Treasury Yield Implied Volatility and Real Activity *

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Abstract

The implied volatility from Treasury derivatives (Treasury 'yield implied volatility') predicts the level and volatility of macroeconomic activity such as the growth rates of GDP, industrial production, consumption, and employment. This predictability is robust to the inclusion of popular forecasting variables used in the current literature. We study one potential explanation for why interest rate uncertainty constitutes a useful forward-looking state variable that characterizes risks and opportunities in the macroeconomy, namely a bank credit channel. Consistent with this mechanism, an increase in Treasury yield implied volatility (interest rate uncertainty) adversely impacts bank deposits, bank credit growth, and banks' cost of capital, as well as investments by bank dependent firms. Our study provides novel evidence that interest rate risk impacts banks not only through levels, but also via uncertainty
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1 Introduction

Understanding the empirical linkages between the real economy and financial markets has long been a goal of financial economists. Financial market variables, such as the prices of financial instruments, incorporate expectations of future economic events. For this reason, there is a widespread belief that forward-looking financial markets should help predict the level and volatility of real activity. On the one hand, researchers, practitioners, policy makers, and monetary authorities, can use financial market information to create robust early warning systems that signal both the direction and volatility of aggregate macroeconomic variables. On the other hand, a financial market variable that predicts the level and volatility of real activity is likely to capture fundamental economic risks that investors worry about, and be informative about asset prices.[1]

A voluminous existing literature has studied the relation between a large number of financial variables, from both bond and stock markets, and real activity. However, this large existing literature has not agreed on which variables can consistently predict the level of future real activity, especially at horizons of more than one quarter, and has argued that both bond market variables (such as the short-rate and the term spread) and stock market variables (such as the VIX) fail to serve as effective hedges against fundamental economic risk. Further, with the exception of Schwert (1989), research on what information from financial markets helps predict macroeconomic volatility is even more limited.

We contribute to this literature by showing that the implied volatility from the Treasury derivatives market (Treasury 'yield implied volatility (YIV)'), a proxy for interest rate uncertainty, predicts future bad macroeconomic times. The Treasury market is one of the largest and most liquid in the world and serves both as a direct exchange for Treasury securities and as a driver of many other financial securities issued by financial institutions and corporations. As a result, a proxy for the level of interest rate uncertainty from the Treasury derivatives market seems ex-ante a good candidate for predicting aggregate economic risk. In addition, existing theory (for e.g., the models

[1]See Breeden (1979), Fama and French (1989), Stock and Watson (2003), Bansal and Yaron (2004), Cochrane (2008), Backus, Chernov, and Martin (2011), Baker, Bloom, and Davis (2012), Stein and Stone (2012), and Bloom (2014).

in Bansal and Zhou (2002), Ang and Bekaert (2002), Dai and Singleton (2002), and Dai, Singleton, and Yang (2007)) implies that interest rate uncertainty strongly co-varies with business cycles and is an important macro state variable for both the level and volatility of real activity. To the best of our knowledge, we are the first paper to test if implied volatilities in the Treasury markets predicts *both* the level and the volatility of several macroeconomic variables.

Our main measure for interest rate uncertainty is the implied volatility of at-the-money options on futures of 5-year Treasury notes (the 'Yield Implied Volatility or YIV). We document that the YIV contains substantial forward-looking information about both the level and the volatility of aggregate macroeconomic activity, even after controlling for information in lagged real activity, short rates, the term spread, stock returns, implied stock volatility (VIX), and the economic uncertainty index from Baker, Bloom, and Davis (2015).[2]

In particular, we document two main results that imply that a higher YIV is strongly associated with worsening macroeconomic conditions and increased future macroeconomic volatility, using U.S. data for the period May 1990 to November 2016. First, we find that a higher YIV predicts lower real activity as measured by the growth rate of GDP, aggregate industrial production, aggregate consumption, and aggregate employment. Economically, a one standard deviation increase in the YIV is associated with a decrease in the following year's annualized growth rate of GDP, industrial production, consumption, and employment of 1.12%, 2.39%, 1.26%, and 1.26%, respectively. Over our sample, the average annual growth of GDP, industrial production, consumption, and employment is 2.44%, 2.03%, 4.83%, and 1.06%, respectively, such that these results are economically significant. In terms of predictive R^2, over a one-year horizon, YIV explains approximately 15%, 32%, 34%, and nearly 45% of the variation in the growth rates of GDP, industrial production, consumption, and employment, respectively.

Second, an increase in YIV is associated with a future increase in the volatility of growth rates of GDP, industrial production, consumption and employment. A one standard deviation increase

[2]Our findings are consistent with those in Choi, Mueller, and Vedolin (2016) and Bretscher, Schmid, and Vedolin (2016), which have some results that parallel ours. However, we measure Yield Implied Volatility directly from observable market prices of option, and analyze its predictive power over a 25-year period (1988 - 2016) for a much broader set of economic variables, and for the volatility as well not just their level.

in the YIV increases the future annualized volatility of GDP, industrial production, consumption, and employment by 0.69%, 2.84%, 0.96%, and 0.76%, respectively, over a one year horizon. Since the annualized volatilities of these variables over our sample period equal 0.76%, 4.84%, 1.06%, 0.87%, respectively, these results are again economically significant. Over our sample, the level of YIV explains up to 36% of the variation in the volatility of these macroeconomic variables over a one-year horizon.

We compare the predictive ability of the YIV with that of the financial market variables used in the existing literature. While some previously used variables also predict both the levels and volatility in the growth rates of GDP, industrial production, consumption, and employment, none do so consistently across all four macroeconomic variables.[3] The YIV is the only predictor in our set of financial market variables that consistently predicts both the level and volatility of macroeconomic activity, and thus serves as a useful summary measure of the likelihood of economic downturns over the next 1–5 years.[4]

Why should YIV – a proxy for interest rate uncertainty – forecast the level and volatility of real activity? Intuitively, interest rate uncertainty can adversely affect financing and investing decisions of all economic agents. This interest rate uncertainty can be hedged in the market for interest rate derivatives, where YIV serves as a proxy for the price of hedging interest rate uncertainty. However, interest rate uncertainty may also impact real activity because some economic agents are unable to completely insure themselves against this uncertainty. This leads us to consider a particular economic channel through which interest rate uncertainty relates to real activity, namely through its impact on banks.

[3]For instance, a higher term spread predicts higher levels of industrial production and employment growth, but not of consumption growth, and predicts lower future volatility in the growth rate of industrial production and consumption, but not of employment. Higher aggregate stock returns predict higher levels of real activity, but do not help predict their volatility. The implied stock volatility (VIX) does not help predict levels of macroeconomic activity, though it strongly predicts higher volatility of the growth rate of industrial production, consumption and employment suggesting that VIX captures risk aversion rather than economic uncertainty, consistent with Carr and Wu (2009), Bekaert, Hoerova, and Duca (2013), and Bekaert and Hoerova (2014).

[4]Our results are robust to a battery of robustness tests, such as using non-overlapping regressions or in out-of-sample tests. Our results are also robust to controlling for the CBOE 10-year U.S. Treasury Note Volatility Index, the implied volatility of options on the 10-year or 20-year Treasury bonds futures, and the 'Treasury implied volatility' measure from Choi, Mueller, and Vedolin (2016). The addition of any or all of these alternative proxies does not strongly affect the coefficients or significance of our main measure.

Banks are large intermediaries in the market for interest rates with maturity transformation (i.e., borrowing short-term and lending long-term) at the heart of their business model. Such maturity transformation exposes banks to interest rate risk. If borrowers increase demands for long-term or fixed rate loans (perhaps partly in response to higher interest rate uncertainty), banks have to hold assets more exposed to interest rate risk. Thus, exogenous shocks to the demand and supply for loans and deposits and maturity transformation exposes banks to interest rate uncertainty that they are unlikely to be able to fully hedge.

We show that increases in YIV forecast a decline in bank deposit growth, an increase in the volatility of bank deposits, more distress in the interbank interest rate market, a decline in bank credit growth, an increase in the volatility of bank credit, and an increase in the proxy for banks' cost of capital. Taken together, these results suggest that higher interest rate uncertainty has strongly negative effects on banks' balance sheets and their capacity to make new loans. Moreover, interest rate uncertainty has stronger effects on balance sheets of banks with a higher exposure to interest rate risk. Finally, we show direct evidence for our proposed mechanism by demonstrating that an increase in interest rate uncertainty adversely impacts the investment growth of bank-dependent industrial firms, but not that of non-bank-dependent firms in the economy.

Collectively, these results support the hypothesis that interest rate uncertainty impacts real activity through the bank credit channel. Our results are robust in a vector auto-regressions (VARs). In particular, our VAR results show that the YIV has significant predictive ability (i.e. Granger causality) not only for subsequent growth rates of macroeconomic variables but also financial market variables such as the aggregate stock market return and the implied volatility of stocks (VIX). Negative shocks to the YIV are associated with significant shocks to the growth rates of industrial production, consumption, employment, and bank credit growth that extend for up to 20 months. In contrast, the various macroeconomic variables considered, including bank credit growth, have only limited ability to predict subsequent changes in the YIV, and shocks to these variables have at best a transitory response on the YIV. The VAR system also shows that shocks to the YIV generate short-run increases in the VIX, but the reverse does not hold. In other words, Granger causality analysis shows that yield implied volatility predicts stock market implied volatility, but not the other way around.

The remainder of this paper is organized as follows: Section 2 reviews the related literature. Section 3 describes the data set. Section 5 shows the main results. Finally, section 7 concludes.

2 Literature overview

This paper is related to five different strands of the literature. First, our paper relates to the large literature on how interest rates impacts the real economy. Under the New Keynesian model, interest rates (both short-term and long-term) affect the real economy through levels. In contrast, we show that interest rate uncertainty matters in its own rights, not only because it affects the value and supply of bank deposits and bank credit, but also because it reflects the cost of hedging interest rate risk in the derivatives markets.

