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Dynamics of the Implied Volatility Term Structure: An Empirical Investigation

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Sommaire

Cet article examine les dynamiques de la structure à terme de volatilité implicite et du *smile* de volatilité. Plus précisément, des indicateurs économiques et financiers sont employés pour étudier la pente de la structure à terme et la forme du *smile* (ou *smirk*) à travers les cycles. Nous utilisons des options quotidiennes sur le S&P 500, entre janvier 1996 et avril 2016. Les résultats empiriques démontrent la cyclicité de la structure à terme de volatilité implicite. La pente de la structure à terme est généralement négative lors de ralentissements de l'activité économique ou en périodes d'instabilité financière, mais positive autrement. De plus, les variations des conditions de marché expliquent une part plus importante des mouvements de la pente de la structure à terme lors de contractions. Le *smirk* est également plus prononcé en périodes économiques et financières difficiles. Les conclusions de cet article s'appliquent à plusieurs indices boursiers, pour différentes spécifications de la structure à terme et différentes méthodes d'estimation de la volatilité implicite.

Abstract

This paper examines the dynamics of the implied volatility term structure and the shape of the volatility smile. In particular, we investigate how the slope of the term structure and volatility smile/smirk varies with changes in economic and financial conditions. The study is conducted with daily options on the S&P 500 index, from January 1996 to April 2016. The results show a clear cyclical pattern in the slope of the implied volatility term structure. The slope is typically negative in periods of economic and financial stress, but positive in good times. Furthermore, changes in economic and financial conditions explain a greater fraction of the slope time-variation during bad times. The volatility smirk also strengthens during adverse economic and financial times. Results are robust across stock indices, term structure specifications, and to various methods for the estimation of implied volatilities.

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Table of Contents

1. Introduction

The analysis of expected volatility is a central theme in modern finance theory. Accurate estimation and prediction of volatility allow for better performance in speculation and hedging. In this regard, the volatility metric derived by inversion of the Black-Scholes (1973) formula, commonly known as the implied volatility (IV), has created keen interest among researchers and practitioners. According to the Black-Scholes model, security prices follow a geometric Brownian motion with constant drift and volatility parameters. The implied volatility surface (IVS) – i.e., the collection of implied volatilities for options of different strike levels and maturities – is thus presumed flat and static. The empirical evidence suggests otherwise. Rubinstein (1994) documents the asymmetric smile (also referred to as smirk) shape of implied volatilities when plotted against an option's moneyness. Campa and Chang (1995) report that the IV term structure is not constant. Furthermore, IVS shapes vary over time, as shown by Dumas et al. (1998).

Volatility measures contained in option prices provide valuable information on future stock market volatility – see Jorion (1995) and Fleming (1998). Therefore, large derivative literature has aimed to construct pricing models consistent with the empirical findings on the IVS (see Fengler et al., 2007 for a review). For some time, these models had difficulty in capturing the complexity of the implied volatility dynamics. For instance, Das and Sundaram (1999) show that stochastic volatility and jump-diffusion models are unable to replicate observed patterns of the IVS adequately. More recent models, such as the two-factor stochastic volatility framework of Christoffersen et al. (2008), have allowed for improved modeling of the most salient features of the volatility surface. For an option-pricing model to accurately reflect IVS intricacy and predictability, it is essential to understand the determinants of the implied volatility function.

The goal of this paper is to explore how the slope of the volatility term structure varies over time and, in particular, with economic and financial conditions. An extensive database of daily S&P 500 (SPX) European options constitutes the basis for this study. The sample starts in January 1996 and ends in April 2016. Alternative stock indices are also examined for robustness. The slope of the term structure is measured daily as the difference between the IV of two (synthetic) options with equal moneyness and varying maturities. To study the conditional movements of the term structure slope, business and financial cycles (which allow us to separate 'good times' and 'bad times') are identified using a set of 10 economic and financial indicators.[1] We also compute aggregate measures of economic and financial cycles, namely the Aggregate Economic Indicator and the Aggregate Financial Indicator, corresponding to the normalized sum of all individual indicators in each category. Further, we explore the dynamics of the implied volatility smile/smirk with regards to economic and financial conditions to provide a comprehensive view on the conditional patterns of the IVS.

Empirical results show a cyclical term structure slope, where slopes are lower in bad times (and typically negative) than in good times. The average slope between at-the-money SPX options with 120 and 60 days to maturity is 0.57% in good times and -0.79% in bad times, based on NBER recession dates. We obtain similar results with the other economic and financial indicators. A two-sample *t*-test shows that the differences between the average IV slopes are always statistically significant. When regressing daily term structure slopes against our set of economic and financial indicators, we find that the main drivers of the slope are the CBOE Volatility Index and the Excess-Bond Premium. The slope is also more sensitive to fluctuations of financial conditions than of economic conditions. In addition, the influence of economic and financial conditions on the slope is more pronounced during bad times. For example, our Aggregate Financial Indicator explains 45% of the time-variation in the IV slope for at-the-money SPX options. When conducting the regression for good and bad times separately, the explanatory power becomes 6.9% and 36.9%, respectively – which shows a stronger relationship between the IV slope and market conditions in periods of stress. We find similar results for the Aggregate Economic Indicator.

Regarding the shape of the volatility smile, we find that the smirk is also more pronounced in bad times than in good times. The average skew, capturing the steepness of the smirk between 1-month options with moneyness levels of 1.05 and 1.00 (defined as the strike price divided by the price of the underlying asset), declines from -2.35% in good times to -3.27% in bad times, based on NBER recession dates. On the other hand, the skew between options with moneyness levels of 1.05 and 1.00 increases from -4.73% in good times to -4.13% in bad times. The differences between the average skews are

[1] Economic indicators include the NBER Recession Indicator, the OECD Recession Indicator, Hamilton's GDP-based Recession Indicator, the Aruoba-Diebold-Scotti Business Conditions Index, and the FRB Diffusion Index for Current General Activity. Financial indicators include year-on-year returns of the S&P 500 Index, the TED spread, the BofA Merrill Lynch US High Yield Option-Adjusted Spread, the CBOE Volatility Index, and the Excess-Bond Premium.

statistically significant. Overall, the opposite variations for the 1.05-1.00 and 1.00-0.95 specifications confirm a more pronounced smirk in periods of stress.

Related works demonstrate the time-varying nature of the IV term structure, as well as the general influence of market shocks on the term structure slope. This paper contributes to the literature (surveyed in the next section) in several dimensions. First, we identify which economic and financial conditions help better explain the cyclical patterns of the term structure, and quantify the influence of such conditions on the term structure slope. We conduct a comprehensive analysis of term structure variations by considering a large set of economic and financial indicators. Second, we analyze different stock indices, maturity sets, moneyness levels, and IVS estimation methods – allowing us to derive robust conclusions on the conditional dynamics of the IV term structure. Third, we provide new insights into the dynamics of the volatility smile/smirk.

The paper is organized as follows. Section 2 discusses the existing literature on the determinants of IVS movements. Section 3 describes the data and the methodology used for the IVS estimation. It also presents the various economic and financial indicators employed in the analysis of the term structure pattern. Section 4 explores the drivers of the IV term structure. Section 5 presents a series of robustness checks, while section 6 discusses volatility smile dynamics. Section 7 concludes.

2. Literature Review

This section surveys the literature on the determinants of IVS movements, which relates to variations in the term structure or in the smile patterns. We then review applications of IV term structure variability in the option literature. Finally, we investigate the use of observable macro-economic and financial indicators in literature to study option implied volatility dynamics.

2.1. Term Structure Patterns

The variability of the IV term structure is well documented in the finance literature, in particular for currencies. Xu and Taylor (1994) analyze term structure movements of at-the-money foreign exchange options on various currency pairs (USD/GBP, USD/DEM, USD/JPY and USD/CHF options traded on the Philadelphia Stock Exchange), between

1985 and 1989. They show that IV variability is greater for short-term options. They also discern different average levels of volatility, possibly signaling the presence of time-varying regimes. Campa and Chang (1995) extend the research of Xu and Taylor (1994) by studying IV term structure dynamics for the same set of currencies, between 1989 and 1992. They note that: i) the term structure varies significantly over time, with similarities across all currencies; ii) the higher variability of short-term implied volatilities is the leading driver of term structure movements; and iii) term structure slopes react strongly to market shocks, such as the 1992 crisis.[2]

Following Campa and Chang (1995), Mixon (2007) examines the IV term structure for multiple international stock indices, between 1994 and 2001. The slope of the term structure is measured using the IV differential between at-the-money call options with 1 and 12 months to maturity. Although this research finds that the term structure is generally upward sloping (except for the Japanese Nikkei Index), Mixon (2007) notes that the slope becomes negative in times of market turbulence (including late 1997, 1998 and 2001).

Overall, studies on the determinants of term structure variations remain relatively scarce in the modern option literature. The papers mentioned above support a high degree of variability in IV term structures and a negative correlation between the term structure slope and the underlying asset's volatility. In addition, Äijö (2008) finds that term structure variations for options on a given asset can have a meaningful impact on term structure dynamics for other securities. In this case, he demonstrates that movements in the term structure of DAX options influence IVS dynamics for options on the Swiss Market Index and the EuroStoxx 50.[3] In this paper, we will seek to understand IVS variations for SPX options as well as for various international stock indices (see section 5).

2.2. Smile Patterns

Although this paper mainly examines conditional variations of the IV term structure, reviewing previous studies on the determinants of smile patterns provides valuable insights on the potential drivers of IVS variations and the techniques used to uncover them. Peña et al. (1999) study smile dynamics on the IBEX-35 Index (the benchmark of the

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[2] This crisis refers to the "Black Wednesday" that occurred in the U.K. in 1992, when the government was compelled to withdraw the pound sterling from the European Exchange Rate Mechanism (ERM).

[3] The DAX is a blue-chip stock market index consisting of the 30 largest firms on the Frankfurt Stock Exchange. The Euro Stoxx 50 is an index of Eurozone equities designed by STOXX (Deutsche Borse Group).

Bolsa de Madrid, Spain's largest stock exchange) between 1994 and 1996. Daily smile shapes are estimated using a volatility averaging process in pre-established moneyness intervals. A deterministic function of moneyness is then calibrated to the data to obtain slope and curvature coefficients. Granger tests indicate that transaction costs (i.e., bid-ask spreads), market uncertainty (the annualized standard deviation of the IBEX), market momentum (a moving average measure of the IBEX) and time to expiration are the key determinants of smile variability.

Hafner and Wallmeier (2000) arrive at comparable conclusions in their analysis of the DAX Index between 1995 and 1999. Implied volatilities are estimated for a maturity of 45 days, using weighted least squares spline regressions. The steepness of the smile, or skew, is the differential between implied volatilities at distinct moneyness levels. Hafner and Wallmeier (2000) find that market frictions (measured as a function of trading volume), changing asset volatility and jumps in the underlying security are important determinants of smile patterns.

Bates (2000) addresses the impact of economic instability on IV patterns. He portrays the evolution of the smile for S&P 500 options, following the 1987 financial crisis. Cubic splines are used to fit daily data, with IV differentials to measure the skew – similar to the approach of Hafner and Wallmeier (2000). Empirical observations show a smirk-shaped IV profile between 1988 and 1993. Higher IV spreads are observed between OTM puts and ATM options in times of market turbulence, notably during the crisis of October 1989 and the Kuwait crisis of 1990.

Finally, Bollen and Whaley (2004) investigate the impact of supply and demand pressures on the level and shape of the IV smile. The study examines the IV behavior of S&P 500 Index options, between June 1988 and December 2000, as well as options on 20 individual stocks, between January 1995 and December 2000. To characterize the IV smile, Bollen and Whaley (2004) compute the average implied volatility for five different moneyness categories. The skew is the difference between the average implied volatilities in two different categories. Their results suggest that option supply and demand levels have a significant influence on the level and skew of the IV smile. Changes in IV are most strongly affected by net buying pressures on out-of-the-money S&P 500 put options.

2.3. Applications of Term Structure Variability in Option Literature

The time-varying nature of the IV term structure has several implications in option literature. For instance, term structure patterns play a role in the validation of the expectations hypothesis.[4] Stein (1989) states that long-term options on the S&P 100 Index tend to overreact to changes in short-term volatilities. This statement is disputed by Heynen et al. (1994), who find that the overreaction depends on the model used to represent changes in asset price volatility. They show that the EGARCH model does not reject the hypothesis of efficiency. Xu and Taylor (1994) arrive to similar conclusions in their study of exchange rate markets. Christoffersen et al. (2013) provide an explanation to the overreaction of long-term options using a GARCH model with a variance premium arising from a new pricing kernel. Johnson (2017) rejects the expectations hypothesis, stating that the term structure slope of the Chicago Board Options Exchange's Volatility Index (VIX) carries information (i.e., predictive power) with regards to future returns on variance derivatives. Vasquez (2017) also rejects the expectations hypothesis and uses the IV term structure slope to identify mispriced options. Complex term structure patterns also have important implications in option pricing. Christoffersen et al. (2009), for instance, introduce a two-factor stochastic volatility model for equity index option valuation. The study shows that a two-factor model works better than a one-factor model for pricing, notably as it allows for improved modeling of the time-changing volatility term structure. Understanding the relationship between term structure dynamics for index options and constituent stock options also allows for improved valuation of stock options (see Christoffersen et al., 2017).

2.4. Business Cycles, Implied Volatility and Option Valuation

This paper investigates the impact of business cycles on the slope of the IV term structure, using a series of observable economic and financial indicators. Previous option pricing studies have also integrated such variables in the analysis and modeling of stochastic asset volatility. For instance, Engle et al. (2013) developed Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models with economic fundamentals impacting the variation of volatility. They find that factors such as inflation and industrial production growth are related to asset volatility movements. Dorion (2016)

[4] The expectations hypothesis asserts that movements in long-term volatility are consistent with expected future short-term volatilities, based on the linearity of variance with respect to time.

proposes a GARCH model for option valuation, using macro-finance variables to determine fundamental asset volatility. The paper considers the Aruoba-Diebold-Scotti Business Conditions Index and the CBOE VIX – two indicators used in the present study (see section 3 for additional information). Dorion (2016) finds that the use of observable economic and financial indicators for option pricing improves model performance versus existing benchmarks, especially when business conditions are deteriorating.

3. Data Set

This section describes the option data set employed throughout this study, along with the various filters applied to the initial database. Various estimation techniques are presented for the computation of implied volatility values at specific maturity and moneyness levels. We also outline the economic and financial indicators used in the conditional analysis of the term structure.

3.1. Database Description

We retrieve end-of-day option data from the OptionMetrics Ivy database.[5] Each observation includes the contract bid and ask prices, strike price, expiration date, exercise style, trading volume, open interest and implied volatility, as well as the closing price of the underlying security. The focus of this paper is on the SPX options market, i.e., the most liquid product offered on the Chicago Board Options Exchange, between January 1996 and April 2016. We also conduct an analysis of IV behavior for options on the Russell 2000 and other non-US securities for robustness (see section 5).

OptionMetrics adopts industry standards to compute implied volatilities. A standard inversion of the Black-Scholes formula is used for European options. Implied volatilities for American options are obtained through OptionMetrics' proprietary algorithm based on the Cox-Ross-Rubinstein binomial tree model (Cox et al., 1978). For all options, the OptionMetrics algorithm computes interest rates from ICE IBA LIBOR rates and settlement prices of CME Eurodollar futures,[6] with linear interpolation between market data points.

[5] OptionMetrics Ivy DB US includes historical data for all US listed equities and market indices, as well as all US listed index and equity options, from 1996 to 2016.
[6] Overnight London Interbank Offered Rate (LIBOR) rates provided by ICE Benchmark Administration Limited (IBA). Eurodollar Futures quotes provided by the CME Group (Chicago Mercantile Exchange & Chicago Board of Trade).

Finally, the algorithm uses a linear regression model based on the put-call parity to compute the continuous dividend yield on stock indices. For more information, refer to the OptionMetrics Reference Manual.

Various filters are applied onto the OptionMetrics database to generate the final data set, following standard practices in the option literature (see, e.g., Bakshi et al., 1997; Dumas et al., 1998; and Skiadopoulos et al., 2000). These measures, described below, are implemented to minimize market microstructure concerns and to remove the impact of outliers. The descriptive statistics for the final sample of S&P 500 options are presented in Table 1, while Appendix 1 discusses the descriptive statistics for options on alternative securities.

i. Options for which time to expiry is inferior to a week are removed from the sample. When options are close to maturity, the corresponding implied volatility metrics become very sensitive to pricing errors and often behave erratically.
ii. Options with maturities over 365 days are omitted, as they are often illiquid.
iii. Options with moneyness levels below 0.8 or above 1.2 are excluded, due to liquidity concerns and IV sensitiveness to pricing errors. We define moneyness as the ratio of the strike price to the value of the underlying asset.
iv. Options with IV values below 4% or above 90% are removed from the sample. Such outliers are often associated with pricing errors.
v. Options priced below $0.10 (as determined by the bid-ask midpoint) are excluded to reduce distortions from variations in discrete market prices.
vi. Options with zero volume or open-interest are removed from the sample.
vii. We only consider out-of-the-money options – i.e., call options with moneyness equal or above 1, and put options with moneyness equal or below 1. In-the-money options are often more expensive and less liquid.

Table 1 [about here]

3.2. Implied Volatility Estimation

Option contracts are traded for a finite number of unevenly distributed maturities and moneyness levels. We consider various estimation techniques in this paper to compute daily IV values at any given maturity or moneyness level. A multivariate interpolation approach, inspired by Carr and Wu (2008), will serve as the basis for this study. Section 5 presents variations of that method, as well as an alternative estimation technique based on cubic spline interpolation, for robustness.

The multivariate interpolation approach that we propose is as follows. For a target time to maturity τ, we first choose the two closest surrounding maturities among all available options. At each of the two maturities, we linearly interpolate between traded options to estimate volatility metrics at the desired moneyness level k. Lastly, we interpolate between the two estimated values to obtain $IV(\tau, k)$. This approach is hereby termed the Proximal Trilinear Interpolation Technique (PTIT). In all steps of the PTIT, we allow for extrapolation of IV values when market data is insufficient to interpolate – within pre-determined limits of maturity, moneyness, and implied volatility. Appendix 2 describes this technique in greater detail and proposes several variations.

We consider the PTIT for two main reasons. First, only four surrounding options are sufficient to estimate one IV at specific moneyness and maturity coordinates. As such, we can precisely calculate an IV without using all the points on the surface – which, in turn, reduces calculation time. Second, a slight variation of the basic PTIT allows us to incorporate a liquidity factor in the selection of the "closest neighbors". We can thus estimate IV values using the most traded options available near the target point, without having to increase liquidity filters on the original database.

3.3. Economic and Financial Indicators

We now present the various economic and financial indicators that we consider to capture the business cycle and, thus, to distinguish between 'good times' and 'bad times'.

