we avoid revealing the identity of the six firms involved. Whenever applicable in graphical representations, we denote the first model by a solid line, model 2 by a dashed line, model 3 by a dash-dotted line, model 4 by a dotted line, model 5 by crosses, and model 6 by diamonds. The analysis is performed in four parts, corresponding to the four listed properties. First, we investigate whether the six OAS series contain any time trend in their levels and rolling volatility estimates. Second, we report and analyze the general statistical properties of the six series, including the sample moments and serial correlations for each series. Third, we examine the cross-correlations among the six OAS series. Finally, we examine whether the OAS series are correlated with any systematic movement in the interest rate and interest rate options market.

3.1 Time Trend in OAS and its Volatility

The left panel of Figure 1 plots the OAS time series of the six models. For ease of comparison, we standardize the six series by demeaning first and then dividing the demeaned series by their respective sample standard deviation. Most of the six series lay above one another and share a similar time trend. The only exception is the dotted line (model 4), which exhibits less time trend. The right panel of

Figure 1 plots the time trend estimates (circle-sold line) and their 95 percent confidence bands (dash-dotted lines). The time trend for each series is estimated via the following simple regression,

$$OAS_t = a + Gt + e_t,$$

where the OAS series is standardized, t denotes time in years and G denotes the annul growth estimate. While the time trend estimates for all six series are positive, the time trend estimate for model 4 is much lower than for the other five models.

The left panel of Figure 2 plots the time series of the 100-day rolling volatility estimates of the six series. Again, the estimates are based on standardized series and the volatility estimates are further normalized by the first estimate. We do not observe any obvious decline over time in the volatility estimates. Instead, some of the series exhibit several volatility spikes more recently, most notable is the model 5 (crossed) and model 6 (diamonds).

The right panel in Figure 2 plots the growth rate estimates (circle-solid line) and 95 percent confidence bands (dash-dotted lines) on the volatility based on the following regression,

$$\ln vol_t = a + bt + e_t,$$

where vol_t denotes the 100-day rolling volatility estimate. The plotted growth rates estimates are in annualized percentages. We observe that the estimated time trend is positive for model 2, 5, and 6. The trends in volatility in model 1, 3, and 4 are less significant. Thus, the volatility of the residuals are not declining over time, but increasing for some models.

3.2 Summary Statistics

Table 1 reports the summary statistics of the six OAS series. The columns under G report the annual growth estimate on each series and $GSTD$ denotes the standard error of the growth estimates, based on standardized series. The growth estimates are statistically significant for all six models. The largest time trend comes from Model 5, smallest from Model 4. The five models (1, 2, 3, 5, and 6) have similar growth trends, while model 4 has markedly smaller time trends.

NCR measures the number of mean crossings based on each demeaned and detrended series. Models 2, 5, and 6 have smaller number of crossing compared to the other three models (1, 3, and 4). The first model has the most mean crossing, and its mean value is also close to zero. The largest mean OAS come from models 2 and 5, so do the largest standard deviation estimates.

All six series exhibit very small skewness, implying that the distribution of the six series are all relatively symmetric. The excess kurtosis estimates are also small, implying that there are not many abrupt adjustments.

All six model series exhibit strong serial dependence. The lowest serial dependence comes from model 4, highest from models 2 and 5. Furthermore, the serial correlation decays very slowly, much slower than implied from an AR(1) specification.[4] The slow decay of the autocorrelation function implies that the OAS spreads are likely to stay away from the mean for a long time before reverting back to the mean.

3.3 Cross-Correlation and Co-Movement

Table 2 reports the cross-correlation matrix between the six OAS series, measured on levels in the left panel and daily changes in the right panel. First, the correlations measured on levels are much stronger than the correlations measured on daily changes, implying that they may share some common trend, but also exhibit independent daily variation.

Whether the correlation is measured on levels or daily differences, we observe strong correlations between models 1, 2, 3, 5, and 6. In contrast, model 4 seems to be relatively independent of the other five models. When measured on levels, the average cross-correlation between the five models is about

---

[4] For example, based on the daily first order autocorrelation estimates, the 20th order autocorrelation would be 0.54, 0.87, 0.70, 0.17, 0.87, 0.54, respectively for the six models based on an AR(1) specification. In contrast, the estimated 20th-order autocorrelations for the six series are, respectively, 0.85, 0.93, 0.90, 0.55, 0.93, 0.77, all much larger than implied from the AR(1) specification.