Second, our paper is also related to the bank lending and bank balance sheet channel of monetary policy. Important papers in this literature include Bernanke (1983) Bernanke and Blinder (1988), Kashyap and Stein (1995), Bernanke and Gertler (1995), and Stein (1998), among others. For monetary policy to impact bank lending and balance sheets, this literature relies on the existence of market frictions, such as, the existence of reserve requirements. Our framework provides an alternative possible channel , i.e., that an increase in interest rate uncertainty reduces banks willingness to take risk. In this sense, our results are consistent with Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Krishnamurthy and He (2011); Zhiguo and Krishnamurthy (2013), Adrian and Shin (2010) and Gertler and Kiyotaki (2015). In these papers, maturity mismatch between assets and liabilities causes banks net worth to fall when interest rates uncertainty increases unexpectedly (e.g. around monetary policy announcements), which forces balance sheets to contract.

Third, our paper also relates to the recent literature that emphasizes the crucial role of intermediaries for asset prices and the real economy. Brunnermeier and Pedersen (2009) and Brunnermeier and Sannikov (2014) present a model where financial intermediary capital is a driver of equity risk premia. Zhiguo and Krishnamurthy (2013) show that risk premia rise when intermediaries face more binding capital constraints. Empirically, Adrian, Etula, and Muir (2014) construct a one factor model using the growth in leverage of US broker-dealers that prices size, book-to-market, momentum, and bond portfolios. Relative to this literature, our contribution is to shift the focus away from markets, which have been the extensive focus of the previous papers, to real activity, and to understand how interest rate uncertainty can directly impact the balance sheets of banks.

Fourth, our paper relates to the literature using information from financial markets to predict real activity. While a comprehensive review of this literature is beyond the scope of this paper, Stock and Watson (2003) examine the large literature on financial market variables as predictors of real economic activity and inflation. Their review empirically assesses the practical value of financial market variables for short- to medium-term economic forecasting. They conclude that only *some* variables have economically and statistically significant marginal predictive content for output growth at *some* times in *some* countries.

Fifth, our paper is related to the literature that considers the predictive power of implied volatilities from the stock (Lamoureux and Lastrapes (1993), Canina and Figlewski (1993)), foreign exchange (Jorion (1995)), and commodities (Ferris, Guo, and Su (2003); Triantafyllou, Dotsis, and Sarris (2015)) markets. Most of these studies analyze whether these implied volatilities can predict the performance of the stock, foreign exchange, and commodities markets, while only a few studies look specifically at forecasting future macroeconomic activity.[5]

In a closely related contribution to the literature, David and Veronesi (2014) develop an equilibrium model of the dynamics of market participants learning about economic and policy variables. Empirically, they show that implied volatilities from Treasury markets are positively related to the probability of a recession, the three-month Treasury bill rate (their proxy for monetary policy), inflation uncertainty, and the probability of deflation. Their model implies a direct link between interest rate implied volatilities and real activity, directly motivating our empirical analysis. In

[5] A few exceptions include Bekaert and Hoerova (2014) and Bloom (2009). Bekaert and Hoerova decompose the VIX into the variance risk premium and expected stock return variance and find that the former predicts stock returns, and the latter economic activity. Bloom shows that increased financial uncertainty as measured by the VIX predicts decreases in employment and output.

our paper, we build on David and Veronesi (2014), who do not directly relate implied volatility from Treasury markets to the future level or volatility of real activity, nor to the future level or volatility of bank balance sheets.

Finally, our paper is also related to the literature on measuring macroeconomic uncertainty. Important papers in this area include Bloom (2009), Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry (2012), Jurado, Ludvison, and Ng (2015), Ludvigson, Ma, and Ng (2015), Bachmann, Elstner, and Sims (2013), Diether, Malloy, and Scherbina (2002), Mankiw, Gregory, and Wolfers (2004), Abraham and Katz (1986), among others. Recently, Jurado, Ludvison, and Ng (2015) measure macroeconomic uncertainty from the volatility of unforecastable movements in more than 100 macroeconomic and financial variables and show that this measure is associated with sizable and protracted declines in real activity.

However, even in the presence of such sophisticated models, forecasting with one or a few financial variables can be useful for several reasons. For one, in contrast to many financial indicators, most macroeconomic variables are not available at daily or intra-day frequency, and thus are less useful for monitoring macroeconomic activity in real-time (Aruoba and Diebold (2010)). Second, simple financial variables can be used to confirm the predictions from more elaborate macro-econometric models, especially to mitigate data-snooping concerns. Finally, liquid financial instruments like Treasury futures derivatives instantaneously reflect new forward-looking information regarding interest rate uncertainty.

3 Data and summary statistics

We describe our data sources, the methodology used to calculate the Treasury yield implied volatility and provide summary statistics for the main variables used in our analysis.

3.1 Options on Treasury notes and bonds futures contract

We collect data for transaction prices of call and put options on U.S. Treasury notes and bonds futures contracts traded on the Chicago Mercantile Exchange (CME). Options on Treasury notes and bond futures contracts are the only Treasury options that are exchange-traded. Options written on actual bonds (rather than on futures contracts) are traded in the over-the-counter market and prices for these are not readily available (Choudhry (2010, p. 139) and Hull (2016, p. 673)).

The buyer of a call option on a futures contract on U.S. Treasury notes or bonds has the right to buy the underlying futures contract at the strike price on any business day prior to expiration by giving notice to CME Clearing. Similarly, the buyer of a put option on a futures contract on the U.S. Treasury notes or bonds has the right to sell the underlying futures contract at the strike price. The U.S. Treasury notes and bonds futures contracts underlying the options contracts are themselves standardized contracts for the future purchase and sale of notes and bonds issued by the U.S. Treasury.

Most of the options and futures volume is concentrated in five types of futures contracts, namely futures on the 2-year Treasury notes, 5-year Treasury notes, 10-year Treasury notes, Treasury bonds (with about 20 years to maturity), and the 'ultra'-Treasury bonds (with close to 30 years to maturity). For example, the 2-year Treasury notes futures contract calls for the seller (i.e., the short) to deliver $100,000 face value of any Treasury bond with at least 1.75 years to the buyer (the long). Similarly, the 5-year, 10-year, and Treasury bond, and 'ultra' Treasury bond futures contract call for the delivery of $100,000 face value of any Treasury note with at least 4, 6.5, 15, and 20 years to maturity, respectively.[6]

Both the market for options on futures on Treasury notes and bonds, as well as the market for the underlying futures contracts themselves, are among the largest and most liquid in the world. The market for Treasury notes and bonds futures started in 1977 on the Chicago Board of Trade (CBOT) with the introduction of the 20-year U.S. Treasury bond futures contract. Over time, other maturities were introduced such as the 10-year (in 1982), the 5-year (in 1988), and the

[6] Treasury bonds and notes delivered via futures contract must meet certain specifications. For example, for the 2-year futures notes, the original maturity of the delivered Treasury note should not be more than 5 years and 3 months. For this contract, the remaining maturity of the note should not be less than 1 year and 9 months from the first day of the delivery month, and also not more than 2 years from the last day of the delivery month. Similarly, For the 5-year Futures contract, the original maturity of the delivered note should not be more than 5 years and 3 months and the remaining maturity of the note should not be less than 4 years and 2 months as of the first day of the delivery month. Similar specifications exist for the 10-year note, and the 20-year and 'ultra' Treasury bond futures contracts. Detailed notes and bond futures contract specifications are made available by the CME at http://www.cmegroup.com/trading/interest-rates/us-treasury/30-year-us-treasury-bond_contractSpecs_options.html.

ultra-Treasury (in 2010) notes and bonds futures contracts. Since inception, the Treasury notes and bonds futures market has exhibited significant growth. The average daily trading volume is now in excess of 2 million contracts per day, with most trading taking place in 5-year and 10-year contracts. The average daily notional amounts traded have also increased steadily over time from $150 billion in 2004 to over $300 billion in 2016. The trading in Treasury notes and bonds futures contracts reached levels in excess of 80% of Treasury cash bond notional amounts traded in 2016.

The market for call and put options on Treasury notes and bonds futures contracts is also large and liquid. Across all futures option contracts, average daily trading volume in December 2016 exceeded 450,000 contracts. Since inception, the 5-year Treasury notes options market has grown from annual daily averages of less than one thousand contracts to more than ten thousand by the year 2000. Since then, trading volume has increased steadily and reached an annual daily average in excess of eighty thousand contracts by the end of our sample period.[7]

The pricing of the underlying Treasury notes and bonds futures contracts is complex and impacted by various delivery options. These include the *quality option* (where the seller can deliver any bond with a maturity in a given range), the *timing option* (where the seller can deliver any time during the expiration month), the *wildcard option* (were the seller can deliver the underlying any time during the day until the bond market closes rather than during the more limited trading hours of the futures exchange), and the *end-of-month option* (where the futures stop trading 8 business days before the end of the month).[8]

On the other hand, the pricing of options contracts on the Treasury futures is relatively straightforward, because the various delivery options are already factored in the price of the underlying futures contract and thus do not matter for the pricing of the options conditional on the price of the underlying futures contract. Given the liquidity and efficiency of this futures market, the value

[7]Table A1 presents the summary statistics and Figure A1 plots the time-series for trading volume and open interest for futures and options contracts on U.S. Treasury bonds and notes and confirms that the market for futures and call and put options on Treasury futures contracts is large and liquid. While the trading volume and open interest on these contracts drops somewhat during financial crisis, it quickly recovers.