3.3.1 <u>Economic Indicators</u>

We measure economic activity using the following indicators: 1) The NBER Recession Indicator (NBER), provided by the National Bureau of Economic Research, reflects the US business cycle based on real GDP, real income, employment, industrial production, as well as wholesale-retail sales; 2) The OECD Recession Indicator (OECD) combines economic and market gauges to determine specific start- and end-dates for economic downturns, notably consumer sentiment, industrial confidence, NYSE share prices, and interest rate spreads; 3) Hamilton's GDP-Based Recession Indicator Index (HGR) uses a two-state regime switching model to determine periods of recessions, based on GDP growth data (see Hamilton, 2011); 4) The Aruoba-Diebold-Scotti Business Conditions Index (ADS) tracks business conditions through weekly initial jobless claims, monthly payroll employment, industrial production, personal income less transfer payments, manufacturing and trade sales, as well as quarterly real GDP; 5) the FRB Diffusion Index for Current General Activity (FRB) – based on the Manufacturing Business Outlook Survey of the Federal Reserve Bank of Philadelphia – reports the change in general business activity for manufacturing firms. Table 2 reports the descriptive statistics of these economic indicators, with visual representations in Figure 1. All data are retrieved from FRED (website of the Federal Reserve Bank of St. Louis), except for the ADS Index, issued by the Federal Reserve Bank of Philadelphia.

Figure 1 and Table 2 [about here]

We apply decision-rules for each indicator to distinguish between good and bad times. The NBER and OECD indicators are straightforward to define: values of 0 and 1 designate times of low and high economic stress, respectively. For the other indicators, dates corresponding to the bottom quintile of the time-series capture bad times. The exception is the HGR indicator, which is countercyclical. As such, the top quintile reflects bad times in this case.

3.3.2 Financials Indicators

Five financial indicators are also considered in this study: 1) Year-on-year returns of the S&P 500 Index (YOY) determine the level of stock market performance; 2) The TED spread (TED) – the rate differential between the 3-Month U.S.-based LIBOR and the 3-Month Treasury Bill – is an indication of monetary liquidity and overall economic stability, and thus measures the perceived level of risk in the financial system; 3) The BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML) indicates the state of the corporate economy through credit quality. It is measured as the spread between a computed Option-Adjusted Spread (OAS) index of junk-bonds (rated BB or below) and a spot Treasury curve; 4) The CBOE Volatility Index (VIX), provided by the Chicago Board Options Exchange, reflects the market's 30-day volatility expectations. It is a measure of market uncertainty. 5) the Excess-Bond Premium (EBP), introduced by Gilchrist and Zakrajšek (2012), serves as a measure of investor sentiment. Descriptive statistics are reported in Table 3, with visual representations in Figure 2. All data is retrieved from FRED (website of the Federal Reserve Bank of St. Louis), except for S&P 500 values and the Excess-

Bond Premium indicator, issued by OptionMetrics and the U.S. Federal Reserve, respectively.

Figure 2 and Table 3 [about here]

We apply quintile-based decision rules to each financial indicator to determine good and bad times. Dates corresponding to the top quintile of the time-series are consistent with periods of financial stress. The YOY indicator is an exception, with the bottom quintile serving as an indication of financial stress.

4. Term Structure Analysis

The following section examines the dynamics of the IV term structure for S&P 500 options. In particular, we study how the slope of the IV term structure varies with economic and financial conditions.

4.1. Term Structure Measurement

We measure the daily slope of the term structure by means of a simple IV differential method, using the implied volatility span between two options with equal moneyness levels and different maturities. The use of IV differentials is standard in the option literature – see Mixon (2007) and Vasquez (2017) with regards to term structure slopes, or Bates (2000) and Hafner and Wallmeier (2000) for representations of smile shapes. The slope is defined as follows:

$$TS_t = IV_t(k, T_2) - IV_t(k, T_1) \quad (1)$$

where TS_t is an indication of the term structure slope on day t, k is the moneyness level, and T is the time to maturity for each option (with T_2 > T_1). Both IV values are found through the Proximal Trilinear Interpolation Technique. We consider two sets of maturities – namely options with 90 and 30 days to maturity, as well as options with 120 and 60 days to maturity. Descriptive statistics of the term structure time series are reported in Table 4, with visual representations in Figure 3.

Figure 3 and Table 4 [about here]

Observations for S&P 500 Index options indicate a positive average slope at moneyness levels of 1.00 and 1.05, and a negative average slope at a moneyness level of 0.95, which is consistent with literature (see Cont and Da Fonseca, 2002). For the 90-30 term structure specification, the average slopes at moneyness levels of 0.95, 1.00 and 1.05 are -1.30%, 0.65% and 0.80%, respectively. For the 120-60 specification, the average slopes at moneyness levels of 0.95, 1.00 and 1.05 are -0.36%, 0.42% and 0.87%, respectively. Based on one-sample *t*-tests, all slopes are statistically significant. Furthermore, slopes appear to be highly time varying (see Figure 3).

4.2. Term Structure Conditional Analysis

We now analyze the dynamics of the slope of the term structure. We first compare average term structure slopes in good and bad times and then carry a regression analysis. In this section, slopes are computed daily using the IV differential between two options with 120 and 60 days to maturity. Appendix 3 provides an analysis with different maturities.

Table 5 shows that the slope is higher in good times than in bad times. At a moneyness level of 1, the average slope is positive in good times (between 0.57% and 0.69% with economic indicators, and between 0.54% and 0.76% with financial indicators) but negative in bad times (between -0.79% and -0.18% with economic indicators, and between -0.93% and -0.02% with financial indicators). The difference between the average slopes in good and bad times is statistically significant for all economic and financial indicators. Results are qualitatively similar at other moneyness levels. Options with longer maturities thus display lower IV values than their shorter-term counterpart during periods of stress, suggesting market expectations that volatility will revert to long-term levels.

Table 5 [about here]

4.3. Regression Analysis

We now analyze the relationship between the slope of the term structure and the financial and economic indicators. To do so, we consider at-the-money S&P 500 options with 120 and 60 days to maturity. Results for alternative specifications are presented in Appendix 3.

4.3.1. Methodology

All economic and financial indicators described in Tables 2 and 3 will serve as independent variables in the regression analysis below, both individually and jointly. Explanatory variables are first adjusted to reflect the sample size of the term structure time series (e.g., monthly indicators are transformed by duplicating the indicator value for a given month to all days in that month).[7] For regressions using the BAML indicator, time periods are adjusted to remove IV observations prior to the 2nd of January 1997 (corresponding to the first occurrence of the BAML indicator). All independent variables are standardized – i.e., centered at a mean of 0 and variance of 1 – to allow for adequate comparisons between regression coefficients. The slope of the term structure is multiplied by 100. Altogether, we estimate the following model on a daily basis:

$$[IV_t(T_2,k) - IV_t(T_1,k)] = \beta_{i,0} + \beta_{i,1} * IND_{i,t} + \varepsilon_{i,t} \quad (2)$$

where IV_t is the implied volatility that we estimate on day t using the PTIT approach, function of moneyness level k and maturity T (with $T_2 > T_1$); $\beta_{i,0}$ is the constant coefficient for indicator i (corresponding to the average IV slope, given the standardization of the independent variables); $\beta_{i,1}$ is the slope coefficient for indicator i; $IND_{i,t}$ is the value of indicator i on day t; and $\varepsilon_{i,t}$ is the error term for indicator i. Regressions are conducted for each indicator separately and for combinations of the various economic and financial indicators. We compute all t-statistics using Newey-West standard errors with 10 lags.

Additionally, we compute aggregate measures of business cycle variations that we use as independent variables for the regression analysis – namely the Aggregate Economic Indicator (AEI) and the Aggregate Financial Indicator (AFI). The AEI is computed as the sum of the economic indicators listed in Table 2, each standardized and adjusted so that bad times correspond to the lower part of the time series (i.e., the NBER, OECD and HGR indicators are reversed). The AEI is also centered at a mean of 0 and variance of 1. Similarly, the AFI is calculated as the standardized sum of the centered and directionally-adjusted financial indicators. Figure 4 illustrates the aggregate indicators and show that both measures capture distinct periods of economic and financial stress.

Figure 4 [about here]

[7] Note that the economic and financial indicators are employed as a means of determining past cycles in the U.S., not for predictive purposes. As such, it is acceptable to adjust the length of the samples in such a way.

4.3.2. Main Results

Table 6 presents the regression results based on the individual economic indicators. Constant parameters, representing the average term structure slope, amount to 0.42% – in line with our previous findings. The slope coefficients show the positive linear relationship between variations in economic conditions and the term structure slope. We obtain negative coefficients for the NBER, OECD and HGR indicators, all of which reach their highest values in bad times. Inversely, the ADS and FRB indicators display positive coefficients. All regression parameters are statistically significant, which indicates that the slope of the term structure is always higher in good times than in bad times. This finding is consistent across the various measures of economic conditions.

Table 6 [about here]

The coefficients of determination are similar across indicators, from 11.9% (OECD) to 18.3% (HGR). The multivariate regression of term structure slopes against all economic indicators shows that economic conditions explain about 22% of term structure slope variations. The FRB Diffusion Index for Current General Activity (FRB) and Hamilton's GDP-based Recession Indicator Index (HGR) are the main drivers of the relationship, with *t*-statistics of 3.53 and 2.85, respectively. Note that the FRB and HGR are also, individually, the indicators that contribute the most to the variations of the IV term structure, as indicated by their coefficients of determination of 17.5% and 18.3%, respectively.

The study of financial indicators yields similar conclusions (see Table 7). Results for univariate regressions suggest that term structure slopes decrease during bad times, as indicated by the negative slope coefficients for the TED, BAML, VIX, and EBP indicators. The relation is positive between the slope and the YOY indicator, where bottom quintile observations of YOY define periods of financial instability. All regression parameters are statistically significant. The coefficients of determination vary substantially across financial indicators, ranging between 16.9% (TED) and 51.8% (VIX). Results for the multivariate linear regression, combining all financial indicators, indicate that market conditions explain 65% of term structure slope variations, mostly driven by the year-on-year returns of the S&P 500 Index, the BofA Merrill Lynch US High Yield Option-Adjusted Spread and the CBOE Volatility Index. It is worth noting that the explanatory power of the financial variables to term structure slope variations is about three times larger than the explanatory power of the economic indicators.

Table 7 [about here]

Table 8 reports the results when using our aggregate indicators, which provide further evidence of the cyclicality of the term structure slope. The slope coefficients amount to 0.52 and 0.80 with regards to the AEI and AFI, respectively, suggesting a decrease in term structure slopes following a deterioration of economic and market conditions. All regression parameters are statistically significant. Also, the IV term structure appears to be more sensitive to variations in the Aggregate Financial Indicator than to variations in the Aggregate Economic Indicator, which confirms our previous finding based on individual series. The adjusted R^2 value is 45.04% for the AFI, whereas it is 20.09% for the AEI – again supporting a close relationship between the slope of the term structure and financial conditions. Table 8 also reports the results for the multivariate regression of the term structure slope against both the AEI and the AFI. In this case, the slope coefficient amounts to 1.05 for the AFI, but -0.30 for the AEI. The adjusted R^2 value is 47.18%, slightly above the adjusted R^2 metric when regressing the term structure slope against the AFI only.

Table 8 [about here]

We now extend the analysis by conducting regressions of term structure slopes against the Aggregate Economic Indicator and the Aggregate Financial Indicator, for good and bad times separately. Bad times are defined for both aggregate indicators as the periods associated with the bottom quintile of their time series, while good times correspond to the remaining observations. The independent variables are standardized to facilitate the interpretation of the results.

Table 8 suggests that the constant parameters (i.e., the average IV term structure slopes) are positive in good times and negative in bad times: 0.64 against -0.45 for the AEI, and 0.77 vs. -0.88 for the AFI. Slope coefficients show that the term structure is more sensitive to variations in the aggregate indicators during bad times. For the AEI, a coefficient of 0.61 during periods of stress compares to a coefficient of 0.13 in good times. Similarly, for the AFI, the coefficient of 1.00 during bad times is much higher than the coefficient of 0.20 in good times. All parameters are different from 0 at a 1% level of significance. Coefficients of determination are also higher in bad times: 12.8% and 36.9% for the AEI and AFI, respectively, vs. 2.4% and 6.9% in good times. In sum, the slope of the term structure does not only decrease in bad times, but it also becomes more sensitive to fluctuations in economic and market conditions.

Overall, we find that there is a positive relationship between the slope of the IV term structure and the state of the economy and that the sensitiveness of the slope to the indicators rises in bad times. Furthermore, we show that financial indicators (vs. economic indicators) explain a more significant fraction of the term structure slope dynamics.

5. Robustness Analysis

In this section, we provide additional results to confirm the robustness of our prior findings. First, we reproduce the above regression analysis with added control variables. Second, we study the movements of the IV term structure for different option specifications. Third, we replicate our analysis by applying four different models for the estimation of the IVS, in addition to the Proximal Trilinear Interpolation Technique used in previous sections. Finally, we investigate the conditional patterns of the IV term structure for five alternative equity indices, in the U.S. and across the world.

5.1. Regression Analysis with Control Variables

To test the robustness of the results in section 4.3, we add control variables in the regression analysis of the term structure slope against the aggregate indicators. First, the IV time series for S&P 500 options, with 60 days to maturity and a moneyness of 1, is added as a control variable. Results are presented in Panel 1 of Table 9. For the regression against the Aggregate Economic Indicator (AEI) and the control variable, we obtain 0.12 and -0.73 slope coefficients, respectively – both significant at a 5% level of significance. The positive relationship between the term structure slope and the AEI remains, but we also observe a strong negative relationship between the level of the IV (at a maturity of 60 days) and the term structure slope. The adjusted R^2 metric is 47.09%, higher than the corresponding 20.09% result without the control variable. We arrive to similar conclusions for the regression involving the Aggregate Financial Indicator (AFI), with slope coefficients of 0.32 and -0.56 for the AFI and the control variable, respectively. Here, the adjusted R^2 value is 50.31%, higher than the 45.04% adjusted R^2 result without the control variable. We also conduct a regression of the term structure slope against the AEI, the AFI and the control variable. Here, the slope coefficient for the control variable is

-0.52. The slope coefficient for the AFI remains positive, at 0.39 (significant at a 10% threshold). However, the slope coefficient for the AEI is not significant at a 10% threshold. We note here that the adjusted R^2 metric (50.34%) is approximately equal to the adjusted R^2 value for the regression of the term structure slope against the AFI and the control variable (i.e. excluding the AEI).

Table 9 [about here]

Second, we reproduce the regression analysis of section 4.3 using the term structure slope with a 30-day lag as a control variable. Results are presented in Panel 2 of Table 9. For the regression against the AEI and the control variable, we observe slope coefficients of 0.35 and 0.39, maintaining a positive relationship between the term structure slope and the AEI after controlling for the persistence of the term structure slope. The adjusted R^2 is 28.80%, superior to the adjusted R^2 for the corresponding regression without the control variable (20.09%). We obtain similar results for the regression against the AFI and the control variable, with the exception that the slope coefficient of the control variable is only significant at a 10% threshold. Finally, we regress the term structure slope against the AEI, the AFI and the control variable. We obtain a 0.15 slope coefficient for the control variable, significant at a 5% level of significance, again indicating persistence in the term structure slope time series. That said, we obtain similar results for the AEI and AFI slope coefficients as we did without the control variable, i.e. a negative slope coefficient for the AEI (-0.30) and a positive coefficient for the AFI (0.96). In this case, we obtain a 49% adjusted R^2 metric, slightly higher than the corresponding 47% adjusted R^2 result in the corresponding regression without the control variable.

5.2. Alternative Specifications

We now verify the robustness of the results by looking at five other option sets. We consider option pairs with 120 and 60 days to maturity, at moneyness levels of 0.95 and 1.05, as well as option pairs with 90 and 30 days to maturity, at moneyness levels of 0.95, 1.00 and 1.05. Summary tables are presented in Appendix 3.

Tables A.7 and A.8 show that, in most cases, the slope of the term structure is significantly lower during bad times, which confirm our previous findings. We note that the average term structure slope is not always negative in bad times at a moneyness of 1.05: for both the 90-30 and 120-60 term structure specifications, the OECD Recession

Indicator, Hamilton's GDP-based Recession Indicator Index, the FRB Diffusion Index for Current General Activity and the TED indicator display positive average slopes in bad times. That said, the slope remains significantly lower in periods of stress than in good times. An exception arises when studying the 90-30 term structure against the TED spread, at a moneyness level of 1.05. In this case, the average slope is 0.76% in good times and 0.94% in bad times, but the difference is not significant at a 1% threshold (p-value of 2.82%). Overall, we confirm that the IV slope is cyclical under various term structure specifications, with a slightly more pronounced distinction between good and bad times at a moneyness level of 1 (average difference of 1.6% between good and bad times for the 90-30 specification, and 1.2% for the 120-60 term structure specification).

Regression results for all options sets also align with previous findings (see Tables A.9 to A.20). The slope coefficients of the univariate regressions are statistically significant for all indicators and indicate a positive relationship between the slope of the IV term structure and business conditions. An exception arises for the 90-30 term structure at a moneyness level of 1.05, with regards to the TED indicator. In this case, the slope coefficient is not significant at a 10% level. Also, for the 90-30 specification at a moneyness level of 1.05, the coefficient for the NBER indicator is significant at a 5% level. The multivariate regressions with all economic indicators indicate that the slope coefficients associated with Hamilton's GDP-based Recession Indicator Index and the FRB Diffusion Index for Current General Activity display the highest *t*-statistics. Turning to the financial indicators, the slope coefficients are statistically significant at a 1% level significance for all indicators across all specifications, except for the TED spread. Also, empirical results show higher slope coefficients and R^2 values during bad times – indicating a stronger relationship between these indicators and the term structure slope in periods of stress.

Overall, previous conclusions are robust across various moneyness and maturity levels, with limited discrepancies between the different specifications considered.

5.3. Alternative Estimation Models

We now investigate the robustness of our empirical results to four additional estimation methods. Model 1 reproduces the nearest-neighbor interpolation method of the PTIT without extrapolation – therefore restricting the estimation of IV values within the bounds of the "traded" IVS. Model 2 comes in-between the PTIT and Model 1, allowing for extrapolation on the moneyness axis. Model 3 incorporates a liquidity factor in the selection of the "nearest neighbors" – i.e., moneyness and maturity ranges are specified around the target identity, and the four most traded options within these limits are selected for the estimation of implied volatility. Lastly, Model 4 uses cubic spline interpolation to estimate the IVS.[8] Refer to the Appendix 2 for more detailed descriptions of each model. Empirical results are reported in Appendix 3.