0.9 while their correlation with model 4 is about 0.5. When measured on daily differences, the average cross-correlation for the five models is about 0.4, but their correlations with model 4 are all less than 0.1. Our suspicious Cartesian friend (Section 2, response 4) warns of the possibility of a malicious sibling here. As we will see in the next section, the malicious outnumber the virtuous by five to one.

Figure 3 plots the results of the principal component analysis on the six series. The left panel reports the percentage variance explained by each principal component, computed based on the eigenvalues of the covariance matrix. The right panel denotes the loading the six principal components, represented by the six eigenvectors. Whether the performance is based on levels or daily changes, we cannot identify one predominant component. These six models are not driven by one factor. Hence, they are not noisy variations of the same model.

3.4 Correlations with the Systematic Movements in Interest Rates and Interest Rate Options

An ideal model should generate residual series r that are, even if not zero, independent of any systematic movements in the underlying market. This subsection investigates whether the six OAS series are correlated with systematic movements in interest rates and in interest rate options. For this purpose, we collect the LIBOR and swap rates. The LIBORs are at maturities of one, three, six months, and the swap rates are at maturities of one, two, three, four, five, seven, ten, twelve, fifteen, 20, and 30 years. We also collect at-the-money caps and swaptions. The caps are one one-year LIBOR and with option maturities of one, one, two, three, four, five, seven, ten, twelve, fifteen, 20, and 30 years. The swaptions are on swaps ar maturities of one, two, three, four, five, seven, ten, 12, 15, 20, 25, and 30 years. For each underlying swap rate, the option maturities include one, two, three, four, five, seven, and ten years.

We first perform principal component analysis to extract the first three factors from the interest rate data. We also extract the first three principal components from the implied volatility data on the interest rate options. We then measure the correlation between each of the six OAS series with the six principal components, three each from the interest rate market and the interest rate options market. These correlation estimates are reported in Table 3.

We observe that the OAS series from five of the six models exhibit very high correlation with the first factor in interest rates and the first factor in interest rate implied volatilities. The correlations with other principal components decline. The only series that exhibit low correlation with the principal components in interest rates and interest rate options is from model 4.

These results indicate that most of the outstanding models generate residuals that are highly correlated with the systematic movement in both the interest rate market and the options market. In a fully hedged portfolio, this property could result in profit and loss that is market directional. Indeed, most seasoned market participants realize this issue and have been under-hedging their MBS portfolios compared to the models. For example, the quarterly reports from the Government Sponsored Enterprises, e.g., Fannie Mae and Freddie Mac, often show a systematic under-hedging in the options market.

More interestingly, however, the five models that are highly correlated with one another are also highly correlated with the systematic movements in interest rates and interest rate options. Model 4 is relatively independent of other models, and it is also relatively uncorrelated with the systematic movements in interest rates and interest rate options. Furthermore, Model 4 also exhibits less time trend and lower serial dependence, and thus comes closest to our wish list for a good model. Therefore, we identify possible “herding” behavior among the research analysts in the MBS market. Furthermore, it is interesting that the one outlier is actually the best model.

4 Mirages and Arbitrages

In an efficient MBS market, using an ”ideal” model, one expects most OAS values to fall in a band, representing transaction costs, around the mean. In addition, any excursions outside of this band, due to temporary market imbalances, are expected to be few and short-lived.

Our study indicates that out of the six models, model 4 performs best against our wish list of an ideal pricing model. The OAS series from model 4 has little time trend, stable rolling volatility, and low correlation to the underlying interest rate and interest rate options. In this section, we compare the OAS values generated from this model to what is expected from an "ideal" model in an efficient market.

The left panel in Figure 4 plots the histogram of the time series of OAS values from model 4. The number of level-crossings for various bands around the mean, representing transaction cost, are plotted in the right panel. Here, level-crossing is defined as any one-sided crosses of the band, including up crosses of the upper band and down crosses of the lower band.