[8]A large literature analyzes how these delivery options impact the prices of U.S. Treasury notes and bonds futures contracts, see, for example, Boyle (1989), Carr (1988), Hegde (1988), Hemler (1990), and Ritchken and Sankarasubramanian (1995), among others.

of the underlying futures contract can be taken as given when pricing the options on the futures.[9] As a result, an option on a Treasury note or bonds futures contract can be treated as an option on an index, which is the futures price itself, i.e., the locked-in price of a Treasury note or bond when delivered at some particular point in the future. Although an option on a Treasury notes or bonds futures contract is not identical to an option on a Treasury note or bonds, it serves much the same purpose and is similarly priced, as spot and futures prices of Treasury notes and bonds are highly correlated.[10]

3.2 Methodology

We obtain daily price data of options on futures on Treasury notes and bonds from the CME. The prices for options on Treasury notes and bonds futures are quoted in terms of points and 64^{ths} of a point. For example, an option price of 1-10 implies a price of $1\frac{10}{64}\%$ of the face value of the underlying futures contract, i.e., 1.15625% of $100,000. Minimum price movements are also $\frac{1}{64}^{th}$ of 1%. We use data for the quarterly options for delivery months of March, June, September, and December. We exclude weekly or monthly options, as these start trading only after 2011.[11] Using option contracts with expiration months in the quarterly futures cycle is common in the literature that analyzes options on Treasury notes and bonds futures contract (Brandt, Kavajecz, and Underwood (2007), Johnston, Kracaw, and McConnell (1991), and Mizrach and Neely (2008)). Finally, we use call and put options with a least one week to expiration, as the options that are very close to expiration have generally very limited liquidity.

Our main focus is on options on futures on the 5-year Treasury note, though we also consider options on futures on the 10-year and 20-year Treasury bonds in our robustness section. There are at least three reasons why we focus on options on futures on the 5-year Treasury note. First, the market for the 5-year Treasury note futures contract is the largest and most liquid. Over 2000 - 2016, trading volume in the 5-year notes futures contract alone has increased from an annual daily

[9] See for example, Fleming, Sarkar et al. (1999), Hegde (1988), and Burghardt, Belton, Lane, and Papa (1994)

[10] See, e.g., Mizrach and Neely (2008).

[11] For details regarding weekly options on Treasury notes and bonds futures see http://www.cmegroup.com/trading/interest-rates/files/Weekly-Treasury-Options-Frequently-Asked-Questions.pdf.

average of less than 100,000 contracts to more than 750,000 contracts per day. By the end of 2016, trading volume in the 5-year Treasury note futures contract alone accounts for nearly 40% of the overall volume in the Treasury notes and bonds futures market.[12]

Second, Brandt, Kavajecz, and Underwood (2007) and Mizrach and Neely (2006) show that price discovery in the Treasury futures market primarily takes place in futures contracts on 5-year Treasury notes. In particular, they find that while trades in the 2- and 5-year notes are significantly related to price movements, the impact of trading in the 10- and 30-year securities is less pronounced. We do not focus on options on futures on the 2-year Treasury notes, as these options are significantly less liquid than those on 5-year Treasury notes and start trading only more recently.[13] Mizrach and Neely (2006) find that the contribution of the 5-year futures to intra-day price discovery increases significantly after 1999, and by 2001 exceeds that of the 10-year futures. They further show that both the 5-year and the 30-year Treasury futures contracts are significant drivers of price discovery in the Treasury market. However, options on the latter are not actively traded on exchanges.

Third, financial institutions are the most active traders in the market of futures contracts on 5-year Treasury notes. In particular, the notional trading volume in the 5-year Treasury futures as a percentage of the notional amount traded by primary dealers in the cash market for 5-year Treasury notes exceeded 62% at the end of 2015.[14] Appendix Table A2 also shows that a vast majority (nearly 85%) of interest rate derivatives contracts bought and sold by financial institutions are of maturity 5-years or less. As will become clear later, the fact that financial institutions dominate interest rate derivatives on Treasury notes with a maturity of 5-years or less is critical for the mechanism via which we posit that Treasury yield implied volatility impacts real activity.

[12]Table A1 and figure A1 in the appendix A provide summary statistics for the open interest and volume for Treasury notes and bonds futures contract, as well as for options on these futures contracts. As the Table shows, the average volume in the 5-years and the 20-year futures contract is comparable at about 370,000 and 330,000 contracts per day. While the volume for options on the 20-year Treasury futures contract is nearly twice that of options on the 5-year Treasury futures contract, the open interest on these options is comparable.

[13]See Brandt, Kavajecz, and Underwood (2007, p. 1024), "Interestingly, the instrument of central importance to the [price impact] results is the 5-year maturity in both the futures and cash market, largely to the exclusion of the other maturities."

[14]See "The New Treasury Market Paradigm", CME Group, June 2016, available at `https://www.cmegroup.com/education/files/new-treasury-market-paradigm.pdf`.

Directly observable market prices for the 5-year Treasury notes derivatives market have been available since 1990, which determines the start date for our sample, while our data ends in 2016. Hence, our study spans a period of over twenty-five years, and includes major economic and financial crises such as such as Black Wednesday (September, 1992) when the U.K. withdrew from European Exchange Rate Mechanism, the collapse of Askin Capital Management (April, 1994) which sent a shock wave through the mortgage market, the Mexican Peso Crisis (December, 1994), the Asian Financial Crisis (July, 1997), the Russian default (August, 1998), the Long-Term-Capital-Management crisis (August, 1998), the sub-prime mortgage crisis (October, 2007), the Lehman Brothers bankruptcy (September, 2008), the European Debt Crisis (starting in May, 2010), and the downgrade of the U.S. credit rating by S&P (August, 2011).

Following Brandt, Kavajecz, and Underwood (2007), Johnston, Kracaw, and McConnell (1991), and Mizrach and Neely (2006), we obtain the time-series of the implied volatility of options on the 5-year Treasury note futures as follows. Each day, we select the two call and put options whose exercise price is closest to the price of the underlying 5-year Treasury note futures contracts (i.e., that are closest to at-the-money). This selection is motivated by Ederington and Lee (1993, 1996), who argue that this ensures the strongest link between spot and futures markets, allowing these to be treated as if they are options on the spot rates themselves. The particular selected options are generally also the most liquid. For example, Ederington and Lee (1996) find that market prices of at-the-money futures options are informationally the most efficient, as these are the first to adjust to macroeconomic news (typically within the first 10 seconds).

We estimate the implied volatility for the selected options on each day by implementing the Black (1976b,a) commodity option pricing model for the expected standard deviation of the log of Treasury notes futures price changes. Specifically, we use the following equation for each of the selected options:

$$c = e^{-rT}\left[FN(d_1) - KN(d_2)\right] \tag{1}$$

where:

$$d_1 = \frac{\left[ln\left(\frac{F}{K}\right) + 0.5\sigma_t^2\right]}{\sqrt{\sigma T}} \tag{2}$$

and:

$$d_2 = d_1 - \sqrt{\sigma T} \tag{3}$$

Here, c is the price of a European call option, r is the riskless discount rate corresponding to the maturity date of the option, F is the price of the bond futures contract underlying the option contract, K is the strike price, σ is the annualized standard deviation of the futures contract, and N is the cumulative normal density function.

Next, we compute the weighted average of the implied volatilities of the two selected call and put options, using each option's moneyness as the weight.[15] This results in a daily time-series of implied volatility for options on the 5-year Treasury note futures contract. We average this time-series within each month over our sample period to obtain the monthly time-series of average implied volatility of options on the 5-year Treasury notes futures contract over May 1990 to November 2016.[16] Throughout the rest of this paper, we reference this time-series by $\sigma_{IV,5}^{INT}$.

The Black model has been widely adopted by market participants and is the default model in practice to calculate implied volatilities.[17] In an early study, Belongia and Gregory (1984) find that in the few instances where prices from the Black model differ from observed market values, they are unable to find consistent arbitrage opportunities, and conclude that Treasury bond option prices derived from the Black model are fundamentally "efficient". Finally, the Black model used above applies to European options, whereas the actual options on Treasury notes and bonds futures are American. Therefore, we use the Barone-Adesi and Whaley (1987) analytical approximation for

[15] Our results are robust to using a volume-weighted, open-interest weighted, as well as a simple average of the implied volatility of the selected options.

[16] Our results are robust to using the average implied volatility over the last two weeks or the last week of a given month. Our results are also robust to using the implied volatility on the last day of each month.

[17] "Although the Black model has many limitations and inconsistent assumptions, it has been widely adopted. Traders often quote the exchange-traded options on Treasury or Eurodollar futures in terms of implied volatilities based on the Black model. These implied volatilities are also published by some investment houses and are available through data vendors." See Fabozzi (2009, p. 819).

American options as a robustness check:

$$\begin{aligned} C &= c + A\left(\frac{F}{F^*}\right)^{\gamma} \text{If } F < F^* \\ &= F - K\text{If } F \geq F^* \end{aligned} \tag{4}$$

where C and c are the American and European call options, respectively, and F^* is the price of the 5-year Treasury note futures contract at which early exercise of the option on the futures contract is optimal and is given by:

$$F * -K = c + \left\{1 - e^{-rT} N\left[d_1\left(F^*\right)\right]\right\} F^*/\gamma \tag{5}$$

A is given by:

$$A = \left(F^*/\gamma\right)\left\{1 - e^{-rT} N\left[d_f\left(F^*\right)\right]\right\} \tag{6}$$

In addition:

$$\begin{aligned} d_1\left(F^*\right) &= \frac{\left[ln\left(F^*/K\right) + 0.5\sigma^2 t\right]}{0.5\sigma t} \\ \gamma &= \frac{\left[1 + \sqrt{1 + 4\alpha/h\left(\right)}\right]}{2} \\ \alpha &= \frac{2r}{\sigma^2} \\ h(t) &= 1 - e^{-rT} \end{aligned} \tag{7}$$

Implied volatility estimates are obtained by substituting equation 1 into 4 and then solving numerically for both the implied volatility and for the price of the 5-year Treasury note futures contract at which early exercise becomes optimal. Overall, we find only a very small early exercise premium and, hence, for our main analysis we utilize non-adjusted implied volatilities obtained using the Black model.[18]

Figure 1 plots the time series of YIV, together with grey regions representing NBER recessions and financial crises. The NBER recession dates are published by the NBER Business Cycle Dating Committee and are available at http://www.nber.org/cycles.html. The dates for financial crises are obtained from Kho, Lee, and Stulz (2000), Romer and Romer (2015), and the FDIC. The YIV varies over time and appears to peak during recessions and financial crises. The most dramatic of these episodes occurred during the recent financial crisis of 2007-2009, when the YIV increased sharply and remained at elevated levels for almost the entire length of the financial crisis, before dropping to its pre-crisis levels. In particular, the YIV increased by over 200% in November 2008, compared to its level a year earlier in November 2007.