For the 120-60 term structure specification at a moneyness level of 1, we find lower (and typically negative) average slopes in bad times vs. average slopes in good times, across all estimation methods. In addition, regression results are similar for all approaches: 1) Statistically significant slope coefficients indicate a positive relationship between business conditions and term structure slopes; 2) The strength of the relationship is generally higher for financial indicators than for economic indicators (R^2 between 17% and 52% for financial indicators, and between 8% and 18% for economic indicators); 3) Constant coefficients are higher during good times than during periods of stress; and 4) Slope coefficients are larger during bad times, indicating that the sensitivity of the term structure to variations in business conditions is more pronounced during periods of stress. We note that the basic PTIT and both the Models 1 and 2 display very similar results, slightly superior to Models 3 and 4 in terms of R^2 values, slope coefficients and *t*-statistics. Altogether, the results of this paper appear to be consistent across a variety of IVS estimation methods.

5.4. Alternative Securities

Although the analysis of the S&P 500 option market constitutes the core of this study, we now consider options on alternative indices. We explore the robustness of our conclusions for 5 Exchange-Traded Funds (ETF) – namely the iShares Russell 2000 Index ETF (ticker IWM), the iShares MSCI Brazil ETF (EWZ), the iShares China Large-Cap ETF (FXI), the iShares EAFA Index ETF (EFA) and the iShares Emerging Markets Index ETF (EEM). ETF options are selected because they display higher trading volumes than their direct index counterparts (notably due to their presence on U.S. exchanges), as discussed in Kelly et al. (2016). Option data are retrieved from the OptionMetrics Ivy database and

[8] The *fit* MATLAB function is employed for the application of the cubic spline interpolation method.

adjusted according to the parameters discussed in section 3.1. Descriptive statistics are presented in Appendix 3.

We investigate the patterns of the IV term structure between July 28, 2009 and April 29, 2016 for at-the-money options with 120 and 60 days to maturity. All IV values are computed using the first derivation of the PTIT that excludes extrapolation (see Model 1 in Appendix 2).[9] We consider four indicators to distinguish between good and bad times, namely the year-on-year returns of the underlying asset, the Aggregate Economic Indicator and Financial Indicators described in section 4.3, as well as the term structure time-series of S&P 500 index options (for the same period and option characteristics). We always define bad times as the bottom quintile of the indicator.

The results are consistent across securities, as reported in Appendix 3. Term structure slopes are lower in bad times than in good times, and display a positive linear relationship with each indicator. Only the results with the Aggregate Economic Indicator are less conclusive. In this case, the subsample analysis indicates that the slopes are not significantly different between good and bad times for the Russell 2000 Index (33% p-value), the EAFA Index (16% p-value) and the Emerging Markets Index (5.2% p-value), at a 5% level of significance (see Table A.35). Also, Table A.36 to A.40 indicate that the effect of the Aggregate Economic Indicator on the slopes of the term structure displays low *t*-statistics for most of the covered securities (not significant at a 10% level of significance for all securities, except the China Large-Cap ETF). These results suggest that IV term structure patterns for securities other than the S&P 500 Index are more sensitive to the state of the U.S. financial market than to U.S. economic conditions.

Notably, we find a strong relationship between the term structure slope of the considered securities and the slope in the U.S. options market. Tables A.36 to A.40 report strong adjusted R^2 values (61% for the Russell 2000 Index, 20% for Brazil equities, 43% for the FXI, 52% for the EAFA Index, and 56% for the EEM). In addition, for all securities except the EWZ, R^2 values for linear regressions against the year-on-year returns of the underlying assets are lower than the R^2 values for the regressions against the Aggregate

[9] Model 1 is used to estimate the implied volatilities (IV) for securities other than the S&P 500 (SPX), as opposed to the basic PTIT used throughout this paper. The PTIT allows for extrapolation when using available option data to estimate implied volatility values at given maturity and moneyness coordinates. The number of options traded daily for non-SPX securities is significantly inferior compared to SPX options. As such, using extrapolation to estimate IV values would yield inaccurate results in many cases.

Financial Indicator – showing again the strong dependence of non-SPX IVS dynamics on the U.S. financial market. Hence, the slopes of the IV term structure appear to strongly co-move around the world.

6. Smile/Skew Patterns

In this section, we investigate the conditional dynamics of the volatility skew for SPX options. The option sample covers the period between January 4, 1996 and April 29, 2016. We measure the volatility skew as the IV differential between two options of different moneyness with 30 days to maturity. One-month maturity options are often used in option literature to study smile patterns – see Dennis et al. (2006) or Yan (2011). We exploit two ranges of moneyness: 1.00 to 0.95 and 1.05 to 1.00. All implied volatilities are estimated using the PTIT. Good and bad times are defined according to the 10 indicators presented in section 3.3. Descriptive statistics and results for the conditional analysis of the skew are presented in Tables 10 and 11. Outcomes for the smile regression analysis are presented in Appendix 4.

First, Table 10 shows that the skew is more pronounced for 1.00-0.95 options (out-of-the money puts) than for 1.05-1.00 options (out-of-the money calls). This asymmetry confirms the typical shape of the volatility smile.

Table 10 [about here]

For the 1.05-1.00 specification, the average skew is significantly lower during periods of stress for all indicators (between -3.55% and -2.79%) than during good times (between -2.37% and -2.17%). With regards to the regression analysis, the constant coefficient (i.e., average skew) is negative and displays a high t-statistics in all cases. We also observe significant slope coefficients for all indicators. The coefficients are positive for the ADS, FRB and YOY indicators (with bad times corresponding to the lowest values of the times series), and negative for the NBER, OECD, HGR, TED, BAML, VIX and EBP indicators (with bad times corresponding to the highest values of the time series). Therefore, results suggest a decrease in the skew in periods of stress.

For the 1.00-0.95 specification, the average skew is higher during periods of stress for all indicators (between -4.33% and 4.03% in bad times, and between -4.83% and 4.73% in good times). When conditioning on the TED or the VIX, the average skew is not significantly different between good and bad times, at least at the 5% level of significance. With regards to the regression analysis, significant slope coefficients are found for all indicators, except for the TED and VIX indicators (positive for the NBER, OECD, HGR, BAML and EBP indicators, with bad times corresponding to the highest values, and negative for the ADS, FRB and YOY indicators, with bad times correspond to the lowest values). As such, results suggest an increase in the skew in periods of stress.

Table 11 [about here]

Overall, it appears that the skew is more pronounced in bad times than in good times. We note here that the R^2 values for all regressions are relatively small: below 4% with regards to the economic indicators, and below 13% for financial indicators.

7. Conclusion

This article presents evidence that the slope of the term structure for index options varies significantly with the business cycle. In particular, the term structure slope is lower (typically negative) and more sensitive to changes in the market environment during periods of economic and financial stress. These findings hold for different stock indices, time periods, maturities, strike levels and IVS estimation methods. Additionally, we find that variations in the IV term structure of non-SPX options are closely related to the shape of the IVS for options on the S&P 500 Index, thereby indicating strong co-movement in their term structure dynamics. This study contributes to a relatively thin literature on IV term structure dynamics (vs. prior findings on smile patterns), providing new insights on the determinants of IVS variations and allowing for a better understanding of the term structure of risk.

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	# Obs.	Median	Average	Std. Dev.	Min.	Max.
Implied Volatility	1,247,116	19.2%	20.7%	8.8%	4.9%	89.9%
Moneyness Level	1,247,116	97.4%	97.2%	8.5%	80%	120%
Maturity (Days)	1,247,116	44.0	67.2	70.4	6.0	365.0
Daily Volume, Total	5,113	207,777	265,900	228,970	4,450	2,003,114
Daily Volume, Per Option Average	5,113	960	1,226	819	63	7,625
Daily Open Interest, Total	5,113	2,826,014	2,873,700	2,045,600	196,000	7,535,554
Daily Open Interest, Per Option Average	5,113	11,619	14,087	7,807	2,820	38,377
Options Traded per Day	5,113	126	244	270	29	1,727
Available Maturities per Day	5,113	6.0	8.7	4.9	4.0	27.0
Av. # of Mon. Levels per Maturity, per Day	5,113	20.0	23.1	10.2	7.2	67.9

Table 1 – Descriptive Statistics of the Final Sample of S&P 500 (SPX) Options. This table reports the descriptive statistics for the implied volatility, the moneyness level (defined as the ratio of the strike price to the value of the underlying asset), the maturity of the options (in days), the daily trading volume (number of traded contracts) for all available options, the daily average trading volume per option, the daily open interest (number of contracts outstanding) for all options, the daily average open interest per option, the number of options traded per day, the number of available maturities per day, and the average number of moneyness levels per available maturity, per day. The data set covers the period between January 4, 1996 and April 29, 2016.

	# of Obs.	Mean	Std. Dev.	Minimum	Maximum
Panel 1: Full Period					
NBER	243	0.11	0.31	0.00	1.00
OECD	243	0.31	0.46	0.00	1.00
HGR	81	16.33	22.30	0.33	99.70
ADS	5113	-0.19	0.76	-4.07	1.88
FRB	243	6.36	14.43	-40.90	36.50
Panel 2: Good Times					
NBER	217	0.00	0.00	0.00	0.00
OECD	167	0.00	0.00	0.00	0.00
HGR	65	7.57	5.47	0.33	22.88
ADS	4090	0.08	0.38	-0.49	1.88
FRB	194	12.01	8.57	-2.30	36.50
Panel 3: Bad Times					
NBER	26	1.00	0.00	1.00	1.00
OECD	76	1.00	0.00	1.00	1.00
HGR	16	51.93	29.00	23.83	99.70
ADS	1023	-1.27	0.91	-4.07	-0.49
FRB	49	-15.99	10.71	-40.90	-3.50

Table 2 – Descriptive Statistics of the Economic Indicators. This table reports the descriptive statistics for the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). Panel 1 includes statistics for the entire period. Panels 2 and 3 cover good and bad times, respectively. Section 3.3 defines the periods of good and bad times for each indicator. The sample covers the period between January 4, 1996 and April 29, 2016.

	# of Obs.	Mean	Std. Dev.	Minimum	Maximum
Panel 1: Full Period					
YOY	5113	0.08	0.18	-0.49	0.69
TED	4987	0.49	0.42	0.09	4.58
BAML	5043	5.82	2.84	2.41	21.82
VIX	5111	20.95	8.28	9.89	80.86
EBP	243	0.02	0.68	-1.14	3.00
Panel 2: Good Times					
YOY	4090	0.16	0.11	-0.05	0.69
TED	3958	0.34	0.15	0.09	0.68
BAML	4031	4.77	1.39	2.41	7.57
VIX	4088	17.81	4.12	9.89	25.65
EBP	194	-0.26	0.29	-1.14	0.50
Panel 3: Bad Times					
YOY	1023	-0.21	0.10	-0.49	-0.05
TED	1029	1.10	0.53	0.69	4.58
BAML	1012	10.00	3.25	7.58	21.82
VIX	1023	33.49	8.85	25.66	80.86
EBP	49	1.15	0.62	0.53	3.00

Table 3 – Descriptive Statistics of the Financial Indicators. This table reports the descriptive statistics for the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). Panel 1 shows statistics for the entire considered period. Panels 2 and 3 cover good and bad times, respectively. Section 3.3 defines the periods of good and bad times for each indicator. The sample covers the period between January 4, 1996 and April 29, 2016.

	Panel 1: 90-30 Term Structure			Panel 2: 120-60 Term Structure		
	0.95 Mon.	**1.00 Mon.**	**1.05 Mon.**	**0.95 Mon.**	**1.00 Mon.**	**1.05 Mon.**
Average Slope	-0.0130	0.0065	0.0080	-0.0036	0.0042	0.0087
Standard Deviation	0.0254	0.0250	0.0231	0.0117	0.0117	0.0114
P-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4 – Slope of the Term Structure by Moneyness. This table reports descriptive statistics for the slope of the term structure for S&P 500 options. Statistics include the average term structure slope, the standard deviation of the term structure, and the p-value of the data set for a one-sample *t*-test. Panel 1 considers the slope between implied volatility (IV) observations for options with 90 and 30 days to maturity. Panel 2 considers options with 120 and 60 days to maturity. Each panel reports statistics for three moneyness levels (defined as the strike price of the option to the price of the underlying asset): 0.95, 1.00, and 1.05. All IV values are computed using the Proximal Trilinear Interpolation Technique. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) Unconditional	(2) Good Times	(3) Bad Times	(4) Difference (2-3)	(5) P-Value
Panel 1: Moneyness of 0.95					
NBER	-0.0036	-0.0024	-0.0136	0.0112	0.0000
OECD	-0.0036	-0.0013	-0.0087	0.0074	0.0000
HGR	-0.0036	-0.0021	-0.0096	0.0075	0.0000
ADS	-0.0036	-0.0017	-0.0112	0.0095	0.0000
FRB	-0.0036	-0.0017	-0.0111	0.0094	0.0000
YOY	-0.0036	-0.0012	-0.0130	0.0117	0.0000
TED	-0.0036	-0.0026	-0.0074	0.0048	0.0000
BAML	-0.0036	-0.0007	-0.0142	0.0135	0.0000
VIX	-0.0036	-0.0002	-0.0169	0.0166	0.0000
EBP	-0.0036	-0.0013	-0.0128	0.0115	0.0000
Panel 2: Moneyness of 1.00					
NBER	0.0042	0.0057	-0.0079	0.0135	0.0000
OECD	0.0042	0.0069	-0.0018	0.0087	0.0000
HGR	0.0042	0.0059	-0.0028	0.0087	0.0000
ADS	0.0042	0.0065	-0.0048	0.0113	0.0000
FRB	0.0042	0.0064	-0.0044	0.0108	0.0000
YOY	0.0042	0.0070	-0.0068	0.0137	0.0000
TED	0.0042	0.0054	-0.0002	0.0055	0.0000
BAML	0.0042	0.0074	-0.0078	0.0152	0.0000
VIX	0.0042	0.0076	-0.0093	0.0169	0.0000
EBP	0.0042	0.0070	-0.0068	0.0138	0.0000
Panel 3: Moneyness of 1.05					
NBER	0.0087	0.0100	-0.0027	0.0128	0.0000
OECD	0.0087	0.0111	0.0032	0.0079	0.0000
HGR	0.0087	0.0102	0.0021	0.0082	0.0000
ADS	0.0087	0.0109	-0.0002	0.0110	0.0000
FRB	0.0087	0.0105	0.0012	0.0093	0.0000
YOY	0.0087	0.0114	-0.0022	0.0136	0.0000
TED	0.0087	0.0094	0.0058	0.0036	0.0000
BAML	0.0087	0.0118	-0.0030	0.0148	0.0000
VIX	0.0087	0.0115	-0.0027	0.0143	0.0000
EBP	0.0087	0.0113	-0.0019	0.0132	0.0000

Table 5 – Descriptive Statistics of the S&P 500 IV Term Structure, for Maturities of 120 and 60 Days, in Relation to Economic and Financial Indicators. This table reports descriptive statistics of the term structure slope with regards to economic and financial conditions. The slope is defined as the difference between the estimated implied volatilities of options with 120 and 60 days to maturity. Panel 1 to 3 show the results for moneyness levels of 0.95, 1.00 and 1.05, respectively. Each panel covers all economic and financial indicators. Economic indicators include the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). Financial indicators include year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). For all indicators, columns (1) to (3) show average IV term structure slopes for the entire period, good times and bad times (as defined by each indicator), respectively. Column (4) presents the difference between (2) and (3). Column (5) displays p-values for two-sample *t*-tests (for the two data sets used to compute (2) and (3)). Section 3.3 defines the periods of good and bad times for each indicator. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.4173***					0.0923
	(5.1800)					(1.0524)
OECD		-0.4037***				-0.1055
		(6.9467)				(1.6227)
HGR			-0.5011***			-0.4072***
			(5.6303)			(2.8481)
ADS				0.4331***		-0.0669
				(5.2716)		(0.8258)
FRB					0.4901***	0.2480***
					(6.5718)	(3.5328)
Constant	0.4215***	0.4215***	0.4215***	0.4215***	0.4215***	0.4215***
	(9.1916)	(9.1423)	(9.5732)	(9.2629)	(9.5461)	(9.8525)
Observations	5113	5113	5113	5113	5113	5113
Adj. R-Squared	0.1271	0.1189	0.1834	0.1369	0.1754	0.2190

Table 6 – Relation between the Slope of the Term Structure and Individual Economic Indicators. This table reports the results of the regression analysis of the term structure slope for S&P 500 options against economic indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.5680***					0.5100***
	(7.8350)					(10.0543)
TED		-0.4818***				0.0284
		(4.4136)				(0.3547)
BAML			-0.5998***			0.9282***
			(7.0146)			(12.1066)
VIX				-0.8420***		-1.0708***
				(12.8250)		(17.6869)
EBP					-0.6617***	-0.3646***
					(8.1913)	(5.9602)
Constant	0.4215***	0.4215***	0.4362***	0.4215***	0.4215***	0.4362***
	(9.8537)	(9.4325)	(9.9207)	(12.4372)	(10.7310)	(14.9469)
Observations	5113	5113	4861	5113	5113	4861
Adj. R-Squared	0.2356	0.1694	0.2521	0.5180	0.3199	0.6534

Table 7 – Relation between the Slope of the Term Structure and Individual Financial Indicators. This table reports the results of the regression analysis of the term structure slope for S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	Agg. Economic Indicator			Agg. Financial Indicator			Both Indicators
	Full Period	Good Times	Bad Times	Full Period	Good Times	Bad Times	Full Period
Constant	0.4215***	0.6387***	-0.4468***	0.4362***	0.7656***	-0.8817***	0.4362***
	(9.7031)	(16.5111)	(2.9778)	(11.7812)	(23.3087)	(7.2484)	(11.9894)
Coef. Eco. Indicator	0.5245***	0.1342***	0.6139***				-0.3014***
	(6.4960)	(2.8297)	(3.1418)				(3.9125)
Coef. Fin. Indicator				0.8017***	0.1968***	1.0046***	1.0470***
				(10.0355)	(5.4883)	(4.6837)	(9.4672)
Obs.	5113	4090	1023	4861	3889	972	4861
Adj. R^2	0.2009	0.0240	0.1280	0.4504	0.0692	0.3688	0.4718

Table 8 – Relation between the Slope of the Term Structure and the Aggregate Economic and Financial Indicators. This table reports the results of the regression analysis of the term structure slope for S&P 500 options against the aggregate economic and financial indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. Independent variables include the Aggregate Economic Indicator (AEI) and the Aggregate Financial Indicator (AFI). Results for separate analysis of the AEI and AFI are presented for three linear regressions: for the full period, good times and bad times. See section 3.3 for a definition of the aggregate indicators and a definition of good and bad times. We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. The sample covers the period between January 4, 1996 and April 29, 2016 for the Aggregate Economic Indicator, and the period between January 2, 1997 and April 29, 2016 for the Aggregate Financial Indicator.