The average transaction cost in fully hedging and maintaining a current coupon position is about five basis points.[5] From Figure 4, we observe 87 crossings at the five basis point level over the sample period of four years, an average of one crossing over every two weeks. If each crossing represents an arbitrage opportunity, these many crossings would point to a highly inefficient market.

Is this a case of a large, highly liquid market exhibiting many arbitrage opportunities, or is it just a mirage? If the market participants saw these crossings as potentially profitable trading opportunities and acted on them quickly, we would expect these crossings to revert quickly to within the band. We hence would also expect the OAS series to exhibit small serial dependence and expect the autocorrelation function to decay rapidly over time. Figure 5 plots the autocorrelation function for the OAS series from model 4. The first order autocorrelation is over 0.9 and hence is anything but small. More troubling is the slow decay of the autocorrelation function, which exhibits a half life of over 25 business days (five weeks).[6] This slow decay implies that the market participants are not acting on the crossings at the five basis point level as actively as one would expect from the pure arbitrage perspective.

A potential explanation is that the market participants assign a wider band than the five basis points estimated from purely transaction costs. The extra width of the band may come from an additional cushion for model risk. All mortgage valuation models rely heavily on projections from a histori-

---

[5] The hedging cost is composed of three components: (1) three points on the swap rate curve for interest rate hedges at a cost of 1.5 basis points, (2) three additional points on the volatility surface for option hedge at 2.5 basis points, and (3) one basis point for coupon swaps to keep the MBS portfolio at Current Coupon. See Dynkin, Hyman, Konstantiovsky, and Mattu (2000) for a similar discussion. The number of systematic factors in the interest rate and interest rate options markets is based on the empirical analysis of Heidari and Wu (2003).

[6] The half life is defined as the number of lags (days) at which the autocorrelation declines to one half of the first-order autocorrelation.

cally based prepayment function. A serious drawback of these models is that they perform poorly out-of-sample (Longstaff (2003)). To keep the models up-to-date, the prepayment functions are regularly re-estimated. At times, this could result in drastic changes of the OAS values. In fact, merely considering the range of sample means and standard deviations (20.25 basis points, and 15.15 basis points respectively) reported on the six models in Table 1, one can obtain a sense for the magnitude of model risk in valuing MBS. In addition to prepayments, there are inherent risks/uncertainties associated with the choice of dynamic term structure models. For a comprehensive review of the dynamic term structure models, see Chapman and Pearson (2001) and Yan (2001).

Although it is difficult to quantify and price model risk, model performance statistics similar to ones reported here should help in identifying its magnitude. For example, if we set the level-crossing band at 15 basis points, there are merely three crossings during the entire four-year sample period. Thus, assuming that the MBS market is relatively efficient and without many arbitrage opportunities, we can infer from Figure 4 that the market adds approximately ten basis points, on top of the five basis points transaction cost, as a cushion to compensate for model risk. This ten basis point value seems reasonable in comparison to the range of mean OAS (20.25 basis points) generated from the six models studied here.

5 Conclusions

In this study, we analyze the statistical properties of six MBS valuation models against a wish list of desired properties. The wish list is derived from a survey of market participants, researchers, as well as practitioners, on ideal model properties. The conclusions of our study are as follows,

1. Only one out of the six models studied has properties close to the ideal model. The most undesirable property in most models is the high correlation of the OAS series with the underlying interest rate and interest rate option markets. In a fully hedged portfolio, this property could result in profits and losses that are market directional.

2. There does not exist one dominant principal component in the OAS time series produced by the six models, indicating that the results are not noisy variations of the same valuation model. However, we find that the five failed models are highly correlated with one another, and less correlated with the best model. The high correlation among the five failed models may indicate "herding" among the MBS research analysts, which may lead the entire flock over the proverbial cliff.
3. Assuming that the MBS market is relatively efficient, we estimate the model risk associated with the best model at ten basis points.