Panel A of 1 shows the summary statistics for the YIV, reporting the mean, standard deviation, minimum, 25^{th}-percentile, median, 75^{th}-percentile, and maximum values for the YIV over the entire sample. Over our entire sample, the mean YIV is 3.38. The standard deviation for the YIV (volatility of implied volatility) is 1.17. Over the full sample, YIV reaches maximum values of 9.21, which is more than 200% of its mean values, during the financial crisis of 2008 - 2009. Finally, the last column of the Table shows that the YIV is highly persistent, with the first-order autocorrelation of 0.70.

We collect data for the macroeconomic variables (the gross domestic product, the index of industrial production, aggregate personal consumption expenditures, total non-farm payroll, and bank credit) from the Federal Reserve Bank at St. Louis.[19] Data for the gross domestic product is available quarterly only, while that for industrial production, aggregate personal consumption expenditures, total non-farm payrolls, and bank credit (denoted by GDP, IND, CON, EMP, and BCG, respectively) is available monthly. We report the summary statistics of their year-on-year growth rates in panel B of Table 1. The average year-on-year growth rate of GDP, IND, CON, EMP, and BCG is 2.44%, 2.03%, 4.83%, 1.06%, and 5.77%, respectively. These macroeconomic

[18] Over our sample period, on average, we find that the average difference between implied volatility estimates from the Black model with and without the approximation for early exercise averages is only around 3-5 basis points across contracts. This is also confirmed by Simon (1997), who analyzes the early exercise premium in these markets.

[19] See, https://research.stlouisfed.org/

variables have low volatility, of the order of 1.5-4.0% annually, and are highly persistent with a first-order correlation that exceeds 0.90 in all cases.

We also collect data for several stock and bond market variables that serve as controls in our empirical tests. These include data for risk-free rates, index returns (of Treasury bonds, corporate bonds, and stocks), the CBOE volatility index, and an index measureing economic policy uncertainty. Data for risk-free rates is from Gürkaynak, Sack, and Wright (2007).[20] We use the risk-free rates to compute the term spread, defined as the difference in the yield to maturity on the zero-coupon 10-year bond and the 1-year note issued by the U.S. Treasury (denoted TRM), and the changes in the short rate, defined as the change in the yield-to-maturity on the 1-year zero coupon note issued by the U.S. Treasury (denoted ΔSY). Data for the return on index of Treasury bonds (denoted ITR) and of corporate bonds (denoted ICB) are from Global Financial Data ($ITUS10D$ and $DJCBPD$, respectively).[21] Return data for a value-weighted index of all stocks (denoted VWR) and the CBOE volatility index (denoted σ_{IV}^{VIX}) are from Wharton Research Data Services. Finally, data for the index of economic policy uncertainty (denoted UNC) is from the Federal Reserve Bank at St. Louis. Panel C of Table 1 presents the summary statistics for these variables.

Table 2 reports the correlation of the YIV with various macroeconomic, bond, and stock market variables. We report the contemporaneous correlation of the YIV with the year-on-year growth rate of GDP, industrial production, consumption, and employment. The YIV has a negative correlation with all macroeconomic variables and all of these correlations are statistically significant at the 1% level. Accordingly, "aggregate bad times" as indicated by a drop in GDP, industrial production, consumption, and employment, are all associated with a contemporaneous increase in YIV.[22]

[20]This dataset is available online at http://www.federalreserve.gov/pubs/feds/2006/200628/200628abs.html. We supplement this data with the the data for the 1-month Treasury bill.

[21]https://www.globalfinancialdata.com/

[22]The correlation between YIV and 20-year YIV is negative and statistically significant at the 1% level which may be consistent with structural models of uncertainty and their impact on real activity (e.g., Bloom (2009)). In these models an unexpected increase in uncertainty is associated with a drop in macroeconomic quantities (output, productivity, employment, etc.) because higher uncertainty increases the real option value to waiting. Thus, market participants respond to higher uncertainty by scaling back consumption, investment, and by increasing precautionary savings that can in the short-run, lead to a contraction. In these models, however, the long-run effect is theoretically ambiguous as higher savings can translate into higher long-term growth through increased investment. Higher uncertainty can also induce investment because it may increase the upside potential of investment projects

Panels B and C of Table 2 show that an increase in the YIV is contempraneously associated with an increase in the slope of the term-structure, a decrease in the short-rate, lower stock market returns, and higher stock market volatility. An increase in YIV is also associated with an increase in economic policy uncertainty as measured by UNC. All of these correlations indicate that the YIV increases during times of economic and financial distress. Finally, the other correlations in Table 2 are as expected. For instance, in panel A, GDP, industrial production, employment, and consumption are positively correlated with each other. In panel B, an increase in the slope of the term structure is associated with a decline in the short rate, and lower returns on an index of corporate bonds. In panel C, an increase in stock market implied volatility is associated with lower returns on an index of all stocks.

While the correlations in Table 2 indicate that an increase in YIV is contemporaneously associated with worsening economic outcomes, we consider a predictive relationship in section 5 below.

4 Treasury Yield implied volatility and interest rate uncertainty

We begin by assessing the ability of YIV to capture future interest rate uncertainty. Since the YIV is the "risk-neutral" expected variance for the 5-year Treasury bond futures contract, it reflects both interest rate uncertainty (i.e. the "physical" expected interest rate volatility) and a variance risk premium. The variance risk premium is the expected premium from selling interest rate volatility and is likely to be correlated with risk aversion. In this section, we first consider how the YIV responds to unexpected changes in short-term interest rates dues to monetary policy decisions, and then the ability of the YIV to predict interest rate volatility more generally.[23]

As market prices (such as those for options on Treasury futures contracts, from which the YIV is derived) should primarily react to unanticipated monetary policy changes (Bernanke and Kuttner

by widening the distribution of future outcomes.

[23]Since the YIV reflects both interest rate uncertainty and variance risk premium, we check that our predictive results in Section 5 are robust to controlling for variance risk premium. See appendix Table A11.

(2005)), we therefore distinguish between expected and unexpected monetary policy changes in the target Federal funds rate. Specifically, we measure unanticipated changes in the target Federal funds rate following the methodology in Rudebusch (1995), Hilton (1994), and Kuttner (2003), who use data for prices of futures contracts that reference the Federal funds rate. For an event on day d of month m, their approach calculates the unexpected (or "surprise") change in the target funds rate from the change in the Federal funds rate "implied" by the current-month futures contract, scaled by a factor related to the number of days in the month affected by the change. This scaling is required because the contract's price is based on the monthly average Federal funds rate. Thus, the unanticipated change in the Federal funds rate is given by:

$$\Delta i^u = \frac{D}{D-d}\left(f^0_{m,d} - f^0_{m,d-1}\right) \tag{8}$$

where Δi^u is the unexpected target rate change, $f^0_{m,d}$ is the current-month futures rate, and D id the number of days in the month. The expected component of the rate change is defined as:

$$\Delta i^e = \Delta i - \Delta i^u \tag{9}$$

Our sample period contains 86 monetary policy announcements related to changes in the target Federal funds rate. Using the methodology outlined above, we classify 43 and 29 of these announcements as "positive" and "negative" surprise for the market, respectively. The remaining 14 events are classified as "no surprise", as the change in the target Federal funds rate is exactly in accordance with market expectations. We define a positive monetary policy shock as events where the Federal funds rate increases by more or is cut by less than anticipated, and negative shocks are defined as the oppositive. Positive (negative) surprises indicate that the Federal Reserve anticipates macroeconomic conditions to improve (worsen), consistent with Bernanke and Blinder (1992), who show that peaks in cyclical economic activity are proceeded by a sustained run-up in the Federal funds rate. They also show that the Federal funds rate responds to unanticipated changes in macroeconomic variables. For example, a positive shock to inflation tends to drive up the Federal funds rate, while positive shocks to unemployment tend to push the Federal funds rate down.

Figure 2 presents the average response of the YIV in the 5-day window around the monetary policy announcement dates. We compute the average response of the YIV separately across all positive, negative, and zero surprise days in our sample. To enable easier interpretation of the results, we divide the average response of the YIV over the event window by the average YIV over the whole sample. As a result, Figure 2 plots how much the YIV increases or decreases during event windows, as compared to its average value over the whole sample.

The results indicate that the YIV increases during both positive and negative events. A positive surprise is associated with a nearly 24% increase in the YIV, while the YIV jumps by nearly 37% during negative surprise events (both compared to its sample mean). The right-most panel in Figure 2 indicates that the YIV hardly reacts on days with no surprise announcements. The average daily change in the YIV is about 6% of its sample mean, such that these increases in the YIV on both positive and negative event days seem economically significant.