	AEI	AFI	AEI and AFI
Panel 1: Regression with IV(60) Control Variable			
Constant	0.4215***	0.4362***	0.4362***
	(11.8442)	(12.1786)	(12.1890)
Coef. Eco. Indicator	0.1239**		-0.0498
	(2.5354)		(0.4649)
Coef. Fin. Indicator		0.3176***	0.3869*
		(2.7895)	(1.7343)
Coef. Control Variable	-0.7281***	-0.5565***	-0.5233***
	(10.9674)	(7.1873)	(4.6630)
Obs.	5113	4861	4861
Adj. R^2	0.4709	0.5031	0.5034
Panel 2: Regression with AR Lag Control Variable			
Constant	0.4236***	0.4400***	0.4400***
	(10.5832)	(12.1006)	(12.3104)
Coef. Eco. Indicator	0.3493***		-0.2951***
	(3.7901)		(3.8457)
Coef. Fin. Indicator		0.7244***	0.9622***
		(6.5583)	(6.7856)
Coef. Control Variable	0.3876***	0.1455*	0,1497**
	(5.8358)	(1.8778)	(2.0592)
Obs.	5083	4831	4831
Adj. R^2	0.2880	0.4649	0.4853

Table 9 – Relation between the Slope of the Term Structure and the Aggregate Economic and Financial Indicators, with Control Variables. This table reports the results of the regression analysis of the term structure slope for S&P 500 options against the aggregate economic and financial indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. Independent variables include the Aggregate Economic Indicator (AEI) and the Aggregate Financial Indicator (AFI). The IV time series for S&P 500 options, with 60 days to maturity and a moneyness of 1, is used as a control variable in Panel 1. The term structure slope with a 30-day lag is used as a control variable in Panel 2. See section 3.3 for a definition of the aggregate indicators. We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. The sample covers the period between January 4, 1996 and April 29, 2016 for the Aggregate Economic Indicator, and the period between January 2, 1997 and April 29, 2016 for the Aggregate Financial Indicator.

	1.00 – 0.95 Skew	1.05 – 1.00 Skew
Average	-0.0467	-0.0245
Standard Deviation	0.0248	0.0225
P-Value (≠0)	0.0000	0.0000

Table 10 – Descriptive Statistics for the Skew. This table reports descriptive statistics for the skew of S&P 500 options. Statistics include the average skew, the standard deviation of the skew, and the p-value of the data set for a one-sample *t*-test. Statistics are reported for two sets of moneyness: 1.00-0.95 and 1.05-1.00. All IV values are computed using the Proximal Trilinear Interpolation Technique. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) Unconditional	(2) Good Times	(3) Bad Times	(4) Difference (2-3)	(5) P-Value
Panel 1: 1.05-1.00 Skew					
NBER	-0.0245	-0.0235	-0.0327	0.0092	0.0000
OECD	-0.0245	-0.0224	-0.0290	0.0066	0.0000
HGR	-0.0245	-0.0235	-0.0287	0.0052	0.0000
ADS	-0.0245	-0.0236	-0.0279	0.0043	0.0000
FRB	-0.0245	-0.0224	-0.0327	0.0102	0.0000
YOY	-0.0245	-0.0236	-0.0281	0.0045	0.0000
TED	-0.0245	-0.0223	-0.0330	0.0107	0.0000
BAML	-0.0245	-0.0237	-0.0290	0.0053	0.0000
VIX	-0.0245	-0.0217	-0.0355	0.0138	0.0000
EBP	-0.0245	-0.0232	-0.0295	0.0062	0.0000
Panel 2: 1.00-0.95 Skew					
NBER	-0.0467	-0.0473	-0.0413	-0.0060	0.0000
OECD	-0.0467	-0.0482	-0.0433	-0.0050	0.0000
HGR	-0.0467	-0.0479	-0.0419	-0.0060	0.0000
ADS	-0.0467	-0.0482	-0.0408	-0.0074	0.0000
FRB	-0.0467	-0.0477	-0.0426	-0.0051	0.0000
YOY	-0.0467	-0.0480	-0.0416	-0.0064	0.0000
TED	-0.0467	-0.0470	-0.0454	-0.0016	0.0639
BAML	-0.0467	-0.0476	-0.0412	-0.0064	0.0000
VIX	-0.0467	-0.0469	-0.0458	-0.0011	0.2005
EBP	-0.0467	-0.0483	-0.0403	-0.0080	0.0000

Table 11 – Descriptive Statistics of the S&P 500 IV *Skew*, at a Maturity of 30 Days, in Relation to Economic and Financial Indicators. This table reports descriptive statistics of the volatility skew with regards to economic and financial conditions. The skew is defined as the difference between the estimated implied volatilities of options with distinct moneyness, at a maturity of 30 days. Panel 1 and 2 show the results for moneyness specifications of 1.05-1.00 and 1.00-0.95, respectively. Each panel covers all economic and financial indicators (see section 3.3. for detailed descriptions of the indicators and definitions of good and bad times). Columns (1) to (3) show average IV term structure slopes for the entire period, good times and bad times (as defined by each indicator), respectively. Column (4) presents the difference between (2) and (3). Column (5) displays p-values for two-sample *t*-tests (for the two data sets used to compute (2) and (3)). The sample covers the period between January 4, 1996 and April 29, 2016.

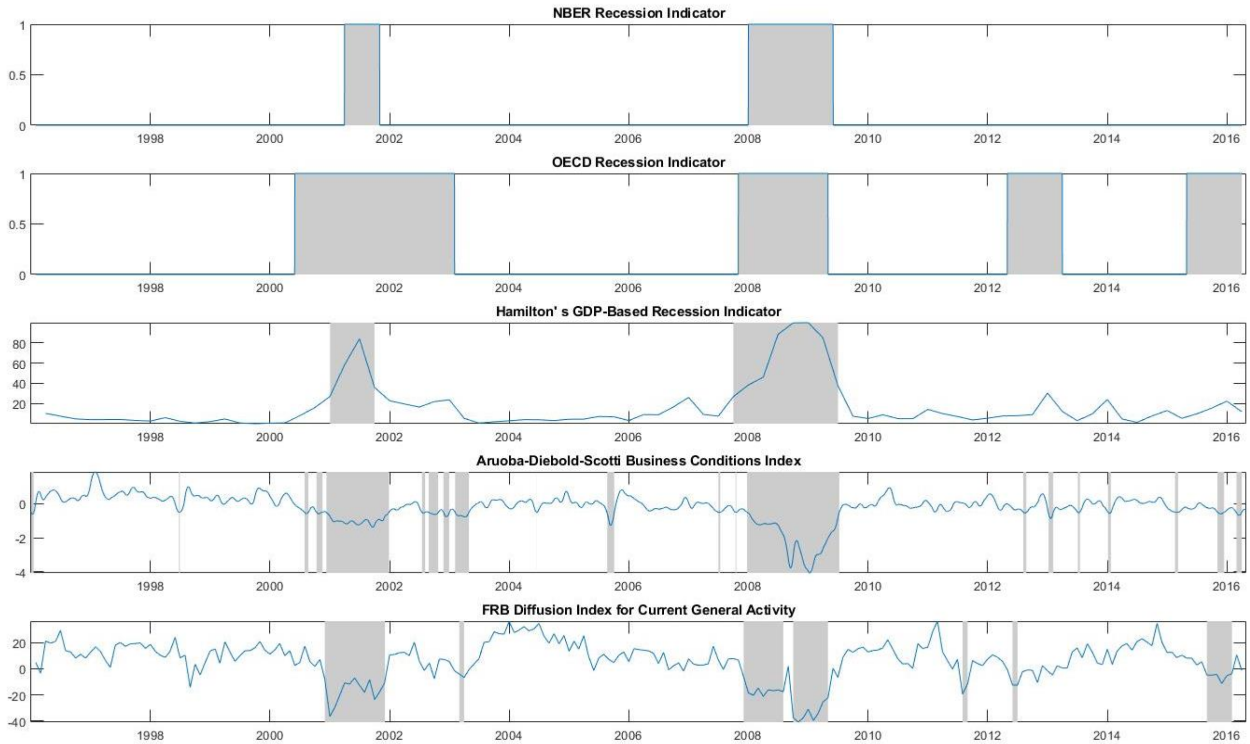

Figure 1 – Time Series of the Economic Indicators. This figure displays the NBER Recession Indicator (monthly), the OECD Recession Indicator (monthly), Hamilton's GDP-based Recession Indicator Index (quarterly), the Aruoba-Diebold-Scotti Business Conditions Index (daily), and the FRB Diffusion Index for Current General Activity (monthly). Grey-zones denote periods of high economic stress, as defined by each indicator. Section 3.3 defines the periods of good and bad times for each indicator. The sample covers the period between January 4, 1996 and April 29, 2016.

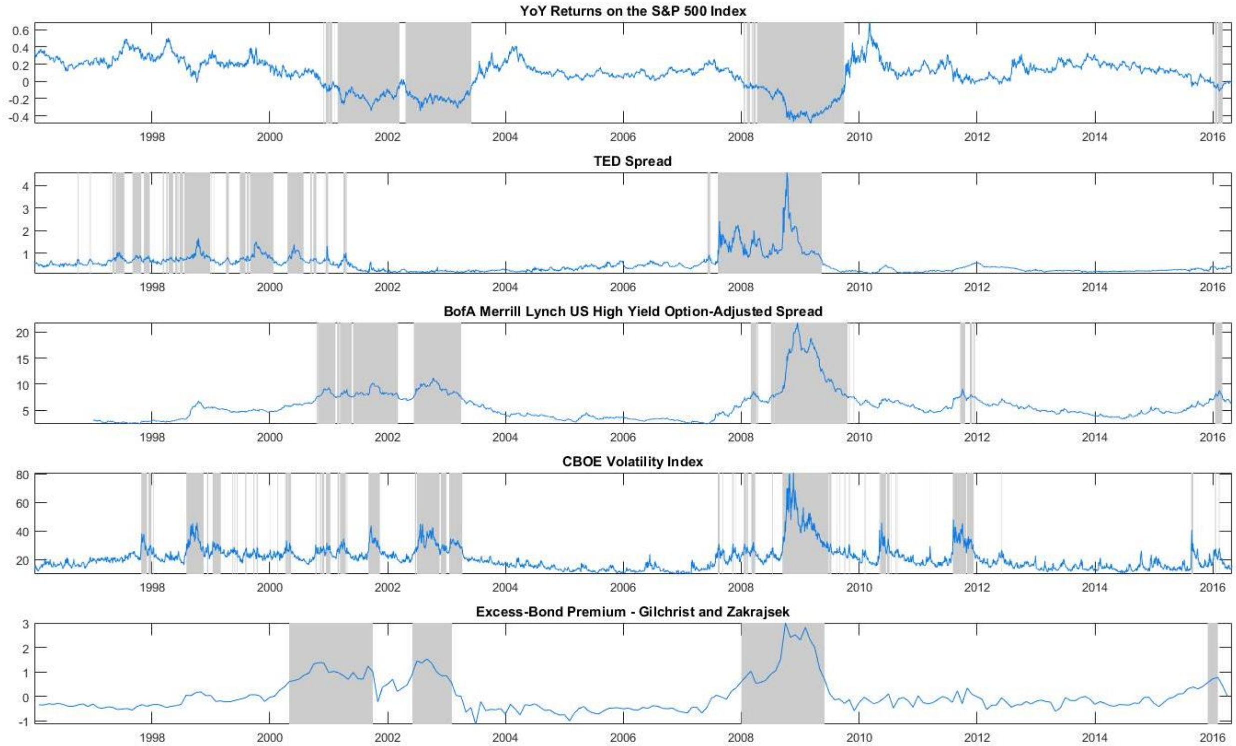

Figure 2 – Time Series of the Financial Indicators. This figure displays year-on-year returns of the S&P 500 Index (daily), the TED spread (daily), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (daily), the CBOE Volatility Index (daily), and the Excess-Bond Premium (monthly). Grey-zones denote periods of financial instability, as defined by each indicator. Section 3.3 defines the periods of good and bad times for each indicator. The sample covers the period between January 4, 1996 and April 29, 2016.

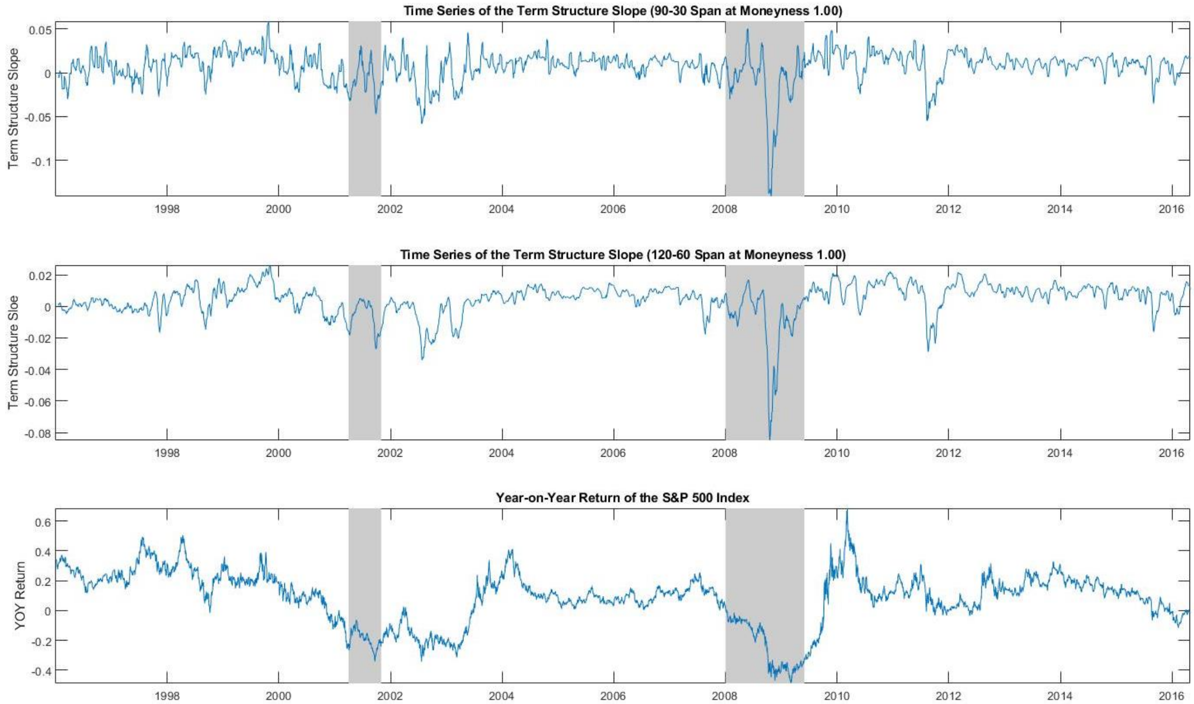

Figure 3 – Dynamics of the Slope of the Term Structure - ATM options. This figure shows the evolution of the term structure slope for S&P 500 options, which is the implied volatility (IV) differential between two options of different maturities but identical moneyness. The top panel considers options with 90 and 30 days to maturity, while the middle panel considers options with 120 and 60 days to maturity. All options are at-the-money (ATM). IV values are computed using the Proximal Trilinear Interpolation Technique. The time series of the top two panels are smoothed using a 10-day moving average for visual clarity. The bottom panel shows the year-on-year return of the S&P 500 Index for comparative purposes. Shaded areas represent periods of NBER recessions. The sample covers the period between January 4, 1996 and April 29, 2016.

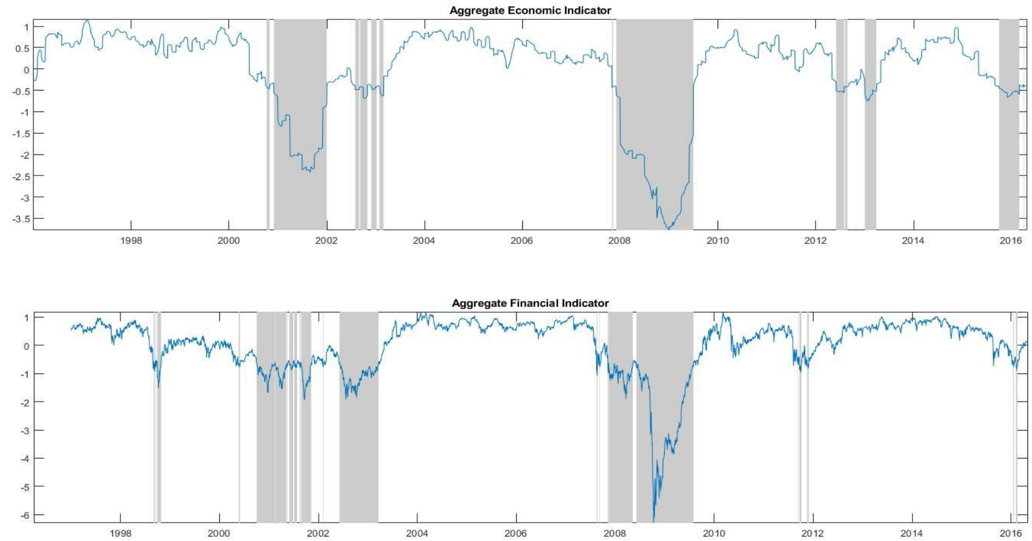

Figure 4 – Dynamics of the Aggregate Economic and Financial Indicators. The top panel displays the evolution of the Aggregate Economic Indicator between January 4, 1996 and April 29, 2016, measured as the sum of the economic indicators listed in Table 2, each standardized and directionally adjusted. The AEI is centered at a mean of 0 and scaled at a variance of 1. The bottom panel shows the Aggregate Financial Indicator between January 2, 1997 and April 29, 2016, also measured as the standardized sum of the centered and directionally-adjusted financial indicators. Shaded areas represent periods of stress according to each indicator, i.e., the observations corresponding to the bottom quintile of the time series.

Appendices

A1. Covered Securities

	# Obs.	Median	Average	Std. Dev.	Min.	Max.
Implied Volatility	1,247,116	19.2%	20.7%	8.8%	4.9%	89.9%
Moneyness Level	1,247,116	97.4%	97.2%	8.5%	80%	120%
Maturity (Days)	1,247,116	44.0	67.2	70.4	6.0	365.0
Daily Volume, Total	5,113	207,777	265,900	228,970	4,450	2,003,114
Daily Volume, Per Option Average	5,113	960	1,226	819	63	7,625
Daily Open Interest, Total	5,113	2,826,014	2,873,700	2,045,600	196,000	7,535,554
Daily Open Interest, Per Option Average	5,113	11,619	14,087	7,807	2,820	38,377
Options Traded per Day	5,113	126	244	270	29	1,727
Available Maturities per Day	5,113	6.0	8.7	4.9	4.0	27.0
Av. # of Mon. Levels per Maturity, per Day	5,113	20.0	23.1	10.2	7.2	67.9

Table A.1 – Descriptive Statistics of the Final Sample of S&P 500 (SPX) Options. This table reports the descriptive statistics for the implied volatility, the moneyness level (defined as the ratio of the strike price to the value of the underlying asset), the maturity of the options (in days), the daily trading volume (number of traded contracts) for all available options, the daily average trading volume per option, the daily open interest (number of contracts outstanding) for all options, the daily average open interest per option, the number of options traded per day, the number of available maturities per day, and the average number of moneyness levels per available maturity, per day. The data set covers the period between January 4, 1996 and April 29, 2016.

