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Department of Economics
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Credit-Implied Forward Volatility and Volatility Expectations

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Credit-Implied Forward Volatility And Volatility Expectations

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We show how one can back out implied forward volatility term structures from credit default swap spreads. Such forward stock volatility term structures are useful for instance in forward start option pricing. We find the term structure to be downward-sloping, and the credit market's volatility forecasts tend to vary more across time than across maturities. Long-term volatility expectations, in turn, are found to be low and stable while short-term expectations are higher and more volatile. The volatility expectation's mean-reversion rate, finally, indicates that the credit market expects volatility shocks in the equity market to last for several years.

Keywords: CDS; implied volatility term structure; forward volatility; forward start options

JEL classification codes: G10; G1

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1. Introduction

We follow Byström (2013) and back out implied stock volatilities from credit default swap spreads. While Byström (2013) backs out ordinary implied volatilities, we instead focus on so-called forward volatilities, i.e. volatilities for time-periods that start in the future. Such volatilities are needed when pricing exotic derivatives such as forward start options, cliquets or forward starting “golden handcuff” employee stock options (Alford & Boatsman, 1995; Glasserman and Wu, 2011). We then proceed to estimating volatility expectations, for the first time (we believe) explicitly estimating the credit market’s short- and long-term equity volatility expectations.

In addition to representing the credit market, rather than the equity market, the credit default swap (CDS) market has certain features that make it particularly useful for the purpose of forecasting forward volatilities. First, the maturities of credit default swaps are much longer than those of ordinary equity options. This makes it possible to forecast stock volatilities starting several years into the future. Second, the availability of constant-maturity CDS contracts with a range of maturities, $n = 1, 2, 3, \dots, 10$ years make it possible to back out forward volatilities for any calendar year 1 to 10 years into the future. This feature sets this study/market apart from previous studies/markets relying on both fewer and/or changing maturities. Third, the CDS market has become a mature market covering many regions, countries and firms (Byström (2015)). This makes the CDS market a promising new candidate for anyone who wants to estimate implied forward stock volatilities.

There are several studies that look at the term structure of implied volatilities.¹ In this paper we build, first and foremost, on Byström (2013) backing out implied stock volatilities using credit

¹ Stein (1989) looks at the mean-reverting properties of implied volatility. Xu and Taylor (1994) estimates forward volatilities and estimates short- and long-term volatility expectations. Heynen et al. (1994) tests restrictions on the

default swaps. We then use these volatilities to calculate forward volatilities and short- and long-term volatility expectations (in the credit market) for the stocks in the Dow Jones Industrial Average (DJIA) index.

2. Implied Volatility

Implied stock volatilities are typically inferred from equity options. As described in Byström (2013, 2015), however, implied stock volatilities can also be inferred from credit default swaps using CDS pricing models such as the industry benchmark CreditGrades model (CreditGrades, 2002). In CreditGrades, a firm defaults when its asset value, V_t , falls below its stochastic default threshold $L_t D$. D is the firm's debt level and L_t is the global recovery rate on the firm's liabilities. The CreditGrades CDS spread for a certain maturity, T , is then

$$spread_{CDS}^T = r(1 - R) \frac{1 - P(0) + e^{r\xi} (G(T + \xi) - G(\xi))}{P(0) - P(T)e^{-rT} - e^{r\xi} (G(T + \xi) - G(\xi))} \quad (1)$$

where the survival probability $P(t)$ is

$$P(t) = N\left(-\frac{A_t}{2} + \frac{\ln(d)}{A_t}\right) - dN\left(-\frac{A_t}{2} - \frac{\ln(d)}{A_t}\right)$$

and

$$d = \frac{V_0}{L_{mean} D} e^{\lambda^2},$$

$$A_t^2 = \sigma^2 t + \lambda^2,$$

implied volatility term structure and Campa and Chang (1995) tests the expectations hypothesis in the implied volatility term structure. Mixon (2007) also tests whether the term structure of implied volatilities is consistent with the expectations hypothesis and Egelkraut et al. (2005) studies forward volatilities and volatility prediction.