More broadly, this study shows the difficulties in modeling complex financial securities, even in markets as liquid as the U.S. mortgage-backed securities. Furthermore, it warns the investors against taking any single, or even a consensus, model at face value. Simple analysis, similar to those performed here, can help identify the good models and separate them from the bad and the ugly. Moreover, the application of the efficient market hypothesis may be a first step in quantifying the magnitude of model risk in complex but liquid markets.

References

Breeden, Douglas, 1994, Complexities of hedging mortgages, *Journal of Fixed Income* 4, 6–41.

Brown, David T., 1999, The determination of expected return on mortgage-backed securities: An empirical analysis of option-adjusted spreads, *Journal of Fixed Income* 9, 8–19.

Chapman, David A., and Neil D. Pearson, 2001, Recent advances in estimating term-structure models, *Financial Analysts Journal* 57, 77–95.

Dynkin, Lev, Jay Hyman, Vadim Konstantiovsky, and Ravi Mattu, 2000, Constant-duration mortgage index, *Journal of Fixed Income* 10, 79–96.

Hayre, Lakhbir, 2001, *Mortgage-Backed and Asset-Backed Securities*. (Wiley New York).

Heidari, Massoud, and Liuren Wu, 2003, Are interest rate derivatives spanned by the term structure of interest rates?, *Journal of Fixed Income* 13, 75–86.

Longstaff, Francis A., 2003, Optimal recursive refinancing and the valuation of mortgage-backed securities, Working paper, UCLA.

Yan, Hong, 2001, Dynamic models of the term structure, *Financial Analysts Journal* 57, 60–76.

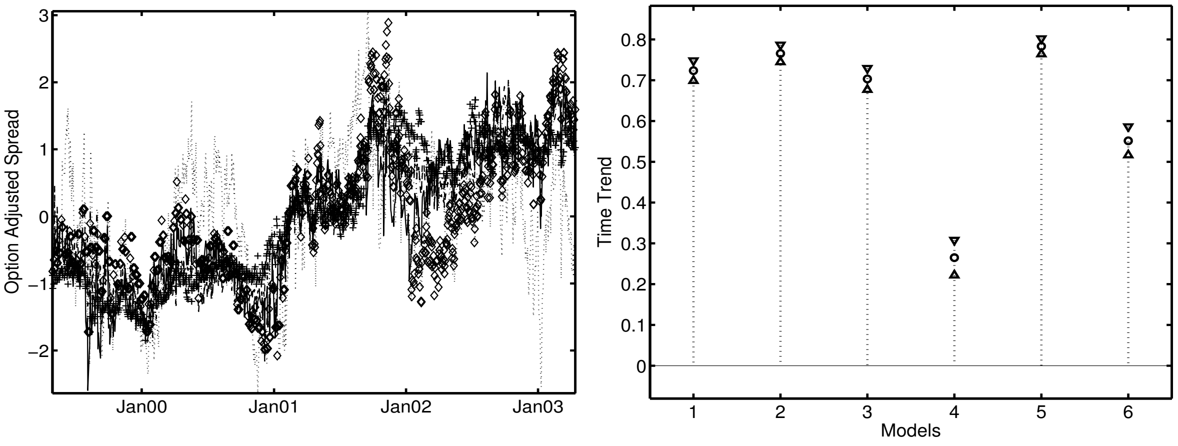

Figure 1: **Time Series of OAS and its Time Trend Estimates**
The left panel depicts the time series of the OAS from the six models. The OAS series are standardized: demeaned and divided by their sample standard deviation. The right panel depicts the growth rate estimates (circles) and the 95 percent confidence band (triangles) on the estimates for the six series.