	# Obs.	Median	Average	Std. Dev.	Min.	Max.
Implied Volatility	365,062	22.1%	23.1%	7.2%	8.6%	89.9%
Moneyness Level	365,062	97.7%	97.4%	8.2%	80.0%	120.0%
Maturity (Days)	365,062	68.0	94.1	80.6	6.0	365.0
Daily Volume, Total	1,702	279,761	309,650	149,170	68,283	1,195,188
Daily Volume, Per Option Average	1,702	1,449	1,640	860	337	6,461
Daily Open Interest, Total	1,702	2,531,081	2,476,284	569,007	822,924	4,279,559
Daily Open Interest, Per Option Average	1,702	12,187	13,662	5,934	3,298	36,319
Options Traded per Day	1,702	183	214	97	67	507
Available Maturities per Day	1,702	13.0	12.8	3.3	6.0	20.0
Av. # of Mon. Levels per Maturity, per Day	1,702	15.1	16.0	3.9	8.6	30.4

Table A.2 – Descriptive Statistics of the Final Sample of iShares Russell 2000 Index ETF (IWM) options. This table reports the descriptive statistics for the implied volatility, the moneyness level (defined as the ratio of the strike price to the value of the underlying asset), the maturity of the options (in days), the daily trading volume (number of traded contracts) for all available options, the daily average trading volume per option, the daily open interest (number of contracts outstanding) for all options, the daily average open interest per option, the number of options traded per day, the number of available maturities per day, and the average number of moneyness levels per available maturity, per day. The iShares Russell 2000 Index ETF reproduces the Russell 2000 Index, an index of small capitalization companies in the U.S. (bottom 2000 of the Russell 3000 Index, with 8% market coverage). It is a total return Exchange-Traded Fund. American-style IWM options (SECID 106445) trade on the CBOE. The data set covers the period between July 28, 2009 and April 29, 2016.

	# Obs.	Median	Average	Std. Dev.	Min.	Max.
Implied Volatility	134,913	30.9%	32.7%	9.7%	11.6%	90.0%
Moneyness Level	134,913	99.6%	99.4%	9.4%	80.0%	120.0%
Maturity (Days)	134,913	53.0	82.6	71.6	6.0	365.0
Daily Volume, Total	1,702	37,194	43,989	31,687	1,811	350,561
Daily Volume, Per Option Average	1,702	493	547	323	35	3,959
Daily Open Interest, Total	1,702	541,178	569,457	249,843	119,228	2,301,171
Daily Open Interest, Per Option Average	1,702	7,150	7,266	2,335	1,427	17,387
Options Traded per Day	1,702	75	79	25	35	227
Available Maturities per Day	1,702	5.0	6.6	2.5	3.0	12.0
Av. # of Mon. Levels per Maturity, per Day	1,702	13.4	13.1	4.2	4.3	27.3

Table A.3 – Descriptive Statistics of the Final Sample of iShares MSCI Brazil ETF (EWZ) options. This table reports the descriptive statistics for the implied volatility, the moneyness level (defined as the ratio of the strike price to the value of the underlying asset), the maturity of the options (in days), the daily trading volume (number of traded contracts) for all available options, the daily average trading volume per option, the daily open interest (number of contracts outstanding) for all options, the daily average open interest per option, the number of options traded per day, the number of available maturities per day, and the average number of moneyness levels per available maturity, per day. The iShares MSCI Brazil ETF reproduces an index of large and mid-capitalizations in Brazil (with 85% free float-adjusted coverage of Brazilian equities). It is a total return Exchange-Traded Fund. American-style EWZ options (SECID 106416) trade on the CBOE. The data set covers the period between July 28, 2009 and April 29, 2016.

	# Obs.	Median	Average	Std. Dev.	Min.	Max.
Implied Volatility	121,727	25.9%	27.4%	7.0%	10.1%	87.7%
Moneyness Level	121,727	99.7%	99.5%	8.7%	80.0%	120.0%
Maturity (Days)	121,727	71.0	93.9	76.7	6.0	365.0
Daily Volume, Total	1,702	45,106	55,996	41,460	3,865	404,730
Daily Volume, Per Option Average	1,702	683	813	521	50	4,868
Daily Open Interest, Total	1,702	770,423	804,406	271,862	146,461	1,724,847
Daily Open Interest, Per Option Average	1,702	11,395	12,615	5,608	1,380	33,439
Options Traded per Day	1,702	63	72	32	30	233
Available Maturities per Day	1,702	7.0	7.3	2.6	3.0	13.0
Av. # of Mon. Levels per Maturity, per Day	1,702	9.8	10.0	2.5	4.4	21.0

Table A.4 – Descriptive Statistics of the FInal Sample of iShares China Large-Cap ETF (FXI) options. This table reports the descriptive statistics for the implied volatility, the moneyness level (defined as the ratio of the strike price to the value of the underlying asset), the maturity of the options (in days), the daily trading volume (number of traded contracts) for all available options, the daily average trading volume per option, the daily open interest (number of contracts outstanding) for all options, the daily average open interest per option, the number of options traded per day, the number of available maturities per day, and the average number of moneyness levels per available maturity, per day. The iShares China Large-Cap ETF reproduces an index of the 50 largest and most liquid Chinese equities. It is a total return Exchange-Traded Fund. American-style FXI options (SECID 122017) trade on the CBOE. The data set covers the period between July 28, 2009 and April 29, 2016.

	# Obs.	Median	Average	Std. Dev.	Min.	Max.
Implied Volatility	94,003	20.6%	22.0%	8.3%	4.7%	89.2%
Moneyness Level	94,003	98.9%	98.4%	7.7%	80.0%	120.0%
Maturity (Days)	94,003	71.0	99.7	84.8	6.0	365.0
Daily Volume, Total	1,702	28,507	35,815	31,291	1,504	346,927
Daily Volume, Per Option Average	1,702	520	640	550	47	7,826
Daily Open Interest, Total	1,702	507,669	510,943	187,331	79,004	1,169,386
Daily Open Interest, Per Option Average	1,702	9,175	9,532	3,577	2,171	22,845
Options Traded per Day	1,702	53	55	14	25	134
Available Maturities per Day	1,702	7.0	7.8	2.1	3.0	13.0
Av. # of Mon. Levels per Maturity, per Day	1,702	7.3	7.5	2.1	3.0	15.2

Table A.5 – Descriptive Statistics of the Final Sample of iShares EAFA Index ETF (EFA) options. This table reports the descriptive statistics for the implied volatility, the moneyness level (defined as the ratio of the strike price to the value of the underlying asset), the maturity of the options (in days), the daily trading volume (number of traded contracts) for all available options, the daily average trading volume per option, the daily open interest (number of contracts outstanding) for all options, the daily average open interest per option, the number of options traded per day, the number of available maturities per day, and the average number of moneyness levels per available maturity, per day. The iShares EAFA Index ETF reproduces an index of large and mid-capitalizations in developed markets, excluding the U.S. and Canada (with 85% free float-adjusted coverage). It is a total return Exchange-Traded Fund. American-style EFA options (SECID 116908) trade on the CBOE. The data set covers the period between July 28, 2009 and April 29, 2016.

	# Obs.	Median	Average	Std. Dev.	Min.	Max.
Implied Volatility	145,421	23.6%	25.0%	7.5%	6.9%	89.7%
Moneyness Level	145,421	98.9%	98.7%	8.5%	80.0%	120.0%
Maturity (Days)	145,421	80.0	106.5	87.2	6.0	365.0
Daily Volume, Total	1,702	142,119	168,824	104,753	17,199	1,022,509
Daily Volume, Per Option Average	1,702	1 739	1 981	1 080	316	11,248
Daily Open Interest, Total	1,702	2115,034	2230,941	650,081	713,770	4,775,355
Daily Open Interest, Per Option Average	1,702	26,665	27,057	7,110	8,756	53,332
Options Traded per Day	1,702	85	85	24	36	177
Available Maturities per Day	1,702	9.0	8.7	2.9	3.0	16.0
Av. # of Mon. Levels per Maturity, per Day	1,702	10.4	10.3	2.3	4.1	18.6

Table A.6 – Descriptive Statistics of the Final Sample of iShares Emerging Markets Index ETF (EEM) options. This table reports the descriptive statistics for the implied volatility, the moneyness level (defined as the ratio of the strike price to the value of the underlying asset), the maturity of the options (in days), the daily trading volume (number of traded contracts) for all available options, the daily average trading volume per option, the daily open interest (number of contracts outstanding) for all options, the daily average open interest per option, the number of options traded per day, the number of available maturities per day, and the average number of moneyness levels per available maturity, per day. The iShares Emerging Markets Index ETF reproduces an index of large and mid-capitalizations across 23 emerging markets. It is a total return Exchange-Traded Fund. American-style EEM options (SECID 116959) trade on the CBOE. The data set covers the period between July 28, 2009 and April 29, 2016.

A2. Implied Volatility Estimation Techniques

Option contracts are traded for a finite number of unevenly distributed maturities and moneyness levels. Consequently, the IV surface has a *degenerated* design. Multiple estimation techniques are employed in this paper to compute daily IV values at any given maturity or moneyness level.

The Proximal Trilinear Interpolation Technique (PTIT) serves as the central IV estimation method throughout this study. The approach can be described as follows. For a target time to maturity T, we choose the closest surrounding maturities available on the market. At each maturity, we linearly interpolate between traded options to estimate volatility metrics at the desired moneyness level M. Lastly, we interpolate between the two estimated values to obtain $IV(M,T)$. The trilinear approach can be expressed as follows:

$$\overline{IV}_t^1(M,T_1) = \frac{IV_t(M_1,T_1) * (M_2 - M) + IV_t(M_2,T_1) * (M - M_1)}{(M_2 - M_1)}$$

$$\overline{IV}_t^2(M,T_2) = \frac{IV_t(M_3,T_2) * (M_4 - M) + IV_t(M_4,T_2) * (M - M_3)}{(M_4 - M_3)}$$

$$\overline{IV}_t(M,T) = \frac{\overline{IV}_t^1(M,T_1) * (T_2 - T) + \overline{IV}_t^2(M,T_2) * (T - T_1)}{(T_2 - T_1)}$$

where $\overline{IV}_t(M,T)$ is the estimated implied volatility at the target time to maturity T and target moneyness level M. T_1 and T_2 correspond to the closest available maturities below and above T, respectively. M_1 and M_2 are the closest available moneyness levels below and above M, for options with maturity T_1. M_3 and M_4 are the closest available moneyness levels below and above M, for options with maturity T_2. IV_t denotes the implied volatility value of an existing (i.e., traded) option, in contrast to $\overline{IV}_t$ for estimated implied volatility values. Refer to Figure A.1 for a visual representation of the PTIT.

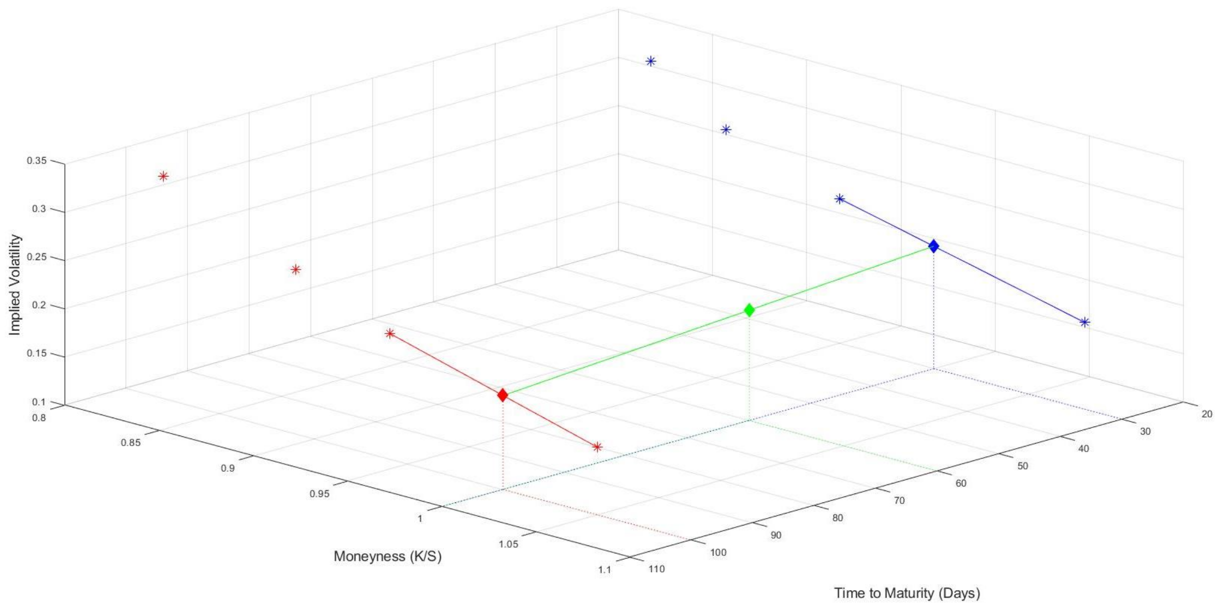

Figure A.1 – Visual Representation of the Proximal Trilinear Interpolation Technique (PTIT). The figure displays an example of the PTIT for a target moneyness level of 1 (computed as the strike price of an option divided by the price of the underlying asset) and a target maturity of 60 days. Available and estimated option metrics are displayed with star and diamond markers, respectively. The values in blue correspond to the closest available maturity below the target of 60 days (i.e., 30 days). The values in red correspond to the closest available maturity above the target of 60 days (i.e., 100 days). The blue and red lines depict the two linear interpolations implemented to estimate the volatility metrics at the desired moneyness level (i.e., the blue and red diamond markers). Lastly, the green line depicts the final linear interpolation used to estimate the IV value at the target maturity and moneyness coordinates (i.e., the green diamond marker).

Specific situations arise when traded options do not provide the required information to execute an approach based entirely on linear interpolation, especially for the less liquid securities employed in this study. In the original PTIT, which is the main approach that we use throughout this paper, we allow for linear extrapolation of implied volatility values, when market data is insufficient to interpolate, on both the moneyness and maturity axis (see Figure A.2). Specific limits are applied to ensure the validity of the extrapolated results at each step of the PTIT, in line with the filters described in section 3.1. For each extrapolation, we only keep the estimate if the obtained IV is above 4% and below 90%. In addition, we only keep the estimate if the difference between the extrapolated IV and the closest available IV (i.e., the IV of the closest available option used for the extrapolation) is inferior to 10%.

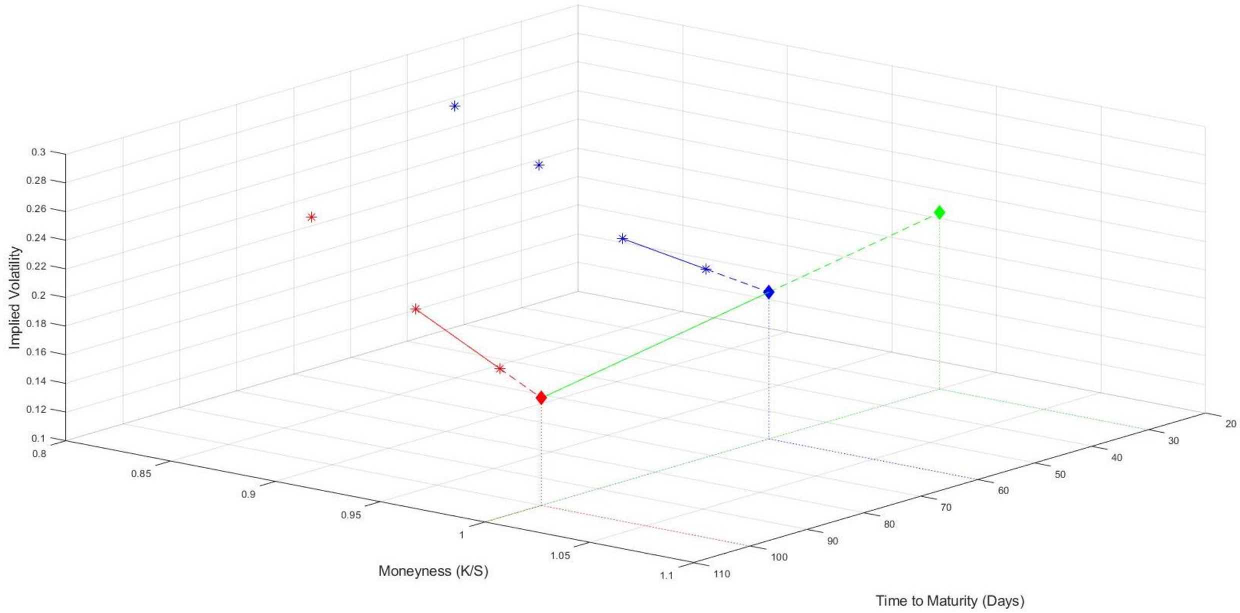

Figure A.2 – Visual Representation of the Basic Proximal Trilinear Interpolation Technique (PTIT), using Extrapolation. The figure displays an example of the basic PTIT for a target moneyness level of 1 (computed as the strike price of an option divided by the price of the underlying asset) and a target maturity of 30 days, assuming that no options are available for a maturity below 30 or a moneyness above 1. Available and estimated option metrics are displayed with star and diamond markers, respectively. The values in blue and red correspond to the two closest available maturities above the target of 30 days (i.e., 60 and 100 days, respectively). The blue and red lines depict the two linear extrapolations implemented to estimate the volatility metrics at the desired moneyness level (i.e., the blue and red diamond markers). Lastly, the green line depicts the final linear extrapolation used to estimate the IV value at the target maturity and moneyness coordinates (i.e., the green diamond marker).