$$G(t) = d^{z+\frac{1}{2}} N\left(-\frac{\ln(d)}{\sigma\sqrt{t}} - z\sigma\sqrt{t}\right) + d^{-z+\frac{1}{2}} N\left(-\frac{\ln(d)}{\sigma\sqrt{t}} + z\sigma\sqrt{t}\right),$$

$$\xi = \frac{\lambda^2}{\sigma^2},$$

$$z = \sqrt{\frac{1}{4} + \frac{2r}{\sigma^2}}.$$

σ is the asset volatility and $\sigma = (\sigma_E E_t) / (E_t + L_{\text{mean}} D)$ where E_t is the equity value and σ_E is the stock volatility (that we back out). r is the risk-free interest rate, R is the CDS-specific recovery rate and L_{mean} and λ is the mean and standard deviation of the global recovery rate, L_t . We set $L_{\text{mean}}=R$ and follow the recommendations in CreditGrades (2002) choosing $R=0.5$ and $\lambda=0.3$.

3. Implied Forward Volatility

Volatilities implied by option prices or CDS spreads are expectations of volatilities over time-periods starting today. For certain purposes, such as pricing forward start options or employee options with “golden handcuffs”, the required volatilities are expected volatilities across time-periods starting in the future. These volatilities are known as forward volatilities and, in our setup, implied forward volatilities (variances) $f_{T,t}$ for each future year T , $2 \leq T \leq 10$, can be computed at time t from implied volatilities $y_{T,t}$ ($y_{T,t} = \sigma_E$) with maturities T , $1 \leq T \leq 10$, as:

$$f_{T,t} = T y_{T,t}^2 - (T-1) y_{T-1,t}^2. \quad (2)$$

4. A Volatility Term Structure Model

In our volatility term structure model, which is similar to the model in Xu and Taylor (1994), CDS market participants form volatility expectations that are functions of three parameters; the short-term expectation α , the long-term expectation μ and the rate of mean reversion, ϕ , which

determines the speed with which the volatility expectation reverts towards μ . Xu and Taylor (1994) shows that the expected forward variance $g_{T,t}$ is a linear combination of α^2 and μ^2 :

$$g_{T,t} = \mu_t^2 + x_{T,t}(\alpha_t^2 - \mu_t^2) \quad (3)$$

with

$$x_{T,t} = \frac{\phi^{T-1} - \phi^T}{1 - \phi}, \quad (4)$$

assuming $\phi < 1$. By minimizing the difference between $f_{T,t}$ and $g_{T,t}$, following the three-step regression-based estimation procedure described in Xu and Taylor (1994), we get daily $\hat{\alpha}_t$, $\hat{\mu}_t$ and $\hat{\phi}_t$ estimates. Compared to Xu and Taylor (1994) we have the advantage of (i) having constant maturities across the sample, (ii) having maturities that are counted in years and (iii) each day having the same number of maturities (ten).

5. Data

Our data set contains CDS spreads, stock prices and leverage ratios for the firms in the DJIA index from January 1, 2006 to September 30, 2010.^{2,3} The CDS data is available for constant maturities of n years with $n = 1, 2, 3, \dots, 10$, and all CDS contracts are senior USD contracts. The

² Only non-financial firms are included in the study and since some firms lack available data our sample is reduced to 22 firms.

³ The start date is dictated by data availability; before 2006 we do not find CDS data for all the (ten) maturities. The end date, in turn, is dictated by the need for a reasonably long out-of-sample period for the forward volatility forecasts (the calendar years 2011-2014).

stock prices are also denominated in USD, and as a proxy for the risk-free interest rate we use the average US 3-month Treasury bill rate.⁴

6. Results

Descriptive statistics on forecasted one-year to nine-year ahead forward volatilities is presented in Table 1 (year 2 starts one year from now and year 10 starts nine years from now etc.).^{5,6} The near-term volatility forecasts are obviously higher than the distant-term forecasts. The near-term forecasts are also more volatile.⁷ In Figure 1 we show the forward volatilities for the average firm in the sample and it is clear that, regardless of horizon, the forecasted volatility increases during the crisis. Figure 2 shows a 3D-plot of the forward volatility term structure sampled on a quarterly basis and it is clear not only that the term structure is downward-sloping but also that both its level and slope vary over time.