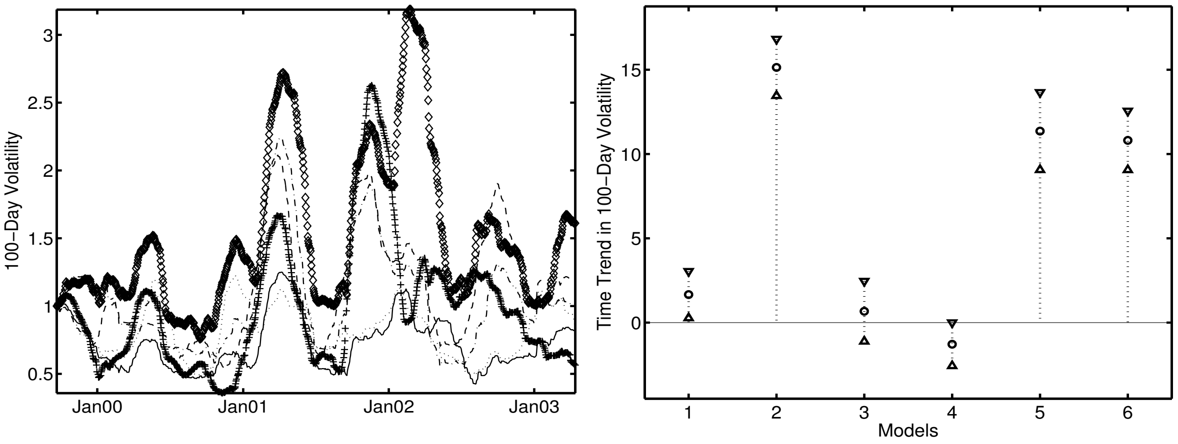

Figure 2: **Time Series of the 100-day rolling Volatility and its Time Trend Estimates**
The left panel depicts the time series of the 100-day rolling volatility estimates for the six OAS series. The volatilities are estimated based on standardized residuals with a 100-day rolling window. The volatility estimates are then normalized by the first estimate of the time series. The right panel depicts the time trend estimates for the six volatility series (circles) and their 95 percent confidence band (triangles).