The application of the PTIT is an iterative process. For instance, when calculating $\overline{IV}_t^1(M,T_1)$ as per the equations above, with T_1 being the closest available maturity below the target maturity T, it is possible that no option trades with a moneyness level below the target moneyness M (i.e., M_1 does not exist). In this case, two options with maturity T_1 and moneyness levels above M could be used to extrapolate $\overline{IV}_t^1(M,T_1)$. If the extrapolation is not applicable (i.e., the data set is insufficient) or does not respect the above-described filters, T_1 would be replaced by the next closest maturity below T. If the calculation of $\overline{IV}_t^1(M,T_1)$ is still not realizable, the iteration continues with the next closest maturity. The same process is applied when computing $\overline{IV}_t^2(M,T_2)$, where T_2 is effectively the closest maturity above T for which the computation of $\overline{IV}_t^2(M,T_2)$ is achievable and in line with the applied filters. If the computation of neither $\overline{IV}_t^1(M,T_1)$ nor $\overline{IV}_t^2(M,T_2)$ is applicable given the data set, $\overline{IV}_t(M,T)$ can still be extrapolated. For instance, if the computation of $\overline{IV}_t^1(M,T_1)$ is impossible, $\overline{IV}_t(M,T)$ can be extrapolated using $\overline{IV}_t^2(M,T_2)$ and $\overline{IV}_t^3(M,T_{2*})$, with T_2 and T_{2*} the two closest maturities above T for which the implied volatility can be estimated at the desired moneyness level (see Figure A.2 for visual representation). Following the full iteration process, if the available option data set does not allow for IV estimation at the desired maturity and moneyness coordinates, the sought data point (i.e., the IV value and the corresponding date) is simply removed from the sample. For S&P 500 options and term structure slopes defined as the IV differential between at-the-money options with maturities of 120 and 60 days, the PTIT achieves a 100% success rate (i.e., no data point is removed from the sample).

Three derivations of the basic PTIT are introduced in Section 5, namely Model 1 to 3. The Model 1 excludes extrapolation. As such, after completion of the iteration process, T_1 and T_2 correspond to the closest maturities below and above T for which the computation of $\overline{IV}_t^1(M, T_1)$ and $\overline{IV}_t^2(M, T_2)$ is achievable without extrapolation, respectively. If the computation of $\overline{IV}_t^1(M, T_1)$ or $\overline{IV}_t^2(M, T_2)$ is not achievable, the sought data point is removed from the sample. For S&P 500 options and term structure slopes defined as the IV differential between at-the-money options with maturities of 120 and 60 days, Model 1 achieves a 99.9% success rate (i.e., 3 data points are removed on a total of 5,113 days). Model 2 allows for extrapolation, but on the moneyness axis only. After completion of the iteration process, T_1 and T_2 correspond to the closest maturities below and above T for which the computation of $\overline{IV}_t^1(M, T_1)$ and $\overline{IV}_t^2(M, T_2)$ is achievable (allowing for extrapolation when computing the IV at a fixed maturity), respectively. If the computation of $\overline{IV}_t^1(M, T_1)$ or $\overline{IV}_t^2(M, T_2)$ is not applicable, the sought data point is removed from the sample. For S&P 500 options and term structure slopes defined as the IV differential between at-the-money options with maturities of 120 and 60 days, Model 2 achieves a 100% success rate (i.e., no data point is removed from the sample).

Model 3, which is the third alternative of the PTIT, incorporates a liquidity factor in the estimation of implied volatility. In this model, we first identify the most traded options surrounding the target moneyness level M and target maturity T:

$$IV_t^A(M^+, T^-) = \ most\ traded\ option\ with\ \ M \le M^+ \le M + 0.2\ and\ T - 200 \le T^- \le T$$

$$IV_t^B(M^-, T^-) = \ most\ traded\ option\ with\ \ M - 0.2 \le M^- \le M\ and\ T - 200 \le T^- \le T$$

$$IV_t^C(M^+, T^+) = \ most\ traded\ option\ with\ \ M \le M^+ \le M + 0.2\ and\ T \le T^+ \le T + 200$$

$$IV_t^D(M^+, T^+) = \ most\ traded\ option\ with\ \ M - 0.2 \le M^- \le M\ and\ T \le T^+ \le T + 200$$

$\overline{IV}_t(M,T)$ is computed using a three-step process. First, $\overline{IV}_t^1(M,T^-)$ is calculated through linear interpolation between $IV_t^A(M^+,T^-)$ and $IV_t^B(M^-,T^-)$. Similarly, we compute $\overline{IV}_t^2(M,T^+)$ through linear interpolation between $IV_t^C(M^+,T^+)$ and $IV_t^D(M^+,T^+)$. Finally, we obtain $\overline{IV}_t(M,T)$ using linear interpolation between $\overline{IV}_t^1(M,T^-)$ and $\overline{IV}_t^2(M,T^+)$. See Figure A.3 for visual representation.

Lastly, Model 4 uses cubic spline interpolation to estimate the IVS. In Model 4, the *fit* MATLAB function is used, with piecewise cubic interpolation.

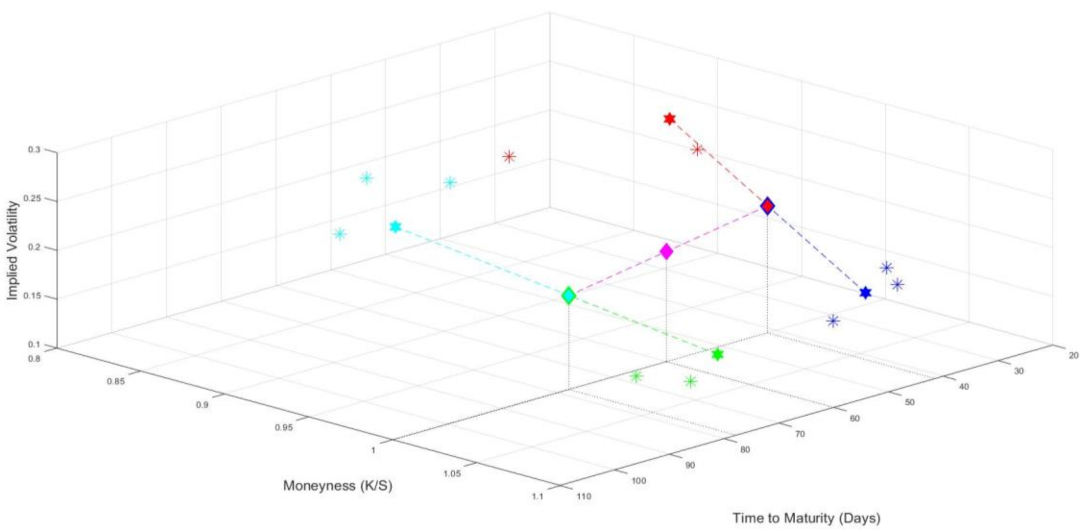

Figure A.3 – Visual Representation of the Model 3 Estimation Approach. The figure displays an example of the Model 3 estimation approach for a target moneyness level of 1 (computed as the strike price of an option divided by the price of the underlying asset) and a target maturity of 60 days. Available option metrics are displayed with star markers (6 or 8 pointed). Estimated metrics are displayed with diamond markers. The values in dark blue correspond to all available options with maturity between 5 and 60 days, as well as moneyness between 1 and 1.2. The values in red correspond to all available options with maturity between 5 and 60 days, as well as moneyness between 0.8 and 1. The values in green correspond to all available options with maturity between 60 and 260 days, as well as moneyness between 1 and 1.2. The values in light blue correspond to all available options with maturity between 60 and 260 days, as well as moneyness between 0.8 and 1. Within each color, the six-pointed star denotes the most traded option. The lines and corresponding diamond markers show the linear interpolations implemented to estimate implied volatility metrics.

A3. Robustness Checks

A3.1. Alternative Specifications

	(1) Unconditional	(2) Good Times	(3) Bad Times	(4) Difference (2-3)	(5) P-Value
Panel 1: Moneyness of 0.95					
NBER	-0.0130	-0.0115	-0.0257	0.0142	0.0000
OECD	-0.0130	-0.0104	-0.0189	0.0086	0.0000
HGR	-0.0130	-0.0115	-0.0192	0.0076	0.0000
ADS	-0.0130	-0.0108	-0.0217	0.0109	0.0000
FRB	-0.0130	-0.0108	-0.0218	0.0110	0.0000
YOY	-0.0130	-0.0101	-0.0246	0.0145	0.0000
TED	-0.0130	-0.0122	-0.0162	0.0040	0.0000
BAML	-0.0130	-0.0092	-0.0256	0.0164	0.0000
VIX	-0.0130	-0.0086	-0.0309	0.0223	0.0000
EBP	-0.0130	-0.0102	-0.0243	0.0141	0.0000
Panel 2: Moneyness of 1.00					
NBER	0.0065	0.0085	-0.0100	0.0185	0.0000
OECD	0.0065	0.0104	-0.0020	0.0125	0.0000
HGR	0.0065	0.0089	-0.0031	0.0119	0.0000
ADS	0.0065	0.0097	-0.0061	0.0158	0.0000
FRB	0.0065	0.0097	-0.0061	0.0159	0.0000
YOY	0.0065	0.0101	-0.0077	0.0178	0.0000
TED	0.0065	0.0078	0.0014	0.0064	0.0000
BAML	0.0065	0.0107	-0.0095	0.0202	0.0000
VIX	0.0065	0.0115	-0.0134	0.0249	0.0000
EBP	0.0065	0.0104	-0.0088	0.0192	0.0000
Panel 3: Moneyness of 1.05					
NBER	0.0080	0.0092	-0.0022	0.0114	0.0000
OECD	0.0080	0.0104	0.0027	0.0078	0.0000
HGR	0.0080	0.0095	0.0019	0.0075	0.0000
ADS	0.0080	0.0103	-0.0013	0.0116	0.0000
FRB	0.0080	0.0098	0.0008	0.0090	0.0000
YOY	0.0080	0.0105	-0.0020	0.0125	0.0000
TED	0.0080	0.0076	0.0094	-0.0018	0.0282
BAML	0.0080	0.0112	-0.0039	0.0151	0.0000
VIX	0.0080	0.0110	-0.0039	0.0149	0.0000
EBP	0.0080	0.0106	-0.0025	0.0131	0.0000

Table A.7 – Descriptive Statistics of the S&P 500 IV Term Structure, for Maturities of 90 and 30 Days, in Relation to Economic and Financial Indicators. This table reports descriptive statistics of the term structure slope with regards to economic and financial conditions. The term structure slope is defined as the difference between the estimated implied volatilities of options with 90 and 30 days to maturity. Panel 1 to 3 show the results for moneyness levels of 0.95, 1.00 and 1.05, respectively. Each panel covers all economic and financial indicators. Economic indicators include the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). Financial indicators include year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). For all indicators, columns (1) to (3) show average IV term structure slopes for the entire period, good times and bad times (as defined by each indicator), respectively. Column (4) presents the difference between (2) and (3). Column (5) displays p-values for two-sample *t*-tests (for the two data sets used to compute (2) and (3)). Section 3.3 defines the periods of good and bad times for each indicator. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) Unconditional	(2) Good Times	(3) Bad Times	(4) Difference (2-3)	(5) P-Value
Panel 1: Moneyness of 0.95					
NBER	-0.0036	-0.0024	-0.0136	0.0112	0.0000
OECD	-0.0036	-0.0013	-0.0087	0.0074	0.0000
HGR	-0.0036	-0.0021	-0.0096	0.0075	0.0000
ADS	-0.0036	-0.0017	-0.0112	0.0095	0.0000
FRB	-0.0036	-0.0017	-0.0111	0.0094	0.0000
YOY	-0.0036	-0.0012	-0.0130	0.0117	0.0000
TED	-0.0036	-0.0026	-0.0074	0.0048	0.0000
BAML	-0.0036	-0.0007	-0.0142	0.0135	0.0000
VIX	-0.0036	-0.0002	-0.0169	0.0166	0.0000
EBP	-0.0036	-0.0013	-0.0128	0.0115	0.0000
Panel 2: Moneyness of 1.00					
NBER	0.0042	0.0057	-0.0079	0.0135	0.0000
OECD	0.0042	0.0069	-0.0018	0.0087	0.0000
HGR	0.0042	0.0059	-0.0028	0.0087	0.0000
ADS	0.0042	0.0065	-0.0048	0.0113	0.0000
FRB	0.0042	0.0064	-0.0044	0.0108	0.0000
YOY	0.0042	0.0070	-0.0068	0.0137	0.0000
TED	0.0042	0.0054	-0.0002	0.0055	0.0000
BAML	0.0042	0.0074	-0.0078	0.0152	0.0000
VIX	0.0042	0.0076	-0.0093	0.0169	0.0000
EBP	0.0042	0.0070	-0.0068	0.0138	0.0000
Panel 3: Moneyness of 1.05					
NBER	0.0087	0.0100	-0.0027	0.0128	0.0000
OECD	0.0087	0.0111	0.0032	0.0079	0.0000
HGR	0.0087	0.0102	0.0021	0.0082	0.0000
ADS	0.0087	0.0109	-0.0002	0.0110	0.0000
FRB	0.0087	0.0105	0.0012	0.0093	0.0000
YOY	0.0087	0.0114	-0.0022	0.0136	0.0000
TED	0.0087	0.0094	0.0058	0.0036	0.0000
BAML	0.0087	0.0118	-0.0030	0.0148	0.0000
VIX	0.0087	0.0115	-0.0027	0.0143	0.0000
EBP	0.0087	0.0113	-0.0019	0.0132	0.0000

Table A.8 – Descriptive Statistics of the S&P 500 IV Term Structure, for Maturities of 120 and 60 Days, in Relation to Economic and Financial Indicators. This table reports descriptive statistics of the term structure slope with regards to economic and financial conditions. The term structure slope is defined as the difference between the estimated implied volatilities of options with 120 and 60 days to maturity. Panel 1 to 3 show the results for moneyness levels of 0.95, 1.00 and 1.05, respectively. Each panel covers all economic and financial indicators. Economic indicators include the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). Financial indicators include year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). For all indicators, columns (1) to (3) show average IV term structure slopes for the entire period, good times and bad times (as defined by each indicator), respectively. Column (4) presents the difference between (2) and (3). Column (5) displays p-values for two-sample *t*-tests (for the two data sets used to compute (2) and (3)). Section 3.3 defines the periods of good and bad times for each indicator. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.4361***					0.2144
	(3.144)					(1.136)
OECD		-0.3966***				-0.0383
		(4.011)				(0.320)
HGR			-0.5553***			-0.6689**
			(3.618)			(2.401)
ADS				0.4297***		-0.2402
				(2.983)		(1.510)
FRB					0.5538***	0.3674**
					(4.294)	(2.534)
Constant	-1.3003***	-1.3003***	-1.3003***	-1.3003***	-1.3003***	-1.3003***
	(15.097)	(15.026)	(15.364)	(15.094)	(15.375)	(15.570)
Obs.	5021	5021	5021	5021	5021	5021
Adj. R^2	2.9%	2.4%	4.8%	2.8%	4.7%	6.0%

Table A.9 – Relation between Individual Economic Indicators and the Slope of the Term Structure, for Maturities of 90 and 30 Days, at a Moneyness of 0.95. This table reports the results of the regression analysis of the term structure slope for S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between options with 90 and 30 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.5713***					0.2718
	(4.044)					(1.644)
OECD		-0.5784***				-0.1313
		(5.912)				(1.153)
HGR			-0.7262***			-0.6865***
			(4.693)			(2.801)
ADS				0.6335***		-0.0767
				(4.377)		(0.519)
FRB					0.7174***	0.3894***
					(5.682)	(2.930)
Constant	0.6537***	0.6537***	0.6537***	0.6537***	0.6537***	0.6537***
	(8.117)	(8.130)	(8.408)	(8.227)	(8.410)	(8.610)
Obs.	4947	4947	4947	4947	4947	4947
Adj. R^2	5.2%	5.4%	8.5%	6.4%	8.3%	10.4%

Table A.10 – Relation between Individual Economic Indicators and the Slope of the Term Structure, for Maturities of 90 and 30 Days, at a Moneyness of 1.00. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between options with 90 and 30 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.3512**					0.3592**
	(2.433)					(2.352)
OECD		-0.3605***				-0.0282
		(3.840)				(0.272)
HGR			-0.5015***			-0.5380**
			(3.080)			(2.217)
ADS				0.4845***		0.1624
				(3.287)		(1.123)
FRB					0.4486***	0.1803
					(3.509)	(1.528)
Constant	0.7999***	0.7999***	0.7999***	0.7999***	0.7999***	0.7999***
	(10.289)	(10.306)	(10.539)	(10.509)	(10.450)	(10.674)
Obs.	4930	4930	4930	4930	4930	4930
Adj. R^2	2.3%	2.4%	4.7%	4.4%	3.8%	5.8%

Table A.11 – Relation between Individual Economic Indicators and the Slope of the Term Structure, for Maturities of 90 and 30 Days, at a Moneyness of 1.05. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between options with 90 and 30 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.3453***					0.1817**
	(4.156)					(1.994)
OECD		-0.3399***				-0.0580
		(5.834)				(0.884)
HGR			-0.4436***			-0.4609***
			(4.791)			(3.035)
ADS				0.3744***		-0.0858
				(4.499)		(1.072)
FRB					0.4417***	0.2605***
					(5.716)	(3.539)
Constant	-0.3580***	-0.3580***	-0.3580***	-0.3580***	-0.3580***	-0.3580***
	(7.626)	(7.613)	(7.929)	(7.711)	(7.947)	(8.146)
Obs.	5113	5113	5113	5113	5113	5113
Adj. R^2	8.8%	8.5%	14.5%	10.3%	14.3%	17.9%

Table A.12 – Relation between Individual Economic Indicators and the Slope of the Term Structure, for Maturities of 120 and 60 Days, at a Moneyness of 0.95. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.4173***					0.0923
	(5.180)					(1.052)
OECD		-0.4037***				-0.1055
		(6.947)				(1.623)
HGR			-0.5011***			-0.4072***
			(5.630)			(2.848)
ADS				0.4331***		-0.0669
				(5.272)		(0.826)
FRB					0.4901***	0.2480***
					(6.572)	(3.533)
Constant	0.4215***	0.4215***	0.4215***	0.4215***	0.4215***	0.4215***
	(9.192)	(9.142)	(9.573)	(9.263)	(9.546)	(9.852)
Obs.	5113	5113	5113	5113	5113	5113
Adj. R^2	12.7%	11.9%	18.3%	13.7%	17.5%	21.9%

Table A.13 – Relation between Individual Economic Indicators and the Slope of the Term Structure, for Maturities of 120 and 60 Days, at a Moneyness of 1.00. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.3932***					0.0703
	(5.006)					(0.761)
OECD		-0.3662***				-0.1093*
		(6.353)				(1.681)
HGR			-0.4707***			-0.4172***
			(5.483)			(3.035)
ADS				0.4025***		-0.0528
				(4.916)		(0.647)
FRB					0.4158***	0.1411**
					(5.625)	(2.088)
Constant	0.8659***	0.8659***	0.8659***	0.8659***	0.8659***	0.8659***
	(19.199)	(19.015)	(19.926)	(19.304)	(19.443)	(20.216)
Obs.	5113	5113	5113	5113	5113	5113
Adj. R^2	11.9%	10.3%	17.0%	12.5%	13.3%	18.9%