The financial crisis makes it difficult to evaluate the accuracy of volatility forecasts and in this paper we therefore choose a different path. In Figures 3-4 we present snapshots from the set of forecasts in Figure 1. We limit the forecasts to those forward volatility forecasts that are done the first trading day each calendar year from 2006 to 2011. The resulting forward volatility forecasts

⁴ Leverage ratios are downloaded from the web-page of A. Damodaran and the rest of the data is downloaded from Datastream.

⁵ While we only estimate one-year forward volatilities, our method and data allow for the estimation of n -year ($n=2,3,\dots$) volatilities as well.

⁶ We proxy the January 1, 2011 forecast with the September 30, 2010 forecast.

⁷ It should be noted, though, that although the nine forward volatility forecasts are made simultaneously they are forecasts for different time-periods. For example, the one-year ahead forecasts are for the calendar years 2007 to 2012 and the nine-year ahead forecasts are for the calendar years 2015 to 2020.

for the calendar years 2007 to 2014 are plotted both in Figure 3, with the dependent variable being the year, τ , for the forecast, and in Figure 4, with the dependent variable instead being the year, t , when the forecast is made.

In an ideal world, where the market always predicts future volatilities correctly, the seven curves in Figure 3 should overlap. In reality, the forecasts differ from each other, however; the credit market over-estimated the forward volatility for the years after the crisis and under-estimated it for the crisis years. The curves in Figure 4, in turn, should be horizontal if the market had perfect foresight. Instead, the actual forecasts demonstrate an upward-sloping pattern where the forecast of the forward volatility increases over time regardless of the year, τ , for the forecast. In general, the forecast variation is smaller among the various τ than among the various t ; i.e. the credit market's equity volatility forecasts tend to vary more across time than across maturities.

The model-implied short- and long-term volatility expectations α and μ are presented in Figure 5 (mean values together with 25%- and 75%-percentiles). The credit market's long-term expectations are quite stable around 30% while the short-term expectations fluctuate between 40% and 75%. The average volatility expectation mean-reversion rate ϕ is found to be 0.9 and varies between around 0.8 in 2006 and 0.95 in 2010; i.e., a "half-life" of 3-13 years with an average of 7 years ($0.9^7 \approx 0.5$).

4. Conclusion

In this paper we show how one can back out implied forward stock volatilities from CDS spreads and then use these volatilities to estimate short- and long-term volatility expectations. We find the forward volatility term structure to be downward-sloping, and the credit market's volatility forecasts tend to vary more across time than across maturities. The credit market's long-term

volatility expectation for the stocks in the DJIA index is around 30% while the short-term expectation fluctuates between 40% and 75%. Meanwhile, the average mean-reversion rate in the volatility expectation corresponds to a “half-life” of around 7 years. I.e., volatility shocks in the equity market are expected to last for long. We believe this to be the first attempt at estimating the credit market’s short- and long-term expectations about future stock volatility.

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Table 1. Descriptive statistics for annualized one-year to nine-year ahead credit-implied forward volatilities averaged across the 22 non-financial DJIA firms for the time-period January 1, 2006 to September 30, 2010.

	Mean (%)	Stdev (%)	Skewness	Kurtosis
Year 2	41.4	5.7	-0.10	-1.22
Year 3	38.8	4.6	0.41	-0.40
Year 4	39.3	4.2	0.14	-1.13
Year 5	38.0	3.7	0.54	-0.21
Year 6	35.4	3.1	0.74	0.88
Year 7	34.2	3.1	0.89	1.36
Year 8	34.0	3.3	0.71	0.42
Year 9	33.5	3.3	0.72	0.50
Year 10	33.1	3.3	0.73	0.55