Next, we regress the YIV on a dummy variable that equals 1 over a 5-day window around all positive and negative unanticipated changes in the Federal funds rate. On average, over a 5-day window around an unexpected positive or negative change in the funds rate, the YIV increases by 0.56%, which is nearly 17% higher than its sample mean and statistically significant at the 5% level (with a t-statistic of 2.18).[24]

Changes in the YIV are more consistently positive around unexpected monetary policy changes than changes in the short-rate (yield on the 1-year bill issued by the U.S. Treasury) and in the stock market implied volatility (VIX). In contrast to the change in the YIV, the short rate shows smaller increases and decreases for positive and negative event windows, respectively. Likewise, the VIX increases only slightly for positive surprise days and remains relatively flat on days with negative or neutral monetary policy surprises. If the YIV primarily captured aggregate risk aversion (or

[24] We also separately regress the YIV on a dummy variable that equals 1 over a 5-day window around positive and negative unanticipated changes in the Federal funds rate, respectively. Over positive event windows, the YIV increases by 15% compared to its sample mean (t-statistic of 1.2), and over negative event windows the YIV increases by 18% compared to its sample mean (t-statistic of 1.65).

time variation in the variance risk premia), it should increase only during negative event windows. Since interest rate volatility tends to be low when the level of interest rates is low (Longstaff and Schwartz (1992)), we would also expect the YIV to decrease during negative announcement events. Therefore, our finding that the YIV increases around both positive and negative surprise monetary policy announcements indicates that it at least partly captures broader interest rate uncertainty.

Finally, Table 3 shows that the YIV predicts future volatility of the short-term interest rates such as the 2-year and the 5-year nominal risk free rates, but is only marginally statistically significant for the 10-year nominal risk free rate. Panel A presents the estimates for predicting the volatility in 2-year interest rates 12, 18, 24, 30, and 36 months ahead using only the YIV as a predictor, while we use both the YIV and the current level of the volatility in Panel B. Panel A shows that the coefficient on the YIV is positive and statistically significant, indicating that a higher yield implied volatility predicts higher future volatility of the 2-year nominal risk free rate. The highest coefficient for the YIV is reached for 12 months ahead, with a coefficient of 1.45 and a t-statistic of 2.49. This implies that a one standard deviation increase in the current 5-year yield implied volatility (equal to 1.17%) is associated with an increase in future volatility of 2-year rate of $12 \times 1.22 \times 1.17\% = 17.13\%$ in the next year. This is an economically large increase in interest rate volatility, given its mean annualized growth rate of 2.64%. The coefficients for the longer horizons indicate that there is some reversal afterwards. In addition, the YIV by itself is able to explain nearly 6% of the variation in future volatility of 2-year interest rates. Controlling for the current level of 2-year interest rate volatility, in panel B, shows that the YIV remains strongly statistically significant.

The remaining panels of Table 3 show the results of analogous regressions predicting the volatility of 5-year and 10-year nominal risk-free rates. The YIV has a positive coefficient that is both statistically and economically significant for predicting volatility of the 5-year rate, but not of the 10-year rate. For example, the coefficient of the YIV in Panel C equals 1.22 (with a t-statistic of 2.33) when predicting consumption growth 12 months ahead. In contrast, in panel E, the coefficient on the YIV is positive but not statistically significant. This shows that the YIV is a good predictor for uncertainty of short-term rates (1 - 5 years) but not for long-term rates (> 10-years).

5 Forecasting regressions

This section considers the relation between YIV and the level and uncertainty of future macroeconomic activity as captured by three aggregate measures that are available at the monthly frequency and are among the most widely studied: industry production growth, consumption growth, and employment growth. We also analyze the relation between YIV and GDP, which is available at a quarterly frequency. Our main approach is to run monthly predictive and overlapping regressions of these proxies for macroeconomic conditions on YIV, with and without controls. The set of controls includes lagged values of the macroeconomic variable (i.e., current level of the dependent variable) plus predictors from the existing literature such as the change in the short-rate, the term spread and the implied volatility of the stock market.

5.1 Treasury yield implied volatility and macroeconomic activity

We begin by plotting the 12-month moving average (months $t-11$ through t) of the YIV along with the growth rates of macroeconomic variables such as the gross domestic product, industrial production, consumption, and employment (Figure 3). The gray-shaded regions represent NBER recessions and financial crises. We plot backward-looking 12-month moving averages for all variables, which explains why growth rates of macroeconomic variables drop a couple of months after the start of the NBER recessions. The YIV increases sharply during recessions and financial crises, is very sensitive to large slowdowns in the growth rate of macroeconomic variables, and tends to increase before the end of the NBER recessions.

Next, we explore whether the YIV can predict future growth rates of macroeconomic activity by estimating the following monthly (quarterly in case of GDP), overlapping regressions:

$$\sum_{j=1}^{j=H} \log(1+MACRO_{i,t+j})/H = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H} \quad (10)$$

where $MACRO_{i,t+j}$ is the growth rate of a particular proxy for macro-economic activity measured at time $t + j$ (either gross domestic product, industrial production growth, consumption growth, or employment), and $\sigma^{INT}_{IV,t}$ is the YIV measured at time t. Our controls include the current (lagged) growth rate of the dependent variable, as well as the current (i) term spread (TRM), (ii) changes in the short-rate (ΔSY), (iii) return on an index of treasury bonds (ITB), (iv) returns on an index of corporate bonds (ICB), (v) value-weighted return on an index of all stocks in CRSP (VWR), (vi) CBOE Volatility Index (VIX), and (vii) equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). These control variables are standard in the literature that uses financial market variables to predict macroeconomic outcomes.[25] The dependent variable can be interpreted as the average annualized growth rate over the next H years, as we divide the sum of the monthly year-on-year growth rates ($\sum_{j=1}^{j=H} \log(1 + MACRO_{i,t+j})$) by H. Throughout the paper, we report robust standard errors that are adjusted for heteroscedasticity and autocorrelation, and apply the Newey-West correction with up to 36 monthly lags. We also confirm that our results are robust to using Hansen-Hodrick errors (with up to 36 lags) that correct standard errors for the overlapping nature of the predictive regressions. Finally, all of the independent variables are standardized in the predictive regressions, by subtracting their time series mean and dividing by their time series standard deviation, enabling easier interpretation and comparison of the coefficients.

Panel A of Table 4 presents the estimates for predicting the year-on-year growth rate in gross domestic product 12, 18, 24, 30, and 36 months ahead using equation (10). We include only the YIV as a predictor in Panel A, and use both the YIV and the current level of the lagged dependent variable in Panel B. The coefficient on the YIV is negative and statistically significant in Panel A of Table 4, indicating that a higher yield implied volatility predicts lower future growth rate of gross domestic product. The highest coefficient for the YIV is reached for predicting the year-on-year growth in GDP 12 months ahead, with a coefficient of -0.08 and a t-statistic of -3.61. This implies that a one standard deviation increase in the current 5-year yield implied volatility (equal to 1.17%,

[25]For example, see Litterman, Scheinkman, and Weiss (1991), Duffie and Kan (1996), Whaley (2000), Collin-Dufresne, Goldstein, and Martin (2001), González-Hermosillo and Stone (2008), among others.

see Table 1) is associated with a decrease in annual GDP growth of $12 \times -0.08 \times 1.17\% = 1.12\%$ in the next year. This is an economically large reduction in the GDP growth rate, given its mean annualized growth rate of 2.44%. In addition, the YIV by itself is able to explain nearly 35% of the variation in GDP growth rate over a one-year horizon.

Panel A also shows that the coefficient over the 18-month horizon equals -0.07, with a t-statistic of -3.46. This indicates that a one standard deviation increase in the YIV is associated with a future decrease in the annualized GDP growth over this period of $18 \times -0.07 \times 1.17\% = 1.47\%$ over 18 months. As a result, the coefficients for the longer horizons indicate that there is no reversal afterwards.

Adding the current level of GDP growth as a control, in Panel B of Table 4, shows that this variable is statistically insignificant across all horizons, while the coefficient on the YIV remains strongly statistically significant.[26]

Panel C of Table 4 presents the regressions predicting the year-on-year growth in the index of industrial production. These results are similar to the results for GDP growth, indicating that a higher yield implied volatility in Treasury derivatives markets predicts lower future growth in industrial production. The highest coefficient for the YIV for predicting year-on-year growth in industry production is again reached 12 months ahead (coefficient of -0.17, t-statistic of -2.61). Thus, a one-standard deviation increase in the current 5-year yield implied volatility (equal to 1.17%, see Table 1) is associated with a decrease in annual industry production growth of 12*-0.17*1.17% = 2.39% in the next year. Compared to the sample mean annualized growth in industrial production of 2.03%, this is again economically significant. Panels E and F of Table 4 shows analogous regressions predicting year-on-year growth in aggregate consumption. We again find that the YIV has a negative coefficient that is strongly significant both statistically and economically. For example, the coefficient of the YIV in Panel E equals -0.05 (with a t-statistic of 3.78) when predicting consumption growth 30 months ahead. This suggests that a standard deviation increase in the YIV predicts a future decrease in consumption growth of 0.05%. Since the average monthly growth

[26]Note that the coefficient on lagged growth rate of gross domestic product is significant over a horizon of 8 months, indicating some level of persistence in its growth rate.

rate of consumption over our sample period is 0.40%, this implies that a one-standard deviation increase in the YIV is associated with a nearly 12% reduction in the future growth rate of consumption. In panel F, the coefficient of the current growth rate in consumption is positive and is strongly statistically significant if added to the regression. This shows that consumption growth is persistent, so that it is important to control for the current level. Doing so attenuates the economic significance of the coefficient on the YIV, though it remains statistically significant.

Finally, the results for predictive regressions for employment growth are presented in panels G and H of Table 4. The YIV has a negative coefficient that is consistently strongly significant both statistically and economically across all horizons, while the coefficient on the lagged employment growth is not significant across all horizons. In Panel G, the coefficient on the YIV for predicting next year's employment growth equals 0.09 (t-statistic of 5.08), while the coefficient on the YIV at the 3-year horizon equals 0.04 (t-statistic of -7.11). Therefore, a one-standard deviation increase in the YIV nearly halves the growth rate of employment. Adding lagged employment growth rate in Panel H does not change the coefficient of the YIV much.