Table A.14 – Relation between Individual Economic Indicators and the Slope of the Term Structure, for Maturities of 120 and 60 Days, at a Moneyness of 1.05. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.6421***					0.9203***
	(5.239)					(8.061)
TED		-0.5571***				0.1826
		(2.721)				(1.141)
BAML			-0.5852***			2.0493***
			(3.882)			(12.413)
VIX				-1.0565***		-1.8199***
				(7.598)		(12.896)
EBP					-0.7342***	-0.6669***
					(4.877)	(4.562)
Constant	-1.3003***	-1.3003***	-1.2450***	-1.3003***	-1.3003***	-1.2450***
	(15.500)	(15.339)	(14.193)	(16.769)	(15.921)	(17.596)
Obs.	5021	5021	4778	5021	5021	4778
Adj. R^2	6.4%	4.8%	5.2%	17.3%	8.3%	29.3%

Table A.15 – Relation between Individual Financial Indicators and the Slope of the Term Structure, for Maturities of 90 and 30 Days, at a Moneyness of 0.95. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 90 and 30 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.8213***					0.8529***
	(6.580)					(7.678)
TED		-0.6411***				0.1051
		(3.134)				(0.658)
BAML			-0.8110***			1.6190***
			(5.527)			(9.333)
VIX				-1.2225***		-1.6872***
				(9.802)		(12.270)
EBP					-0.9271***	-0.5827***
					(6.373)	(4.380)
Constant	0.6537***	0.6537***	0.6623***	0.6537***	0.6537***	0.6623***
	(8.544)	(8.204)	(8.355)	(9.629)	(8.961)	(10.568)
Obs.	4947	4947	4702	4947	4947	4702
Adj. R^2	10.8%	6.6%	10.5%	24.0%	13.8%	32.9%

Table A.16 – Relation between Individual Financial Indicators and the Slope of the Term Structure, for Maturities of 90 and 30 Days, at a Moneyness of 1.00. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 90 and 30 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.6338***					0.8480***
	(5.167)					(6.820)
TED		-0.3465				0.0553
		(1.442)				(0.269)
BAML			-0.5067***			1.1193***
			(3.436)			(5.506)
VIX				-0.6545***		-0.8466***
				(4.009)		(5.224)
EBP					-0.5833***	-0.3811**
					(3.713)	(2.276)
Constant	0.7999***	0.7999***	0.8165***	0.7999***	0.7999***	0.8165***
	(10.812)	(10.243)	(10.337)	(10.630)	(10.715)	(11.193)
Obs.	4930	4930	4689	4930	4930	4689
Adj. R^2	7.5%	2.2%	4.8%	8.0%	6.4%	15.2%

Table A.17 – Relation between Individual Financial Indicators and the Slope of the Term Structure, for Maturities of 90 and 30 Days, at a Moneyness of 1.05. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 90 and 30 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.4891***					0.4614***
	(6.580)					(9.773)
TED		-0.4488***				0.0780
		(4.045)				(0.992)
BAML			-0.5323***			1.0347***
			(5.916)			(14.128)
VIX				-0.8165***		-1.1637***
				(11.425)		(17.652)
EBP					-0.6016***	-0.3885***
					(7.052)	(6.440)
Constant	-0.3580***	-0.3580***	-0.3359***	-0.3580***	-0.3580***	-0.3359***
	(8.030)	(7.925)	(7.391)	(10.185)	(8.714)	(11.113)
Obs.	5113	5113	4861	5113	5113	4861
Adj. R^2	17.6%	14.8%	20.1%	49.1%	26.6%	63.9%

Table A.18 – Relation between Individual Financial Indicators and the Slope of the Term Structure, for Maturities of 120 and 60 Days, at a Moneyness of 0.95. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.5680***					0.5100***
	(7.835)					(10.054)
TED		-0.4818***				0.0284
		(4.414)				(0.355)
BAML			-0.5998***			0.9282***
			(7.015)			(12.107)
VIX				-0.8420***		-1.0708***
				(12.825)		(17.687)
EBP					-0.6617***	-0.3646***
					(8.191)	(5.960)
Constant	0.4215***	0.4215***	0.4362***	0.4215***	0.4215***	0.4362***
	(9.854)	(9.433)	(9.921)	(12.437)	(10.731)	(14.947)
Obs.	5113	5113	4861	5113	5113	4861
Adj. R^2	23.6%	16.9%	25.2%	51.8%	32.0%	65.3%

Table A.19 – Relation between Individual Financial Indicators and the Slope of the Term Structure, for Maturities of 120 and 60 Days, at a Moneyness of 1.00. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.5375***					0.5297***
	(7.481)					(8.580)
TED		-0.3852***				0.0490
		(3.382)				(0.558)
BAML			-0.5411***			0.8053***
			(6.378)			(8.328)
VIX				-0.7068***		-0.8732***
				(9.811)		(12.178)
EBP					-0.5842***	-0.3194***
					(7.268)	(4.311)
Constant	0.8659***	0.8659***	0.8863***	0.8659***	0.8659***	0.8863***
	(20.558)	(19.081)	(20.130)	(22.850)	(21.423)	(25.797)
Obs.	5113	5113	4861	5113	5113	4861
Adj. R^2	22.2%	11.4%	21.7%	38.4%	26.3%	51.8%

Table A.20 – Relation between Individual Financial Indicators and the Slope of the Term Structure, for Maturities of 120 and 60 Days, at a Moneyness of 1.05. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

A3.2. Alternative Estimation Models

	Panel A: 90-30 Term Structure			Panel B: 120-60 Term Structure		
	0.95 Mon.	**1.00 Mon.**	**1.05 Mon.**	**0.95 Mon.**	**1.00 Mon.**	**1.05 Mon.**
1) Model 1						
Average Slope	-0.0118	0.0049	0.0069	-0.0035	0.0043	0.0087
Standard Deviation	0.0186	0.0183	0.0168	0.0115	0.0116	0.0114
P-Value (≠0)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2) Model 2						
Average Slope	-0.0119	0.0048	0.0066	-0.0036	0.0042	0.0087
Standard Deviation	0.0188	0.0186	0.0173	0.0117	0.0117	0.0114
P-Value (≠0)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3) Model 3						
Average Slope	-0.0124	0.0028	-0.0003	-0.0042	0.0031	0.0051
Standard Deviation	0.0177	0.0158	0.0168	0.0126	0.0108	0.0112
P-Value (≠0)	0.0000	0.0000	0.2115	0.0000	0.0000	0.0000
4) Model 4						
Average Slope	-0.0115	0.0051	0.0074	-0.0032	0.0044	0.0093
Standard Deviation	0.0189	0.0190	0.0177	0.0118	0.0121	0.0120
P-Value (≠0)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A.21 –Slope of the Term Structure by Moneyness, for various implied volatility estimation techniques. This table reports descriptive statistics for the slope of the term structure for S&P 500 options. Statistics include the average term structure slope, the standard deviation of the term structure, and the p-value of the data set for a one-sample *t*-test. Panel A considers the slope between implied volatility (IV) observations for options with 90 and 30 days to maturity. Panel B considers options with 120 and 60 days to maturity. Each panel reports statistics for three moneyness levels (defined as the strike price of the option to the price of the underlying asset): 0.95, 1.00, and 1.05. All IV values are computed using the Proximal Trilinear Interpolation Technique. The sample covers the period between January 4, 1996 and April 29, 2016. Section 5.2 defines the 4 IV estimation techniques.

	(1) Unconditional	(2) Good Times	(3) Bad-Times	(4) Difference (2-3)	(5) P-Value
NBER	0.0043	0.0057	-0.0078	0.0135	0.0000
OECD	0.0043	0.0070	-0.0018	0.0088	0.0000
HGR	0.0043	0.0059	-0.0027	0.0087	0.0000
ADS	0.0043	0.0065	-0.0048	0.0113	0.0000
FRB	0.0043	0.0064	-0.0044	0.0108	0.0000
YOY	0.0043	0.0070	-0.0067	0.0137	0.0000
TED	0.0043	0.0054	-0.0002	0.0056	0.0000
BAML	0.0043	0.0074	-0.0077	0.0152	0.0000
VIX	0.0043	0.0076	-0.0092	0.0168	0.0000
EBP	0.0043	0.0070	-0.0068	0.0139	0.0000

Table A.22 – Descriptive Statistics of the S&P 500 IV Term Structure Slope, for ATM Options with Maturities of 120 and 60 Days, using the Model 1 Estimation Approach. This table reports descriptive statistics of the term structure slope with regards to economic and financial conditions. The term structure slope is defined as the difference between the estimated implied volatilities of options with 120 and 60 days to maturity. IV values are estimated using the Model 1 approach (see section 5.2). The table covers all economic and financial indicators (see section 3.3. for a description of the indicators and the definitions good and bad times). Columns (1) to (3) show average IV term structure slopes for the entire period, good times and bad times, respectively. Column (4) presents the difference between (2) and (3). Column (5) displays p-values for two-sample *t*-tests (for the two data sets used to compute (2) and (3)). The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) Unconditional	(2) Good Times	(3) Bad-Times	(4) Difference (2-3)	(5) P-Value
NBER	0.0042	0.0057	-0.0079	0.0135	0.0000
OECD	0.0042	0.0069	-0.0018	0.0087	0.0000
HGR	0.0042	0.0059	-0.0028	0.0087	0.0000
ADS	0.0042	0.0065	-0.0048	0.0113	0.0000
FRB	0.0042	0.0064	-0.0044	0.0108	0.0000
YOY	0.0042	0.0070	-0.0068	0.0137	0.0000
TED	0.0042	0.0054	-0.0002	0.0055	0.0000
BAML	0.0042	0.0074	-0.0078	0.0152	0.0000
VIX	0.0042	0.0076	-0.0093	0.0169	0.0000
EBP	0.0042	0.0070	-0.0068	0.0138	0.0000

Table A.23 – Descriptive Statistics of the S&P 500 IV Term Structure Slope, for ATM Options with Maturities of 120 and 60 Days, using the Model 2 Estimation Approach. This table reports descriptive statistics of the term structure slope with regards to economic and financial conditions. The term structure slope is defined as the difference between the estimated implied volatilities of options with 120 and 60 days to maturity. IV values are estimated using the Model 2 approach (see section 5.2). The table covers all economic and financial indicators (see section 3.3. for a description of the indicators and the definitions good and bad times). Columns (1) to (3) show average IV term structure slopes for the entire period, good times and bad times, respectively. Column (4) presents the difference between (2) and (3). Column (5) displays p-values for two-sample *t*-tests (for the two data sets used to compute (2) and (3)). The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) Unconditional	(2) Good Times	(3) Bad-Times	(4) Difference (2-3)	(5) P-Value
NBER	0.0031	0.0042	-0.0062	0.0104	0.0000
OECD	0.0031	0.0051	-0.0016	0.0067	0.0000
HGR	0.0031	0.0043	-0.0021	0.0065	0.0000
ADS	0.0031	0.0048	-0.0040	0.0088	0.0000
FRB	0.0031	0.0047	-0.0035	0.0082	0.0000
YOY	0.0031	0.0052	-0.0057	0.0109	0.0000
TED	0.0031	0.0039	-0.0003	0.0042	0.0000
BAML	0.0031	0.0056	-0.0066	0.0121	0.0000
VIX	0.0031	0.0058	-0.0078	0.0135	0.0000
EBP	0.0031	0.0053	-0.0060	0.0113	0.0000

Table A.24 – Descriptive Statistics of the S&P 500 IV Term Structure Slope, for ATM Options with Maturities of 120 and 60 Days, using the Model 3 Estimation Approach. This table reports descriptive statistics of the term structure slope with regards to economic and financial conditions. The term structure slope is defined as the difference between the estimated implied volatilities of options with 120 and 60 days to maturity. IV values are estimated using the Model 3 approach (see section 5.2). The table covers all economic and financial indicators (see section 3.3. for a description of the indicators and the definitions good and bad times). Columns (1) to (3) show average IV term structure slopes for the entire period, good times and bad times, respectively. Column (4) presents the difference between (2) and (3). Column (5) displays p-values for two-sample *t*-tests (for the two data sets used to compute (2) and (3)). The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) Unconditional	(2) Good Times	(3) Bad-Times	(4) Difference (2-3)	(5) P-Value
NBER	0.0044	0.0058	-0.0076	0.0134	0.0000
OECD	0.0044	0.0072	-0.0017	0.0089	0.0000
HGR	0.0044	0.0061	-0.0024	0.0084	0.0000
ADS	0.0044	0.0067	-0.0047	0.0114	0.0000
FRB	0.0044	0.0066	-0.0043	0.0110	0.0000
YOY	0.0044	0.0072	-0.0066	0.0138	0.0000
TED	0.0044	0.0056	-0.0000	0.0056	0.0000
BAML	0.0044	0.0077	-0.0076	0.0153	0.0000
VIX	0.0044	0.0078	-0.0090	0.0168	0.0000
EBP	0.0044	0.0072	-0.0068	0.0140	0.0000

Table A.25 – Descriptive Statistics of the S&P 500 IV Term Structure Slope, for ATM Options with Maturities of 120 and 60 Days, using the Model 4 Estimation Approach. This table reports descriptive statistics of the term structure slope with regards to economic and financial conditions. The term structure slope is defined as the difference between the estimated implied volatilities of options with 120 and 60 days to maturity. IV values are estimated using the Model 4 approach (see section 5.2). The table covers all economic and financial indicators (see section 3.3. for a description of the indicators and the definitions good and bad times). Columns (1) to (3) show average IV term structure slopes for the entire period, good times and bad times, respectively. Column (4) presents the difference between (2) and (3). Column (5) displays p-values for two-sample *t*-tests (for the two data sets used to compute (2) and (3)). The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.4165***					0.0878
	(5.1918)					(1.0027)
OECD		-0.4047***				-0.1079*
		(6.9772)				(1.6567)
HGR			-0.4987***			-0.3968***
			(5.6290)			(2.7805)
ADS				0.4322***		-0.0649
				(5.2861)		(0.8006)
FRB					0.4901***	0.2494***
					(6.6162)	(3.5566)
Constant	0.4253***	0.4253***	0.4253***	0.4253***	0.4253***	0.4253***
	(9.2783)	(9.2345)	(9.6543)	(9.3486)	(9.6391)	(9.9408)
Obs.	5110	5110	5110	5110	5110	5110
Adj. R^2	13%	12%	18%	14%	18%	22%

Table A.26 – Relation between Individual Economic Indicators and the Slope of the Term Structure, using the Model 1 Approach for IV Estimation. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 1 approach (see section 5.2 for details). The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.4173***					0.0923
	(5.1800)					(1.0524)
OECD		-0.4037***				-0.1055
		(6.9467)				(1.6227)
HGR			-0.5011***			-0.4072***
			(5.6303)			(2.8481)
ADS				0.4331***		-0.0669
				(5.2716)		(0.8258)
FRB					0.4901***	0.2480***
					(6.5718)	(3.5328)
Constant	0.4215***	0.4215***	0.4215***	0.4215***	0.4215***	0.4215***
	(9.1916)	(9.1423)	(9.5732)	(9.2629)	(9.5461)	(9.8525)
Obs.	5113	5113	5113	5113	5113	5113
Adj. R^2	13%	12%	18%	14%	18%	22%

Table A.27 – Relation between Individual Economic Indicators and the Slope of the Term Structure, using the Model 2 Approach for IV Estimation. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 2 approach (see section 5.2 for details). The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.3197***					0.0986
	(4.9351)					(1.3649)
OECD		-0.3095***				-0.0715
		(6.3888)				(1.2395)
HGR			-0.3918***			-0.3366***
			(5.4851)			(2.8636)
ADS				0.3418***		-0.0352
				(5.2488)		(0.5644)
FRB					0.3786***	0.1883***
					(6.0887)	(2.9016)
Constant	0.3051***	0.3051***	0.3051***	0.3051***	0.3051***	0.3051***
	(8.0447)	(8.0022)	(8.3709)	(8.1345)	(8.3207)	(8.5715)
Obs.	5096	5096	5096	5096	5096	5096
Adj. R^2	9%	8%	13%	10%	12%	15%

Table A.28 – Relation between Individual Economic Indicators and the Slope of the Term Structure, using the Model 3 Approach for IV Estimation. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 3 approach (see section 5.2 for details). The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0.4141***					0.0859
	(5.1140)					(0.9687)
OECD		-0.4130***				-0.1218*
		(7.0413)				(1.8398)
HGR			-0.4954***			-0.3874***
			(5.5119)			(2.6434)
ADS				0.4283***		-0.0763
				(5.2369)		(0.9293)
FRB					0.4948***	0.2584***
					(6.6024)	(3.6361)
Constant	0.4421***	0.4421***	0.4421***	0.4421***	0.4421***	0.4421***
	(9.4488)	(9.4449)	(9.8092)	(9.5113)	(9.8351)	(10.1201)
Obs.	5113	5113	5113	5113	5113	5113
Adj. R^2	12%	12%	17%	13%	17%	21%

Table A.29 – Relation between Individual Economic Indicators and the Slope of the Term Structure, using the Model 4 Approach for IV Estimation. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against economic indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 4 approach (see section 5.2 for details). The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.5665***					0.5057***
	(7.8417)					(10.0263)
TED		-0.4811***				0.0297
		(4.4345)				(0.3704)
BAML			-0.5995***			0.9271***
			(7.0638)			(12.1144)
VIX				-0.8410***		-1.0686***
				(13.0081)		(17.8706)
EBP					-0.6622***	-0.3692***
					(8.2799)	(5.9927)
Constant	0.4253***	0.4253***	0.4400***	0.4253***	0.4253***	0.4400***
	(9.9420)	(9.5225)	(10.0177)	(12.5589)	(10.8455)	(15.0931)
Obs.	5110	5110	4858	5110	5110	4858
Adj. R^2	24%	17%	25%	52%	32%	66%

Table A.30 – Relation between Individual Financial Indicators and the Slope of the Term Structure, using the Model 1 Approach for IV Estimation. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 1 approach (see section 5.2 for details). The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.5680***					0.5100***
	(7.8350)					(10.0543)
TED		-0.4818***				0.0284
		(4.4136)				(0.3547)
BAML			-0.5998***			0.9282***
			(7.0146)			(12.1066)
VIX				-0.8420***		-1.0708***
				(12.8250)		(17.6869)
EBP					-0.6617***	-0.3646***
					(8.1913)	(5.9602)
Constant	0.4215***	0.4215***	0.4362***	0.4215***	0.4215***	0.4362***
	(9.8537)	(9.4325)	(9.9207)	(12.4372)	(10.7310)	(14.9469)
Obs.	5113	5113	4861	5113	5113	4861
Adj. R^2	24%	17%	25%	52%	32%	65%