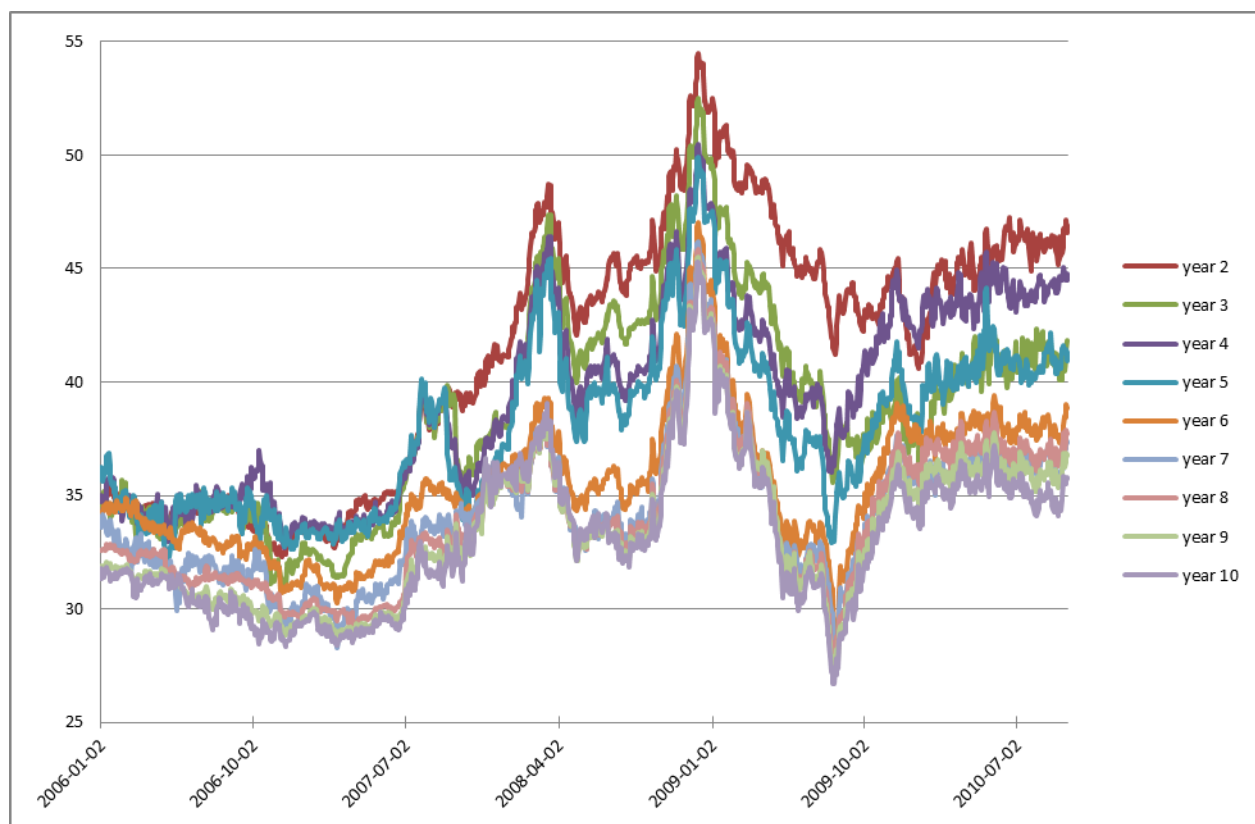


Figure 1. One-year to nine-year ahead credit-implied forward volatilities averaged across the 22 non-financial DJIA firms for the time-period January 1, 2006 to September 30, 2010.