Tables A3 - A6 in Appendix B show the results when the YIV is used to predict growth rates of macroeconomic quantities with the full set of controls. Adding the controls does not change the coefficient on the YIV much. In all cases, the coefficient on the YIV is still economically and statistically significant.

For example, Panel B of Table A3 presents the estimates when the YIV is used to predict GDP growth rate along with the full set of control variables. The coefficients on the YIV with the controls have economic and statistical significance similar to that of the coefficients on the YIV without the controls (see Panel A of Table 4). This indicates that the predictive power of the YIV for GDP growth rates is largely independent to that of the controls. Out of the control variables, the term spread and changes in the short rate are most robustly and positively associated with future GDP growth, consistent with Ang, Piazzesi, and Wei (2006) and Wright (2006). The returns on an index of corporate bonds and of stocks also predict GDP, consistent with Estrella and Mishkin (1998). The implied volatility in equity markets, as proxied by the VIX, has predictive ability when the

YIV is excluded, but it is largely absorbed by the YIV. The equity-market uncertainty proxy in Baker, Bloom, and Davis (2015) also helps predict gross domestic product growth. However, the values for R^2 in panel B indicate that the YIV still explains an additional 12% of the variation in the growth rate of GDP over a one-year horizon, over and above the explanatory power of the combined set of control variables.

Table A4 shows that adding the full set of control variables does not affect the ability of the YIV to predict industrial production growth. Out of the controls, the term spread, changes in the short-rate, and the aggregate stock returns are the only ones that robustly predict the growth rate of industrial production. We find no evidence that the equity-market uncertainty proxy in Baker, Bloom, and Davis (2015) helps predict industrial production growth.

These conclusions also hold when the YIV is used to predict consumption and employment growth. In Table A5, adding the full set of control variables attenuates the economic significance of the coefficient on the YIV, though it remains statistically significant. Out of the controls (other than the current level of consumption growth), only the aggregate return on the stock market has a statistically significant coefficient across all horizons. Over shorter horizons for up to 18 months, changes in the short-rate and the term spread are also significant predictors. The term spread, changes in the short-rate, and aggregate return on the stock market also predict employment growth, but do not affect the economical and statistical significance of the coefficient on the YIV.

While Table 4 and Tables A3 - A6 present predictive regressions for up to 36 months ahead, Figures 4 and 5 summarize analogous predictive regressions for up to 60 months ahead. Figure 4 shows the R^2 and Figure 5 shows the coefficient on the YIV with and without the control variables. The results indicate that the predictive R^2 of the YIV for predicting the growth rate of various macroeconomic variables is highest for up to 12 months ahead. The predictive R^2 of the YIV for growth rate of gross domestic product peaks at about 9 months (3-quarters ahead) at approximately 35%. The predictive R^2 of the YIV is highest for predicting industrial production growth for up to 12 months ahead as well, for which the R^2 of the YIV by itself stands at over 30%, and is higher than the R^2 of all controls jointly without the YIV (as also shown in Panel C of

Table A4). The coefficient on the YIV is similar across all horizons, for each of the macroeconomic variables

Next, we consider the extent to which the yield implied volatility helps predict future macroeconomic uncertainty, as measured by the volatility of observations of the various macroeconomic variables previously considered. Figure 6 plots the moving volatility (months $t-11$ through t) of the various macroeconomic variables and the 12-month moving average of the YIV, showing that the YIV increases when the volatility in the growth rate of various macroeconomic variables increases.

Table 5 summarizes our tests of the YIV's ability to predict macroeconomic volatility. These predictive regressions (all without controls) for the volatility of GDP growth are presented in panels A and B, for the volatility of industrial production growth in panels C and D, for the volatility of consumption growth in Panels E and F, and finally for the volatility of employment growth in Panels G and H. The analogous results that also include the standard set of controls are presented in the online appendix Tables A7 - A10.

The results in Table 5 show that higher YIV consistently predicts higher volatility of the growth rate of GDP, industrial production, consumption and employment. The predictive R^2 is highest over the first 12 18 months. For example, in the predictive regression of the volatility of GDP growth the YIV has a coefficient of 0.25 with a t-statistic of 2.95, and an R^2 of 25% (see Panel A). Analogous predictions of next year's volatility in the growth rate of industrial production, consumption, and employment have R^2's of 34%, 25%, and 28%, respectively. Adding lagged volatility (Panels B, D, F, and H) or other control variables (Tables A7 - A10) has little impact on the ability of YIV to predict the volatility of these macroeconomic variables.

The coefficients in Table 5 imply that a one-standard deviation increase in the YIV is associated with an increase of 0.30%, 1.00%, 0.33%, 0.26% in the volatility of growth rates of GDP, industrial production, consumption, and employment, respectively. Over our sample, the average volatility in the growth rates of gross domestic product, industrial production, consumption, and employment over a one year period is 2.01%, 4.61%, 0.91%, and 1.00%, respectively. Therefore, a one-standard deviation increase in the YIV causes volatility of growth rates of macroeconomic variables to increase by 15% (for GDP), 21% (for industrial production), 36% (for consumption), and 26% (for employment) compared to their respective sample mean.

Tables A7 - A10 in the appendix show that none of the standard control variables are able to predict the volatility of the growth rates of all 4 macroeconomic variables across all horizons. For example, while the return on an index of investment grade corporate bonds (ICB) predicts the volatility of GDP growth, it has no predictive power for the remaining 3 macroeconomic variables. Similarly, the slope of the term structure (TRM) predicts volatility of industrial production and consumption growth, but not of GDP and employment growth. While economic policy uncertainty (UNC) predicts volatility of the growth rates of industrial production and consumption, it has no significant relation for GDP or employment. Further, in all regressions, the coefficient on UNC is consistently negative, suggesting that higher economic policy uncertainty – as measured by UNC – is associated with a lower future macroeconomic volatility, the opposite sign from the expected.

The only control variable that predicts higher volatility of growth rates of real variables is the stock market implied volatility (VIX). In Tables A7 - A10, an increase in VIX is associated with an increase in the volatility of the growth rate of GDP, industrial production, and consumption, but not of employment. Further, VIX only predicts higher macroeconomic volatility for some variables across all horizons. Compared to the YIV, the economic significance of VIX in explaining macroeconomic volatility is smaller, as the coefficient on the VIX is generally less than half of the coefficient on the YIV at all horizons.[27] Finally, including the YIV in the predictive regression attenuates the predictive ability of the VIX, while the addition of the VIX hardly affects the economic and statistical significance of the coefficient on the YIV.

Figures 7 and 8 plot the predictive R^2 and the coefficients, respectively, for the four mean measures of macroeconomic volatility. In all cases, the predictive R^2 peaks at a horizon of 12 - 18 months at values that range between 30 - 40%. For predicting macroeconomic volatility for up to 2 years horizons, the predictive R^2 of the regression with only the YIV is higher (up to about 40%)

[27] Since all RHS variables are standardized by subtracting the mean and dividing by the standard deviation, the coefficients are directly comparable.

than for a specification that includes all seven controls but not the YIV. For longer horizons of 3 – 5 years ahead, the R^2 on only the YIV stands at about 20%, for only using the seven controls at about 35%, and for using both the YIV and the controls at about 40%-50%. As shown in Figure 8, the predictive coefficient of the YIV is fairly stable across horizons, and is largely unaffected by the inclusion of the seven controls. Therefore, we conclude that the YIV by itself can predict a substantial fraction of macroeconomic volatility across all horizons.

5.2 Robustness

We report the results from multiple robustness tests. In the first test, we compare the performance of the YIV with other measures of implied volatility from the Treasury markets, namely the implied volatility on options on the 20-year Treasury bond futures contract, the Treasury Implied Volatility (TIV) from Choi, Mueller, and Vedolin (2016) and the CBOE/CBOT US Treasury Volatility Index (TYVIX), and variance risk premia (VRP).[28] Our results in Table A11 in Appendix B show that the predictive power of the YIV is robust to the inclusion of these additional variables.

The YIV is the only variable that consistently predicts the growth rates of GDP, industrial production, unemployment, and consumption across horizons with statistical significance at conventional levels. In contrast, an increase in the 20-year YIV indicates that the growth rate of industrial production is higher (not lower) in the future. Moreover, the coefficient on the 20-year YIV is not statistically significant at conventional levels when used to predict employment growth. The results in Table A11 show that the coefficient on other measures such as the TIV and the TYVIX are also not consistently statistically significant and with signs that are not always negative. Table A12 in the appendix shows that the YIV is also the only variable among these that is positively correlated with future volatility of the macroeconomic variables, while being statistically significant at conventional levels.

The results in Table A11 and A12 suggest that the negative predictive relation between the YIV and real activity is unlikely to be due to time-varying variance risk premium as we now

[28]See, http://www.cboe.com/TYVIX for details.

directly control for time variation in variance risk premia. In addition, if changes in the YIV would primarily capture changes in the variance risk premium, we should find that an increase in either the 20-year YIV or TIV or the TYVIX should also predict a decline in real activity or increases in volatility, but this is not the case.

Table A13 shows results for the predictive regressions with non-over-lapping observations to address concerns that Newey-West adjustments may be insufficient in small samples. This drastically reduces the number of observations in our sample, especially over longer horizons, and thus significantly affects the statistical power of our empirical analysis. However, the results in Table A13 show that the predictive power of the YIV for future growth rates of macroeconomic variables, at least at the 12-month horizon, does not seem to be driven (spuriously) by the overlapping nature of our observations.

Table A14 shows our baseline results in 4 but now excluding the years spanning the financial crisis. The results indicate that these results are not driven just by the events surrounding the credit crisis of 2007-2009.