Table A.31 – Relation between Individual Financial Indicators and the Slope of the Term Structure, using the Model 2 Approach for IV Estimation. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 2 approach (see section 5.2 for details). The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.4537***					0.3672***
	(7.6074)					(8.1983)
TED		-0.3561***				0.0655
		(4.0888)				(1.1505)
BAML			-0.4971***			0.6804***
			(7.0825)			(9.1797)
VIX				-0.6870***		-0.8805***
				(12.3663)		(13.3106)
EBP					-0.5310***	-0.2694***
					(8.2166)	(4.4738)
Constant	0.3051***	0.3051***	0.3152***	0.3051***	0.3051***	0.3152***
	(8.6582)	(8.1590)	(8.8116)	(10.9382)	(9.3951)	(12.5147)
Obs.	5096	5096	4846	5096	5096	4846
Adj. R^2	18%	11%	20%	40%	24%	49%

Table A.32 – Relation between Individual Financial Indicators and the Slope of the Term Structure, using the Model 3 Approach for IV Estimation. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 3 approach (see section 5.2 for details). The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0.5684***					0.5144***
	(7.7356)					(10.6581)
TED		-0.4848***				0.0366
		(4.2660)				(0.4219)
BAML			-0.5989***			0.9754***
			(6.8905)			(12.9977)
VIX				-0.8428***		-1.0774***
				(12.4585)		(17.7921)
EBP					-0.6706***	-0.4113***
					(8.2091)	(6.4560)
Constant	0.4421***	0.4421***	0.4592***	0.4421***	0.4421***	0.4592***
	(10.1150)	(9.7125)	(10.2147)	(12.6454)	(11.0566)	(15.3978)
Obs.	5113	5113	4861	5113	5113	4861
Adj. R^2	22%	16%	24%	49%	31%	62%

Table A.33 – Relation between Individual Financial Indicators and the Slope of the Term Structure, using the Model 4 Approach for IV Estimation. This table reports the results of the regression analysis of the term structure slope of S&P 500 options against financial indicators. The dependent variable is slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 4 approach (see section 5.2 for details). The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

A3.3. Alternative Securities

	Panel A: 90-30 Term Structure			Panel B: 120-60 Term Structure		
	0.95 Mon.	**1.00 Mon.**	**1.05 Mon.**	**0.95 Mon.**	**1.00 Mon.**	**1.05 Mon.**
1) IWM						
Average Slope	0.0002	0.0109	0.0158	0.0027	0.0086	0.0126
Standard Deviation	0.0168	0.0157	0.0129	0.0101	0.0096	0.0088
P-Value (≠0)	0.6915	0.0000	0.0000	0.0000	0.0000	0.0000
2) EWZ						
Average Slope	-0.0126	-0.0028	0.0010	-0.0055	-0.0006	0.0019
Standard Deviation	0.0339	0.0356	0.0356	0.0219	0.0217	0.0216
P-Value (≠0)	0.0000	0.0014	0.2798	0.0000	0.2376	0.0003
3) FXI						
Average Slope	-0.0051	-0.0001	-0.0018	0.0008	0.0019	n/a
Standard Deviation	0.0203	0.0185	0.0177	0.0129	0.0122	n/a
P-Value (≠0)	0.0000	0.8608	0.0001	0.0124	0.0000	n/a
4) EFA						
Average Slope	-0.0079	0.0081	0.0169	-0.0014	0.0062	0.0106
Standard Deviation	0.0196	0.0177	0.0173	0.0131	0.0117	0.0102
P-Value (≠0)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5) EEM						
Average Slope	-0.0026	0.0085	0.0121	0.0001	0.0059	0.0085
Standard Deviation	0.0183	0.0168	0.0164	0.0119	0.0110	0.0106
P-Value (≠0)	0.0000	0.0000	0.0000	0.8153	0.0000	0.0000

Table A.34 – Slope of the Term Structure by Moneyness, for options on various indices. This table reports descriptive statistics for the slope of the term structure for: iShares Russell 2000 Index ETF (IWM) options, iShares MSCI Brazil ETF (EWZ) options, iShares China Large-Cap ETF (FXI) options, iShares EAFA Index ETF (EFA) options, and iShares Emerging Markets Index ETF (EEM) options. Statistics include the average term structure slope, the standard deviation of the term structure, and the p-value of the data set for a one-sample *t*-test. Panel A considers the slope between implied volatility (IV) observations for options with 90 and 30 days to maturity. Panel B considers options with 120 and 60 days to maturity. Each panel reports statistics for three moneyness levels (defined as the strike price of the option to the price of the underlying asset): 0.95, 1.00, and 1.05. All IV values are computed using the Model 1 approach (see section 5.2 for details). The sample covers the period between July 28, 2009 and April 29, 2016.

	(1) Unconditional	(2) Good Times	(3) Bad-Times	(4) Difference (2-3)	(5) P-Value
Panel 1: IWM					
YOY	0.0086	0.0096	0.0044	0.0051	0.0000
AEI	0.0086	0.0087	0.0081	0.0006	0.3266
AFI	0.0086	0.0108	-0.0005	0.0113	0.0000
SPX TS	0.0086	0.0114	-0.0030	0.0144	0.0000
Panel 2: EWZ					
YOY	-0.0006	0.0009	-0.0066	0.0075	0.0000
AEI	-0.0006	0.0001	-0.0036	0.0037	0.0050
AFI	-0.0006	0.0019	-0.0108	0.0127	0.0000
SPX TS	-0.0006	0.0035	-0.0169	0.0204	0.0000
Panel 3: FXI					
YOY	0.0019	0.0035	-0.0045	0.0080	0.0000
AEI	0.0019	0.0027	-0.0014	0.0041	0.0000
AFI	0.0019	0.0039	-0.0061	0.0100	0.0000
SPX TS	0.0019	0.0049	-0.0102	0.0151	0.0000
Panel 4: EFA					
YOY	0.0062	0.0075	0.0012	0.0063	0.0000
AEI	0.0062	0.0060	0.0070	-0.0010	0.1612
AFI	0.0062	0.0086	-0.0032	0.0117	0.0000
SPX TS	0.0062	0.0095	-0.0067	0.0162	0.0000
Panel 5: EEM					
YOY	0.0059	0.0076	-0.0009	0.0084	0.0000
AEI	0.0059	0.0061	0.0048	0.0013	0.0521
AFI	0.0059	0.0083	-0.0040	0.0123	0.0000
SPX TS	0.0059	0.0091	-0.0070	0.0161	0.0000

Table A.35 – Descriptive Statistics of the IV Term Structure Slope for various index options, for ATM Options with Maturities of 120 and 60 Days. This table reports descriptive statistics of the term structure slope with regards to economic and financial conditions. The term structure slope is defined as the difference between the estimated implied volatilities of options with 120 and 60 days to maturity. IV values are estimated using the Model 1 approach (see section 5.2). Statistics for iShares Russell 2000 Index ETF (IWM) options are presented in Panel 1. Statistics for iShares MSCI Brazil ETF (EWZ) options are presented in Panel 2. Statistics for iShares China Large-Cap ETF (FXI) options are presented in Panel 3. Statistics for iShares EAFA Index ETF (EFA) options are presented in Panel 4. Statistics for iShares Emerging Markets Index ETF (EEM) options are presented in Panel 5. Results are shown for four indicators, namely the year-on-year returns of the underlying asset for each security (YOY), the Aggregate Economic Indicator (AEI), the Aggregate Financial Indicator (AFI) and the time series of the IV term structure for S&P 500 options (for at-the-money option pairs with 120 and 60 days to maturity) (SPX TS). Section 3.3 defines the periods of good and bad times for each indicator. Columns (1) to (3) show average IV term structure slopes for the entire period, good times and bad times (as defined by each indicator), respectively. Column (4) presents the difference between (2) and (3). Column (5) displays p-values for two-sample *t*-tests (for the two data sets used to compute (2) and (3)). The sample covers the period between July 28, 2009 and April 29, 2016.

	(1) YOY	(2) AEI	(3) AFI	(4) SPX TS
YOY	0.2680***			
	(5.4731)			
AEI		0.0492		
		(0.9700)		
AFI			0.4351***	
			(5.5550)	
SPX TS				0.7562***
				(15.7440)
Constant	0.8554***	0.8554***	0.8554***	0.8554***
	(13.5845)	(13.0005)	(14.8577)	(26.1848)
Obs.	1702	1702	1702	1702
Adj. R^2	8%	0%	20%	61%

Table A.36 – Relation between Indicators of Business Conditions and the Slope of the Term Structure for iShares Russell 2000 Index ETF (IWM) options. This table reports the results of the regression analysis of the term structure slope against economic and financial indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 1 approach (see section 5.2 for details). The independent variables are: the year-on-year returns of IWM index (YOY), the Aggregate Economic Indicator (AEI), the Aggregate Financial Indicator (AFI) and the time series of the IV term structure for S&P 500 options (for at-the-money option with 120 and 60 days to maturity) (SPX TS). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 5.3 for a definition of the business indicators. The sample covers the period between July 28, 2009 and April 29, 2016.

	(1) YOY	(2) AEI	(3) AFI	(4) SPX TS
YOY	0.5100***			
	(4.9067)			
AEI		0.0459		
		(0.2674)		
AFI			0.4807***	
			(3.6419)	
SPX TS				0.9717***
				(8.1463)
Constant	-0.0624	-0.0624	-0.0624	-0.0624
	(0.4045)	(0.3917)	(0.4016)	(0.4411)
Obs.	1693	1693	1693	1693
Adj. R^2	6%	0%	5%	20%

Table A.37 – Relation between Indicators of Business Conditions and the Slope of the Term Structure for iShares MSCI Brazil ETF (EWZ) options. This table reports the results of the regression analysis of the term structure slope against economic and financial indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 1 approach (see section 5.2 for details). The independent variables are: the year-on-year returns of EWZ index (YOY), the Aggregate Economic Indicator (AEI), the Aggregate Financial Indicator (AFI) and the time series of the IV term structure for S&P 500 options (for at-the-money option with 120 and 60 days to maturity) (SPX TS). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 5.3 for a definition of the business indicators. The sample covers the period between July 28, 2009 and April 29, 2016.

	(1) YOY	(2) AEI	(3) AFI	(4) SPX TS
YOY	0.2414***			
	(3.0014)			
AEI		0.2039***		
		(2.8830)		
AFI			0.4215***	
			(4.6950)	
SPX TS				0.8068***
				(14.7302)
Constant	0.1878**	0.1878**	0.1878**	0.1878***
	(2.3418)	(2.3328)	(2.4674)	(3.4955)
Obs.	1700	1700	1700	1700
Adj. R^2	4%	3%	12%	43%

Table A.38 – Relation between Indicators of Business Conditions and the Slope of the Term Structure for iShares China Large-Cap ETF (FXI) options. This table reports the results of the regression analysis of the term structure slope against economic and financial indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 1 approach (see section 5.2 for details). The independent variables are: the year-on-year returns of FXI index (YOY), the Aggregate Economic Indicator (AEI), the Aggregate Financial Indicator (AFI) and the time series of the IV term structure for S&P 500 options (for at-the-money option with 120 and 60 days to maturity) (SPX TS). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 5.3 for a definition of the business indicators. The sample covers the period between July 28, 2009 and April 29, 2016.

	(1) YOY	(2) AEI	(3) AFI	(4) SPX TS
YOY	0.2449***			
	(3.6357)			
AEI		0.0503		
		(0.7296)		
AFI			0.4741***	
			(5.1942)	
SPX TS				0.8460***
				(15.3339)
Constant	0.6221***	0.6221***	0.6221***	0.6221***
	(8.1104)	(7.9192)	(8.8229)	(13.7285)
Obs.	1697	1697	1697	1697
Adj. R^2	4%	0%	47%	52%

Table A.39 – Relation between Indicators of Business Conditions and the Slope of the Term Structure for iShares EAFA Index ETF (EFA) options. This table reports the results of the regression analysis of the term structure slope against economic and financial indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 1 approach (see section 5.2 for details). The independent variables are: the year-on-year returns of EFA index (YOY), the Aggregate Economic Indicator (AEI), the Aggregate Financial Indicator (AFI) and the time series of the IV term structure for S&P 500 options (for at-the-money option with 120 and 60 days to maturity) (SPX TS). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 5.3 for a definition of the business indicators. The sample covers the period between July 28, 2009 and April 29, 2016.

	(1) YOY	(2) AEI	(3) AFI	(4) SPX TS
YOY	0.2724***			
	(3.7454)			
AEI		0.0761		
		(1.1355)		
AFI			0.4650***	
			(5.2640)	
SPX TS				0.8226***
				(14.1485)
Constant	0.5868***	0.5868***	0.5868***	0.5868***
	(8.0541)	(7.7910)	(8.6871)	(13.5398)
Obs.	1701	1701	1701	1701
Adj. R^2	6%	0%	18%	56%

Table A.40 – Relation between Indicators of Business Conditions and the Slope of the Term Structure for iShares Emerging Markets Index ETF (EEM) options. This table reports the results of the regression analysis of the term structure slope against economic and financial indicators. The dependent variable is the slope of the term structure, which is computed as the IV differential between at-the-money options with 120 and 60 days to maturity. All IV values are computed using the Model 1 approach (see section 5.2 for details). The independent variables are: the year-on-year returns of EEM index (YOY), the Aggregate Economic Indicator (AEI), the Aggregate Financial Indicator (AFI) and the time series of the IV term structure for S&P 500 options (for at-the-money option with 120 and 60 days to maturity) (SPX TS). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 5.3 for a definition of the business indicators. The sample covers the period between July 28, 2009 and April 29, 2016.

A4. Smile/Skew Patterns

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	0,1864***					-0,0312
	(3,1601)					(0,2461)
OECD		0,2309***				0,1580**
		(4,0980)				(2,0441)
HGR			0,2259***			0,1278
			(4,2890)			(0,8105)
ADS				-0,2282***		-0,0937
				(4,2084)		(0,7544)
FRB					-0,1664***	0,0610
					(3,2384)	(0,7516)
Constant	-4,6693***	-4,6693***	-4,6693***	-4,6693***	-4,6693***	-4,6693***
	(81,3327)	(81,8547)	(81,7703)	(81,7501)	(81,1260)	(82,3261)
Observations	4907	4907	4907	4907	4907	4907
Adj. R-Squared	1%	1%	1%	0%	0%	1%

Table A.41 – Relation between Individual Economic Indicators and the Implied Volatility Skew at 1.00 and 0.95 Moneyness Levels. This table reports the results of the regression analysis of the volatility skew of S&P 500 options against economic indicators. The dependent variable is the implied volatility skew, which is computed as the IV differential between options with moneyness levels of 1.00 and 0.95, at a maturity of 30 days. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) NBER	(2) OECD	(3) HGR	(4) ADS	(5) FRB	(6) Full
NBER	-0,2824***					-0,1390
	(5,1388)					(1,3105)
OECD		-0,3057***				-0,1053
		(5,1035)				(1,3788)
HGR			-0,2723***			0,0791
			(4,8615)			(0,5820)
ADS				0,2418***		-0,1292
				(4,1962)		(1,2259)
FRB					0,4231***	0,4120***
					(7,1328)	(4,0252)
Constant	-2,4482***	-2,4482***	-2,4482***	-2,4482***	-2,4482***	-2,4482***
	(37,5388)	(37,6586)	(37,4771)	(37,3302)	(38,5971)	(38,7420)
Observations	4900	4900	4900	4900	4900	4900
Adj. R-Squared	2%	2%	1%	0%	4%	4%

Table A.42 – Relation between Individual Economic Indicators and the Implied Volatility Skew at 1.05 and 1.00 Moneyness Levels. This table reports the results of the regression analysis of the volatility skew of S&P 500 options against economic indicators. The dependent variable is the implied volatility skew, which is computed as the IV differential between options with moneyness levels of 1.05 and 1.00, at a maturity of 30 days. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the NBER Recession Indicator (NBER), the OECD Recession Indicator (OECD), Hamilton's GDP-based Recession Indicator Index (HGR), the Aruoba-Diebold-Scotti Business Conditions Index (ADS), and the FRB Diffusion Index for Current General Activity (FRB). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the economic indicators. The sample covers the period between January 4, 1996 and April 29, 2016.

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	-0,2230***					-0,0506
	(3,7862)					(0,5157)
TED		0,0661				0,0673
		(1,0551)				(0,9226)
BAML			0,2293***			0,3371***
			(4,4451)			(2,6002)
VIX				0,1108**		-0,2376***
				(2,1874)		(2,7249)
EBP					0,2154***	0,0174
					(4,1562)	(0,1287)
Constant	-4,6693***	-4,6693***	-4,6360***	-4,6693***	-4,6693***	-4,6360***
	(81,7068)	(80,4627)	(80,9557)	(80,7224)	(81,6533)	(81,5711)
Observations	4907	4907	4669	4907	4907	4669
Adj. R-Squared	1%	0%	1%	0%	1%	1%

Table A.43 – Relation between Individual Financial Indicators and the Implied Volatility Skew at 1.00 and 0.95 Moneyness Levels. This table reports the results of the regression analysis of the volatility skew of S&P 500 options against financial indicators. The dependent variable is the implied volatility skew, which is computed as the IV differential between options with moneyness levels of 1.00 and 0.95, at a maturity of 30 days. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).

	(1) YOY	(2) TED	(3) BAML	(4) VIX	(5) EBP	(6) Full
YOY	0,2731***					-0,0679
	(5,4773)					(0,7540)
TED		-0,4052***				0,0186
		(4,6154)				(0,1723)
BAML			-0,4419***			0,4591***
			(6,9223)			(3,4260)
VIX				-0,7559***		-1,0050***
				(9,5186)		(9,7445)
EBP					-0,4808***	-0,2184*
					(7,8034)	(1,7973)
Constant	-2,4482***	-2,4482***	-2,4717***	-2,4482***	-2,4482***	-2,4717***
	(37,3494)	(38,5652)	(37,4671)	(42,7879)	(39,0986)	(42,3243)
Observations	4900	4900	4660	4900	4900	4660
Adj. R-Squared	1%	3%	4%	11%	5%	13%

Table A.44 – Relation between Individual Financial Indicators and the Implied Volatility Skew at 1.05 and 1.00 Moneyness Levels. This table reports the results of the regression analysis of the volatility skew of S&P 500 options against financial indicators. The dependent variable is the implied volatility skew, which is computed as the IV differential between options with moneyness levels of 1.05 and 1.00, at a maturity of 30 days. All IV values are computed using the Proximal Trilinear Interpolation Technique. The independent variables are: the year-on-year returns of the S&P 500 Index (YOY), the TED spread (TED), the BofA Merrill Lynch US High Yield Option-Adjusted Spread (BAML), the CBOE Volatility Index (VIX), and the Excess-Bond Premium (EBP). We compute *t*-statistics (reported below the coefficients) using Newey-West standard errors with 10 lags. See section 3.3 for a definition of the financial indicators. The sample covers the period between January 4, 1996 and April 29, 2016 (except for columns (3) and (6), covering the period between January 2, 1997 and April 29, 2016).