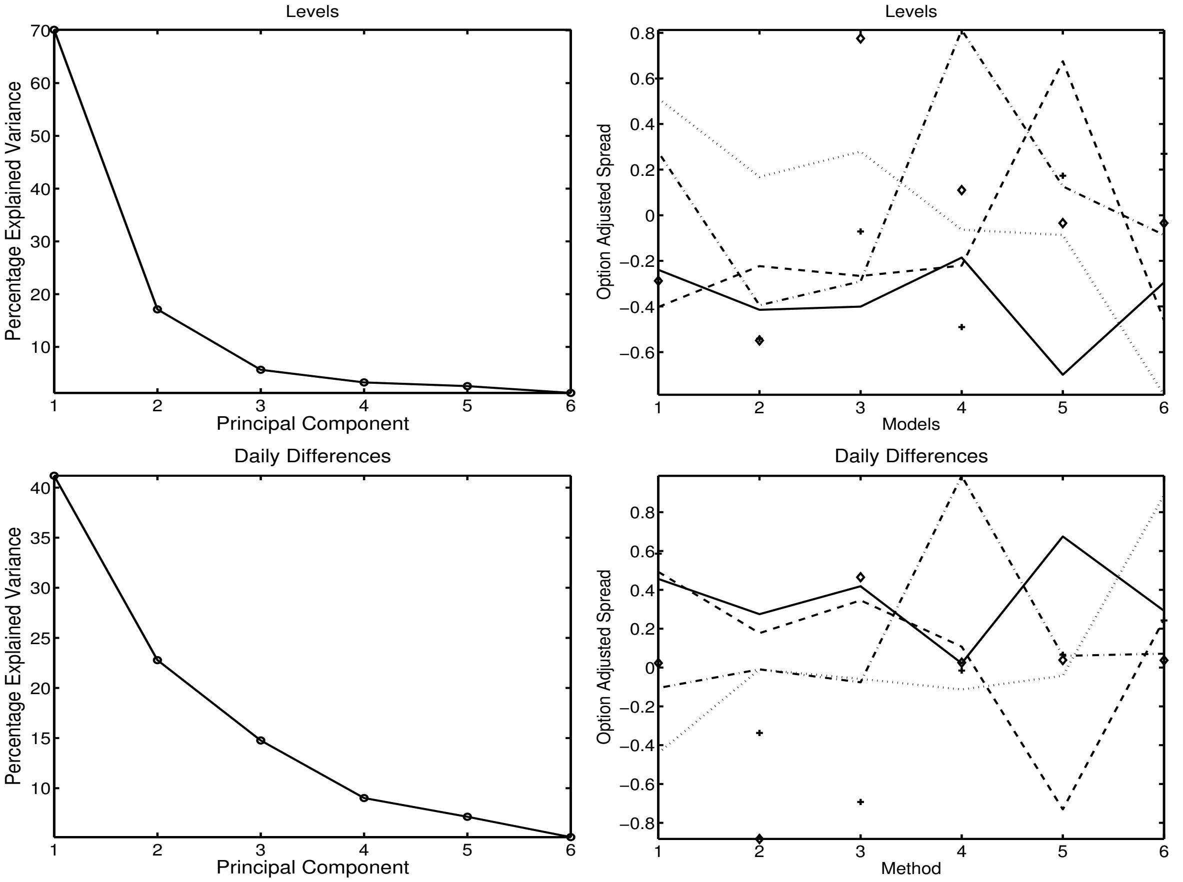

Figure 3: **Principal Component Analysis**

The left panels depict the percentage explained variance of the six principal components and the right panels plot the corresponding eigenvectors. The top panels are based on principal component analysis on levels while the bottom panels are based on daily differences.

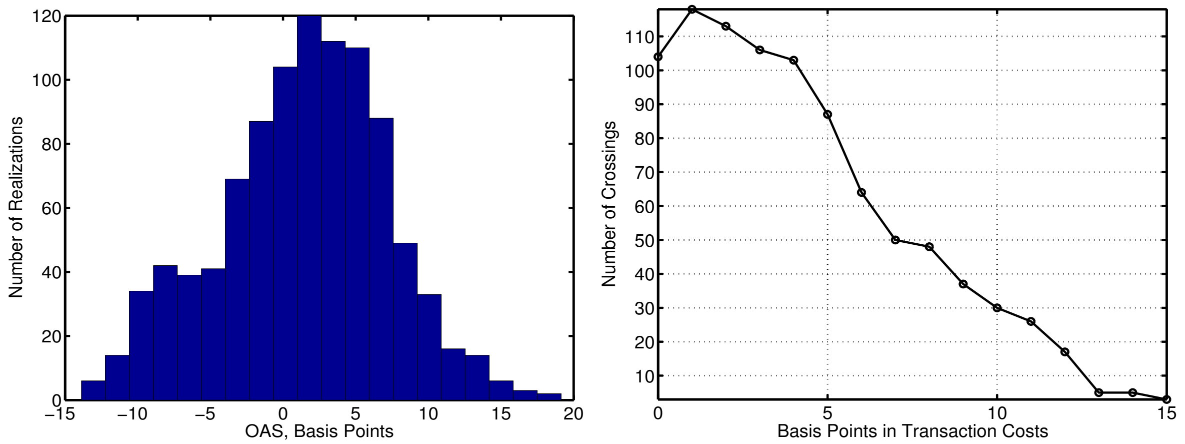

Figure 4: **Histogram of the OAS Series from Model 4 and Number of Crossings**
The left panel plots the histogram of the OAS series from Model 4. The right panel plots the number of crossings at different OAS magnitudes in the series.

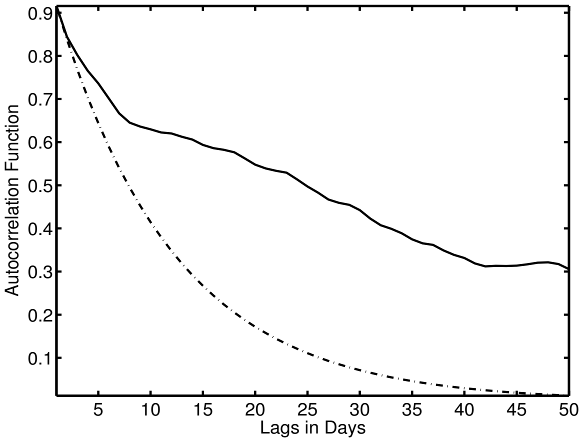

Figure 5: **The Autocorrelation Function**
The solid line is the autocorrelation function of the OAS series from model 4. The dash-dotted line is implied from the AR(1) assumption and based on the first-order autocorrelation estimate.