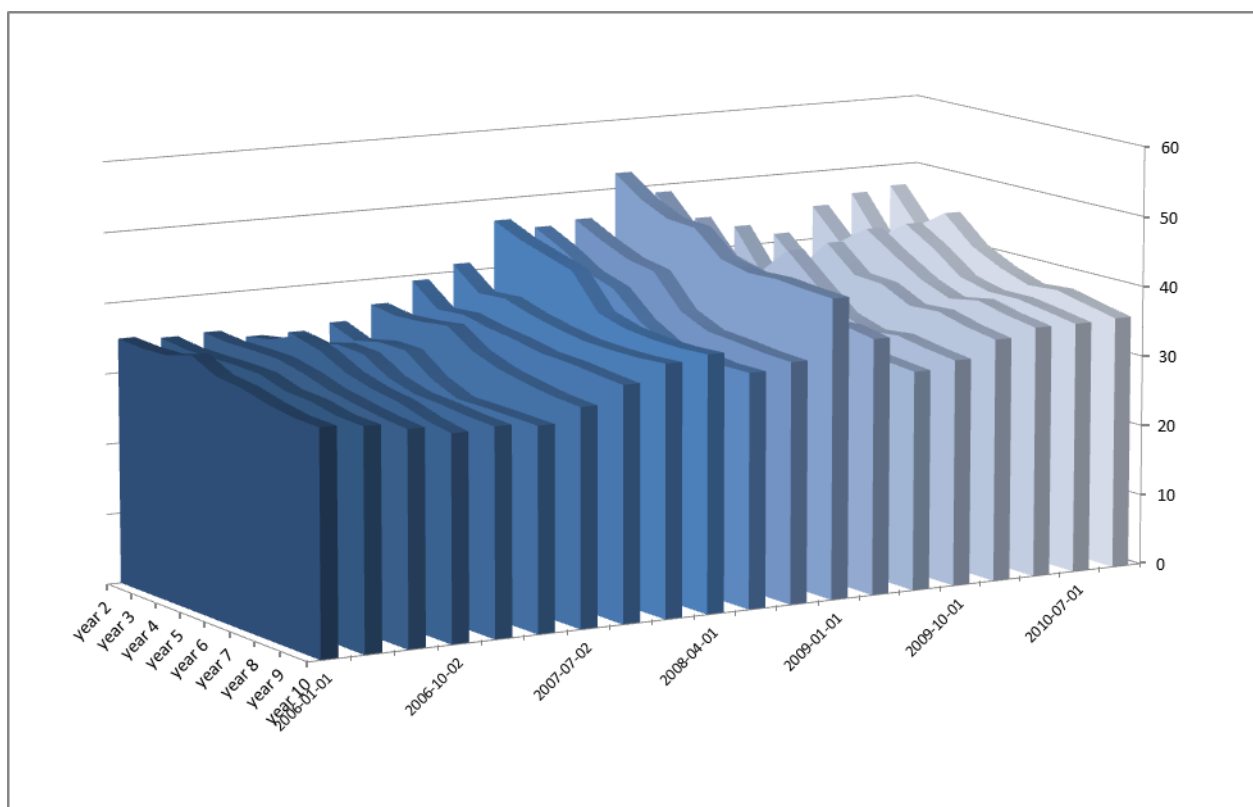


Figure 2. The (average) credit-implied forward volatility term structure sampled on a quarterly basis over the time-period January 1, 2006 to September 30, 2010.