Finally, we test the out-of-sample predictive ability of the YIV regarding the year-on-year growth rate of industrial production, consumption, and employment. For this, we use 10-year rolling windows to estimate the relation between the YIV and each macroeconomic variable. We then use the coefficients of the estimated model to predict the growth rates of each macroeconomic variable 12-, 18-, 24-, 30-, and 36-months (out of sample) ahead. We compare the predicted values to the actual (realized) growth rates of macroeconomic variables and estimate the root-mean-square errors.[29] We repeat the entire process for a predictive model that uses only the lagged values of the growth rates of the macroeconomic variable itself as the sole predictor. Table 6 compares the root-mean-squared errors from these out of sample forecasts.

Overall, the results so far indicate that YIV predicts level and volatility of macroeconomic activity and that this predictability is robust to the inclusion of several popular forecasting variables used in the literature. Treasury yield implied volatility thus constitutes a useful forward-looking state variable that characterizes risks and opportunities in the macroeconomy. In the next section,

[29] Tge root-mean-square error (RMSE) is defined as the standard deviation of the regression residuals.

we study one potential explanation for these results.

To compare the out-of-sample performance for each model we regress the actual future values of growth rates and volatility of macroeconomic variables on their predicted values and report the regression statistics in Table 7. Panel A assesses the out-of-sample performance when only the YIV is used to predict growth rates of industrial production, consumption, and employment respectively. Panel B reports the analogous results when only the lagged values are used to predict growth rates of macroeconomic variables. Panels C and D report the results for similar regressions when either the YIV or the lagged volatility is used to predict volatility of macroeconomic variables. In all cases, we report the coefficients, t-statistics, and R^2 for this regression.

6 Treasury yield implied volatility and bank credit

So far we document that the YIV is a proxy for interest rate uncertainty and that it forecasts the level and volatility of real activity. In this section, we examine one possible economic channel through which interest rate uncertainty relates to real activity, namely through a bank credit channel.

Intuitively, an increase in interest rate uncertainty can adversely affect macroeconomic activity via its impact on all firms in the economy. In other words, interest rate uncertainty may negatively impact macroeconomic activity by depressing investment for all firms in the economy. However, most firms can hedge interest rate uncertainty in the market for interest rate derivatives, where the YIV serves as a proxy for the price of hedging. This leads us to consider a particular set of economic agents that are not completely immune from interest rate risk – i.e., banks – through which interest rate uncertainty relates to real activity.

Maturity transformation i.e. borrowing at the short-end of the yield curve via deposits payable on demand and lending at the long-end of the yield curve (typically) via fixed rate loans is at the heart of the business model of a bank. Such maturity transformation inevitably exposes banks to interest rate risk that they may be unable or unwilling to hedge completely. In theory, banks can hedge interest rate risk inherent in maturity transformation by using adjustable rate (or floating rate loans). In practice, banks may be unable to do so because borrowers' demand for fixed rate loans is higher when interest rate uncertainty is high. Banks, like other non-financial firms, can also hedge interest rate risk in the market for interest rate derivatives. However, **?** show that in practice banks use interest rate derivatives to amplify not reduce their exposure to interest rate risk.

The magnitude of banks' net exposure to interest rate risk is large. **?** show that the aggregate U.S. banking sector holds nearly $4 trillion in interest sensitive assets at the end of 2014. They further document that U.S. banks effectively hold a leveraged fixed income portfolio that is long interest rates.

We examine whether the YIV predicts a decrease n the demand for deposits from customers by banks, an increase int he cost of capital of banks, a decrease in the supply of credit by banks, and a decrease in the investment of bank dependent firms. We study if these predictions are stronger for banks that are more exposed to interest rate risk. Finally, in the second subsection, we estimate a reduced form VAR system to test whether shocks to the YIV predict changes in the level and volatility of real activity through changes in bank credit.

6.1 Interest rate uncertainty and banks

A large literature studies the nature of bank deposits (**?**, **?**, among others). This literature establishes that deposits are a primary stable source of funds for banks and accounts for nearly 70% of total liabilities for a typical bank. Deposits, especially large time deposits, are sensitive to changes in deposit interest rates. Recent literature (for e.g., **?** show that changes in interest rates impact the rate which banks pay on deposits, and affects the quantity of deposits flowing in and out of the banking system. For example, households respond to a reduction in the deposit rate paid by banks by reducing their deposit holdings and replacing them with imperfect substitutes, such as higher yielding but lower-liquidity assets.

Table 8 indicates that an increase in the YIV predicts a decrease in the level of bank deposits (Panels A and B) as well as an increase the volatility of bank deposits (Panels C and D). A one-standard deviation increase in the YIV is associated with a -0.32% decrease in the growth rate of bank deposits and an increase of 0.57% in the volatility of bank deposits at the 12-month horizon. Both coefficients are statistically significant at the 1% level with t-statistics of -4.84 and 2.47, respectively. Given that the average growth rate of bank deposits during our sample period is 0.57%, and that the average volatility of bank deposit growth rates during our sample period is 6.83%, the effect of the yield implied volatility on bank deposits is also economically meaningful.

Prior literature establishes that the supply of deposits from customers to banks varies over time and is counter-cyclical. For example, **?** show that when market liquidity declines deposits flow into the banking system. In other words, when business conditions decline, funds flow to banks because banks are viewed as safe havens (due to deposit insurance). The negative association between the YIV and deposit growth, that is robust to adding controls (Table 8 in appendix B) suggests that banks are less likely to seek increased customer deposits, perhaps because of increased uncertainty of the cost or interest to be paid on these deposits.

Next, interest rate uncertainty may impact bank cost of capital. Banks are primarily funded by short-term debt (such as deposits) and use these funds to finance longer-term risky loans. This maturity transformation – that is at the heart of banks' business model – exposes their balance sheet to interest rate uncertainty. An increase in interest rate uncertainty is likely to make banks more risky, because of increased risk related to either the interest to be paid on their short-term debt (or deposits) or the interest to be received from their customers, both of which could impact their cost of capital.

As a proxy for the bank cost of capital, we use Libor-OIS spread for the widely used three-month maturity, i.e. the difference between the three-month USD London interbank offer rate (Libor) at which banks in London lend to each other and the three-month USD overnight index swap (OIS) rate that captures borrowing rates in the Treasury market. The Libor-OIS spread proxies for the price of bank credit and liquidity risk, relative to the risk-free rate for inter-bank loans, as Libor measurs banks' unsecured term wholesale borrowing rates and OIS measures the borrowing rates of the federal government of the U.S.

Table 9 shows results for predictive regressions of the Libor-OIS spread on the YIV alone (Panel A) and on the YIV and the current Libor-OIS spread (Panel B) 12, 18, 24, 30, and 36 months ahead. We find that an increase in the YIV predicts an increase in the Libor-OIS spread and hence an increase in the cost of borrowing in the interbank market. A one-standard deviation increase in the YIV is associated with a 30 basis point increase in the Libor-OIS spread at the 12-month horizon. Over our sample period, the average Libor-OIS spread is around 6 basis points. Thus, an increase in Libor-OIS of 30 basis points due to a one-standard deviation shock to the YIV is economically significant.

As an alternative proxy for bank cost of capital, panels C and D of Table 9 examine the predictive relation between the YIV and the dividend yield of an index of bank stocks, a common proxy for expected returns (Fama and French (1989)). expected returns on bank stocks. The index of bank stocks is the bank index from 49 industry portfolios provided by Kenneth French. An increased YIV predicts an increased dividend yield and hence an increased equity cost of capital of banks. A one-standard deviation increase in the YIV is associated with up to 0.32% increase (compared to a sample mean of 0.41%) in the dividend-yield on bank stock at the 36-month horizon. Although the coefficient is not always significant, it is always positive and the effect is robust to controlling for the current dividend yield (in panel D).

Increased interest rate uncertainty negatively predicts changes in bank credit, measured as the year-on-year growth rate of total commercial and industrial loans extended by all commercial banks in the U.S. over a horizon of 1 - 3 years. The data for the commercial and industrial loans comes from the Federal Reserve report H.8, titled 'Assets and Liabilities of Commercial Banks in the U.S.' and is available at a monthly frequency over our full time period.

Panel A of Table 10 shows that a one-standard deviation increase in the YIV predicts a -0.13% decrease in the growth rate of bank credit over a one year horizon. This coefficient is statistically significant, with a t-statistic of -3.07. The adverse effect of YIV on bank credit growth persists for some time, as the YIV coefficient at a horizon of 36 months is comparable at -0.14% with a t-statistic of -5.06. Panel B of this Table shows that adding lagged values of bank credit growth hardly effects our results and Table A17 in Appendix B that results are robust when also adding controls. Economically, a one-standard deviation increase in YIV (equal to 1.17%) implies a $-0.13 \times 1.17 \times 12 = 1.83\%$ decrease in bank credit growth over a one year horizon. The sample bank credit growth is 6.12%, hence a one-standard deviation increase in the YIV implies that bank credit is curtailed by nearly 32%. Table A17 shows that changes in the short rate and the returns on an index of Treasury bond also predict bank credit growth. However, surprisingly, increases in short rates are associated with higher, and not lower level of bank credit growth, as the "bank lending" channel would suggest.

Panels C and D of Table 10 shows that the YIV also predicts future volatility of bank credit. A one-standard deviation increase in the YIV increases the annual volatility of bank credit by ($0.61 \times 1.17 = 0.71\%$), which is economically meaningful given that the average annual volatility of bank credit growth equals 1.37% over our sample period.