Table 1: **Summary Statistics of OAS Series**

Entries are summary statistics of the six OAS series. "G" and "GSTD" denote the annual time trend estimate and standard deviation, based on the following regression,

$$OAS_t = a + Gt + e_t$$

where OAS_t denotes the standardized OAS series, t is in years so that G denotes annual growth. NCR denotes the number of crossing of zero for the regression residual e_t. Mean, STD, Skew, Kurt, and Auto(k) denote, respectively, the sample estimates of the mean, standard deviation, skewness, kurtosis, and kth-order daily autocorrelation. The data are daily OAS values from five dealers, from April 29, 1999 to April 14, 2003 (989 observations).

Model	G	GSTD	NCR	Mean	STD	Skew	Kurt	Autocorrelations			
								1	5	10	20
1	0.72	0.01	143	0.00	11.04	0.03	-1.03	0.97	0.90	0.86	0.85
2	0.77	0.01	79	14.56	16.77	0.17	-1.33	0.99	0.97	0.96	0.93
3	0.70	0.02	133	3.08	12.88	0.06	-1.19	0.98	0.95	0.93	0.90
4	0.26	0.03	131	1.41	5.80	-0.15	-0.20	0.92	0.74	0.63	0.55
5	0.78	0.01	73	20.25	30.95	0.02	-1.47	0.99	0.98	0.96	0.93
6	0.55	0.02	88	5.92	8.98	0.41	-0.34	0.97	0.88	0.82	0.77

Table 2: **Cross-Correlation Between the Six OAS Series**

Entries report the cross-correlation matrix of the six OAS series, based on levels on the left panel and daily differences on the right panel. The data are daily OAS values from April 29, 1999 to April 14, 2003 (989 observations).

	Levels						Differences					
Model	1	2	3	4	5	6	1	2	3	4	5	6
1	1.00	0.91	0.91	0.57	0.85	0.82	1.00	0.45	0.56	0.03	0.20	0.37
2	0.91	1.00	0.96	0.48	0.94	0.82	0.45	1.00	0.51	0.04	0.27	0.33
3	0.91	0.96	1.00	0.52	0.90	0.86	0.56	0.51	1.00	0.02	0.26	0.39
4	0.57	0.48	0.52	1.00	0.43	0.58	0.03	0.04	0.02	1.00	-0.01	0.07
5	0.85	0.94	0.90	0.43	1.00	0.71	0.20	0.27	0.26	-0.01	1.00	0.19
6	0.82	0.82	0.86	0.58	0.71	1.00	0.37	0.33	0.39	0.07	0.19	1.00

Table 3: **Cross-Correlation Between the Six OAS Series and Systematic Movements in Interest Rates and Interest Rate Options**

Entries report the cross-correlation of the six OAS series with the first three principal components from the LIBOR and swap series and the first three principal components from the cap and swaption implied volatilities. The left panel are measured on levels whereas in the right panel the correlations are measured between daily changes in the OAS series and the principal components from the daily changes in interest rates and interest rate options.

	Levels						Differences					
Models	1	2	3	4	5	6	1	2	3	4	5	6
Factors	A. Correlation with Interest Rate Movements											
1	-0.86	-0.96	-0.93	-0.34	-0.93	-0.73	-0.06	-0.27	-0.14	-0.03	-0.29	-0.18
2	0.30	0.43	0.29	0.00	0.28	0.34	0.02	0.03	0.02	-0.02	0.06	0.01
3	0.37	0.49	0.41	0.26	0.56	0.35	-0.04	0.01	-0.08	0.03	0.04	-0.08
	B. Correlation with Interest Rate Option Movements											
1	-0.79	-0.91	-0.87	-0.24	-0.84	-0.71	-0.10	0.11	0.03	-0.02	0.18	0.01
2	-0.33	-0.35	-0.38	-0.34	-0.51	-0.23	-0.18	-0.00	-0.12	0.04	0.08	-0.10
3	0.08	-0.17	-0.10	-0.05	-0.18	0.05	0.22	0.14	0.13	0.04	0.00	0.12