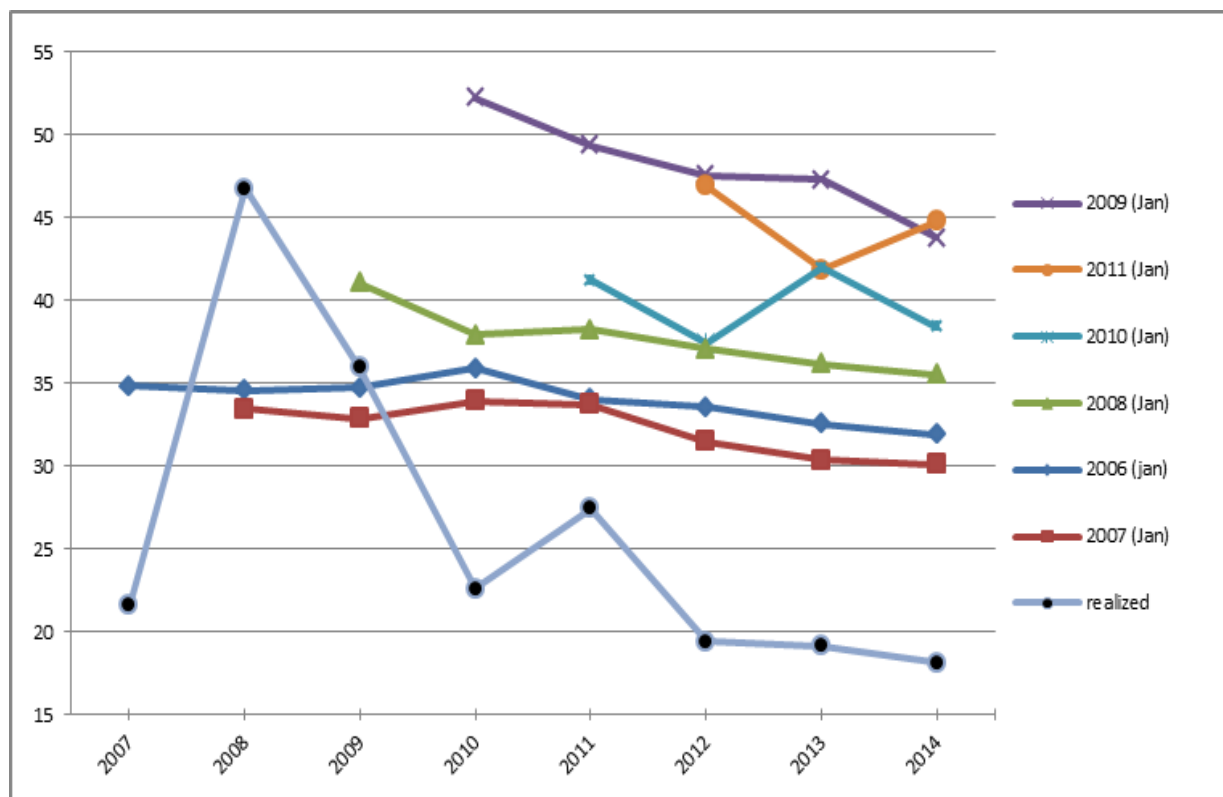


Figure 3. Credit-implied forward volatility forecasts made the first trading day in January each year from 2006 to 2011. The variable on the x-axis is the year, τ , for the forecast (the calendar years 2007 to 2014).

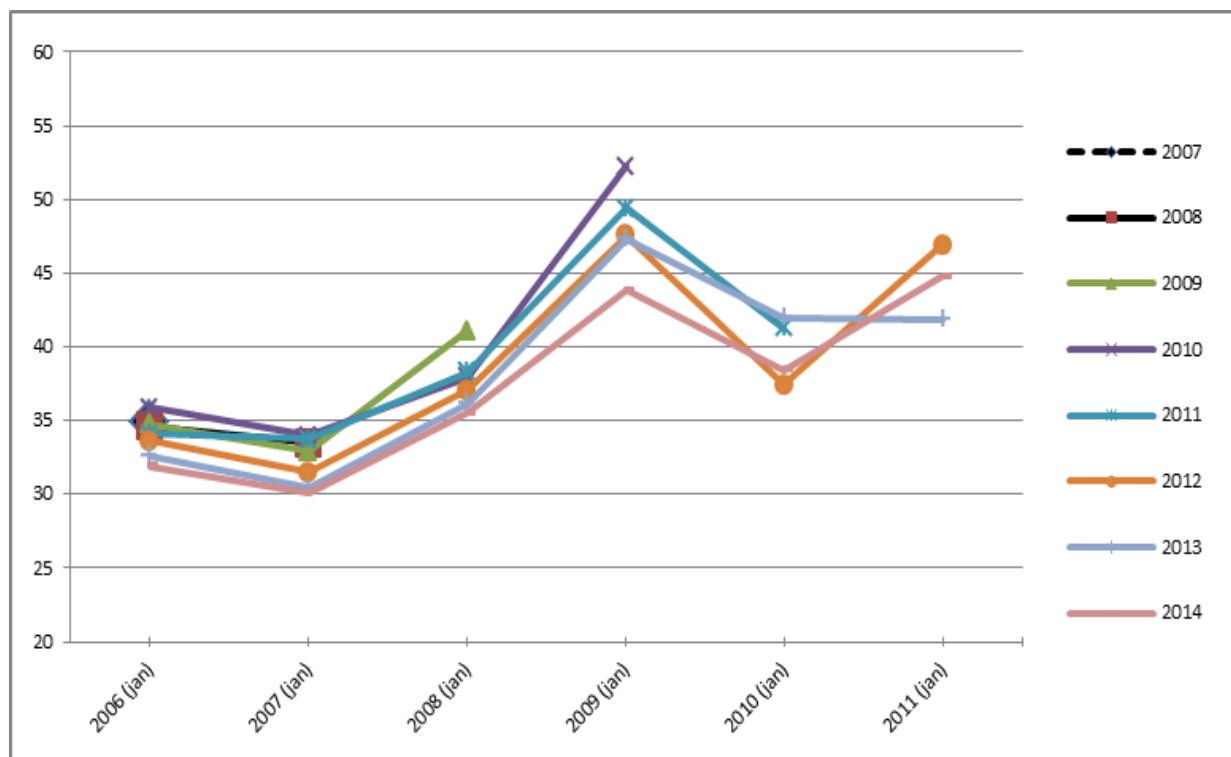


Figure 4. Credit-implied forward volatility forecasts for the calendar years 2007 to 2014. The variable on the x-axis is the year, t , when the forecast is made (the first trading day in January each year from 2006 to 2011).

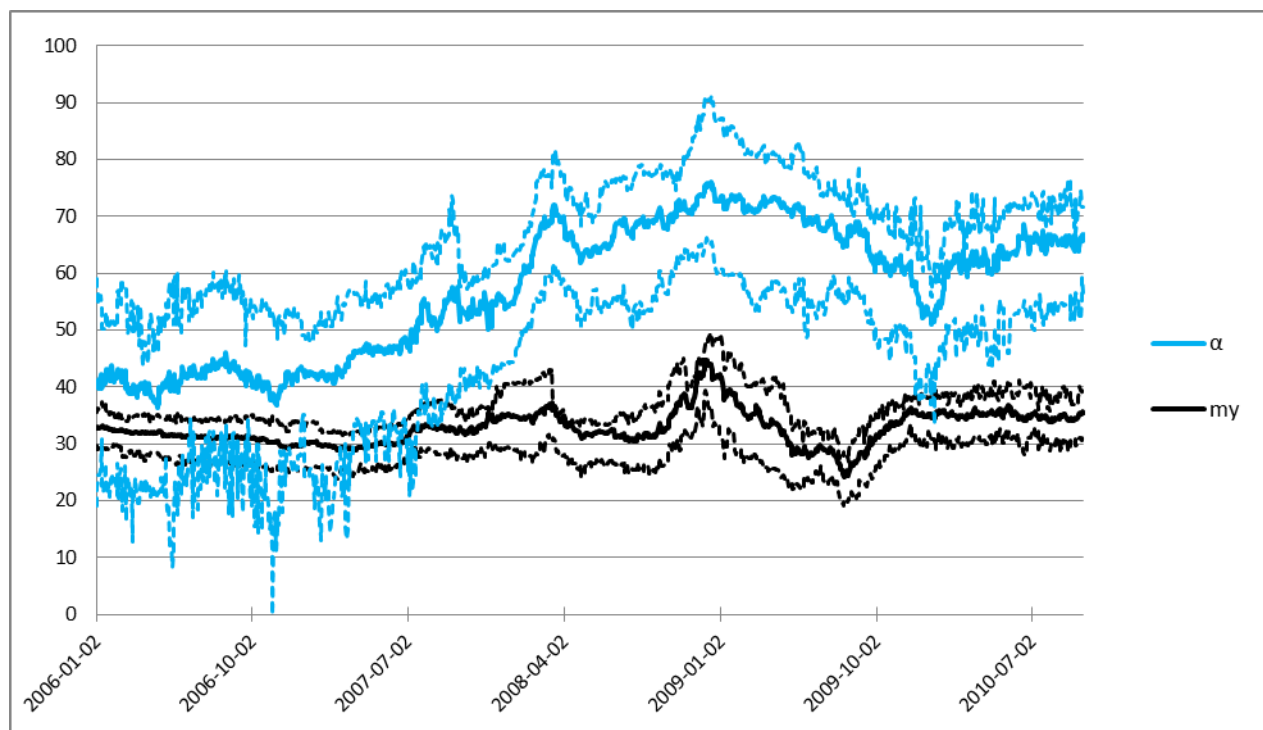


Figure 5. Short- and long-term volatility expectations (α and μ) averaged across the 22 non-financial DJIA firms for the time-period January 1, 2006 to September 30, 2010.