If banks cannot fully hedge interest rate uncertainty, then increases in YIV may matter more for banks with larger exposure to interest rate risk, such that we would expect YIV to have a stronger predictabiulity for the growth of credit given by banks with such larger exposure to interest rate risk. We argue that the ability of banks to hedge interest rate uncertainty is likely related to both the size of the bank as well as their involvement with interest rate derivatives. We expect larger banks to be better able to hedge interest rate uncertainty, because they have more resources to devote to risk management, while banks with greater participation in interest rate derivatives markets for trading purposes are more exposed to interest rate risk.

Accordingly, we independently double sort all banks into (i) two groups based on whether the total book value of their assets is above or below the sample median, and into (ii) two groups based on whether the ratio of the notional value of "interest rate derivatives held for trading" to the total book value of assets is above or below the sample median. Data of the amount of interest rate derivatives on bank balance sheet comes from the call report data collected by the Federal Reserve bank, which data is available on a quarterly basis for all bank holding companies.[30]

[30] Purnanandam (2007) shows that banks for whom the ratio of the notional value of "interest rate derivatives held for trading" to the total book value of assets is high are more exposed to interest rate risk and are more sensitive to monetary policy announcements.

Table 11 presents the results. Each panel in the table presents the results for a separate groups of banks. "Small" and "Large" refer to the subsamples of banks sorted by total book value of assets and "Low" and "High" refer to the subsamples of banks sorted by the ratio of notional value of derivatives held for trading to total book value of assets.

Panels A and B of Table 11 indicate that an increase in the YIV predicts a significantly larger decrease in bank credit growth for small banks with above-median interest rate derivatives on their balance sheet. A one-standard deviation increase in the YIV is associated with a -0.26% future decline in bank credit growth over the next 12-months for small banks with below-median interest rate derivatives exposure, but with a -1.66 decline (i.e. nearly 7 times as high) for small banks with above-median exposure.

Panels C of Table 11 shows analogous results for large banks. Consistent with the notion that large banks are better able to hedge interest rate uncertainty, YIS is less predictive of bank credit growth for large banks that for small banks. More specifically, we find that YIV only predicts bank credit growth for large banks with above-median balance sheet exposure to interest rate derivatives, though with significantly less economic magnitude than for small banks. A one-standard deviation increase in the YIV is associated with -0.18% decline in bank credit growth over the next 12-month horizon (statistically significant) for the subsample of banks with below-median balance sheet exposure to interest rate derivatives, and with a -0.31% decline (strongly statistically significant) for the subsample of banks with above-median balance sheet exposure to interest rate derivatives. Overall, the results in Table 11 suggest that changes in interest rate uncertainty matter more for future amount of credit provided by banks that are likely more exposed to such uncertainty, consistent with the bank credit channel explanation for the predictive association between YIV and real activity.

Finally, we examine the relation between interest rate uncertainty and investment growth of non-financial firms. We posit that if interest rate uncertainty impacts real activity via bank credit, then the relation between the YIV and investment growth is likely to be stronger for bank-dependent firms. Empirically, we follow Kashyap, Lamont, and Stein (1994) to measure the dependence of publicly traded firms on banks for their financing. Following their strategy, a publicly-traded firm is classified as bank dependent if it is not rated by a credit rating agency (i.e., has no publicly traded bonds outstanding) but still reports an interest expense on Compustat.

Panel A of Table 12 presents the results for aggregate investement growth regressions for the subsample of bank-dependent firms and Panel B presents for the subsampple of firms that are less dependent on banks. We find that higher interest rate uncertainty, as proxy by YIV, strongly predicts lower future investment growth for bank dependent firms, but not for the subsample of firms that are less dependent on bank financing. The predictability is strongest over shorter horizons. A one-standard deviation increase in the YIV is associated with a -0.53% decline in the investment growth of bank dependent firms at the 12-month horizon and this coefficient is statistically significant at the 5% level. Over our sample, the mean investment growth rate for bank dependent firms is 1.09% such that this coefficient is economically significant. Panel B indicates that there is no relation between the YIV and the investment growth of firms that are less dependent on banks. The coefficient on the YIV is almost zero at all horizons and the coefficient is not statistically significant at conventional levels.

Overall, the results in this section support the economic mechanism that interest rate uncertainty impacts real activity through bank balance sheets. Interest rate uncertainty directly impacts the asset and liabilities of banks. For example, an sudden unexpected increase in interest rates causes the value of bank assets to fall and their liabilities to increase. This depresses the net worth of banks, increasing their cost of capital, and thereby forcing banks to shrink their balance sheets. This contraction in bank balance sheets (lending) is what causes changes in the yield implied volatilities to influence real activity. Higher interest rate uncertainty also hinders the ability of bank managers to accurately assess the quantity and cost of capital available to them. Uncertainty about interest rates causes banks to limit the impact of such uncertainty on their balance sheets, and therefore adversely effects bank lending and hence is associated with lower levels of real activity.

6.2 Vector auto-regression

In this subsection, we employ a reduced form vector autoregression framework (VAR) system to determine Granger causality of the relations between the YIV, macroeconomic variables, and bank credit growth. The VAr allows us to investigate whether the predictability of the YIV for the macro variables primarily comes through the predictability of the YIV for bank credit growth, or whether the predictability of the YIV for the macroeconomic variables is more direct. Specifically, we estimate unrestricted (or reduced-form) VARs with the following specification:

$$Y_t = \alpha + \sum_{i=1}^{I=4} \beta_t Y_{t-i} + \epsilon_t \tag{11}$$

The Y_t variables are the YIV, the growth rate of aggregate industrial production, the return on an index of Treasury bonds, the return on an index of corporate bonds, the change in the short rate, the return on an value-weighted index of all stocks, the CBOE Volatility index (VIX), and the growth rates of aggregate bank credit. That is, the VAR systems includes 8 variables, one macroeconomic variable, the YIV, bank credit, and an additional 5 control variables. We include 4 lags for each variable, which lag structure is suggested by the data according to the minimum Akaike Information Criterion (AIC).

We do not present the estimated coefficients of equation 11, as the significance and the absolute magnitude of these coefficients are hard to interpret. Rather, we present the results for a series of Granger-causality tests for VAR system in Table 13. Each row reports the p-values from the Granger causality Wald Test (i.e. the χ^2 test) that the lagged values of the column variable have marginal predictive power for the row variable. The first row shows that lagged values of almost all VAR variables do not have significant predictive ability (Granger causality) for subsequent changes in the level of the YIV. The only variable that can significantly predict changes in the YIV is return on an index of investment grade corporate bonds, which result is marginally significant with a p-value of 0.06.

In contrast the YIV has significant predictive ability for the growth rate of industrial production (siginficant at the 1% level), as well as for the return on an value-weighted index of all stocks, and the stock market implied volatility, and bank credit growth (significant at the 5% level).[31]

Finally, the other predictive relations in Tables 13 are as expected. For example, the VIX predicts returns on the value-weighted index of all stocks, and the reverse relation also holds.[32] The Granger causality results also indicate that increases in the short rate adversely predict bank credit, consistent with the lending channel.

Figure 9 plots the impulse responses to a one-standard deviation shock increase to the YIV. Several interesting insights emerge from the analysis of the impulse response functions. First, shocks to the YIV (see the left panel in the first row) are fairly persistent, as a one-standard deviation shock to the YIV slowly declines over the next 20 months (consistent with its first-order autocorrelation of 0.71). Second, positive shocks to the YIV are followed by sustained decline in the year-on-year growth rate of both industrial production and bank credit. The decline in industrial production lasts for about one year, and the in bank credit extends for up to 20 months. Third, shocks to the YIV do not have a substantial effect on the returns on index of Treasury bonds or changes in the short rate, confirming the results in Table 13 that the YIV does not predict these two variables. Finally, a positive shock to the YIV results in a downward jump in the returns on corporate bonds and stocks and an increase in the VIX. However, in contrast to the response of industrial production, the effects for stock and bond returns and VIX are transitory and disappear within 3-5 months.

Figure 10 shows the reverse, namely the response of the YIV to a one-standard deviation increase of the other VAR variables, separately for each variable. The results indicate that shocks to the other variables have at most a transitory effect on the YIV, as any effect generally dissipates within a couple of months. The only exception is the shock to the growth rate of industrial production. As shown in the top-left panel, a positive shock to industrial production growth

[31]In untabulated results we confirm that these conclusions generally also hold for VAR systems with growth rates of consumption and employment. That is, the YIV has significant marginal predictive power for the growth rates of consumption and employment, but not vice versa.

[32]Similarly, the VIX also predicts the returns on an index of corporate bonds, which is consistent with Cremers, Driessen, and Maenhout (2008) who show that implied volatilities from options have important information for credit spreads.

causes a drop in the YIV, which persists for at least one year. However, this is consistent with the YIV being a proxy for interest rate uncertainty and thus capturing an important aspect of macroeconomic uncertainty. An unexpected jump in industrial production growth indicates an improved macroeconomic outlook and thus reduced uncertainty, resulting in a persistent decrease in the YIV.

7 Conclusion

In conclusion, we make two main contributions. First, we introduce a novel measure of interest rate uncertainty from interest rate derivatives, namely the implied volatility in Treasury note futures (the YIV) and show that increases in the YIV negatively predict the growth and positively predict the volatility of real activity. These predictability results are economically and statistically significant and robust to other well-known forecasting variables. As a result, the YIV can serve as a simple leading indicator for the likelihood of future "aggregate bad times" that is readily available to market participants in real time.

Second, we show that the bank credit channel is a plausible economic explanation for the predictability of the YIV for real activity, where increases in interest rate uncertainty limit the ability of banks to provide credit, which in turn limits real activity. Empirically, increases in the YIV predict increases in bank cost of capital and short-term borrowing costs, and decreases in the amount of credit they provide, and also predicts reduced investments by bank-dependent industrial firms.

Finally, our results are robust to a reduced-form VAR system that simultaneously estimates Granger predictability of growth rates of real activity, bank credit, and a number of other frequently used financial variables.

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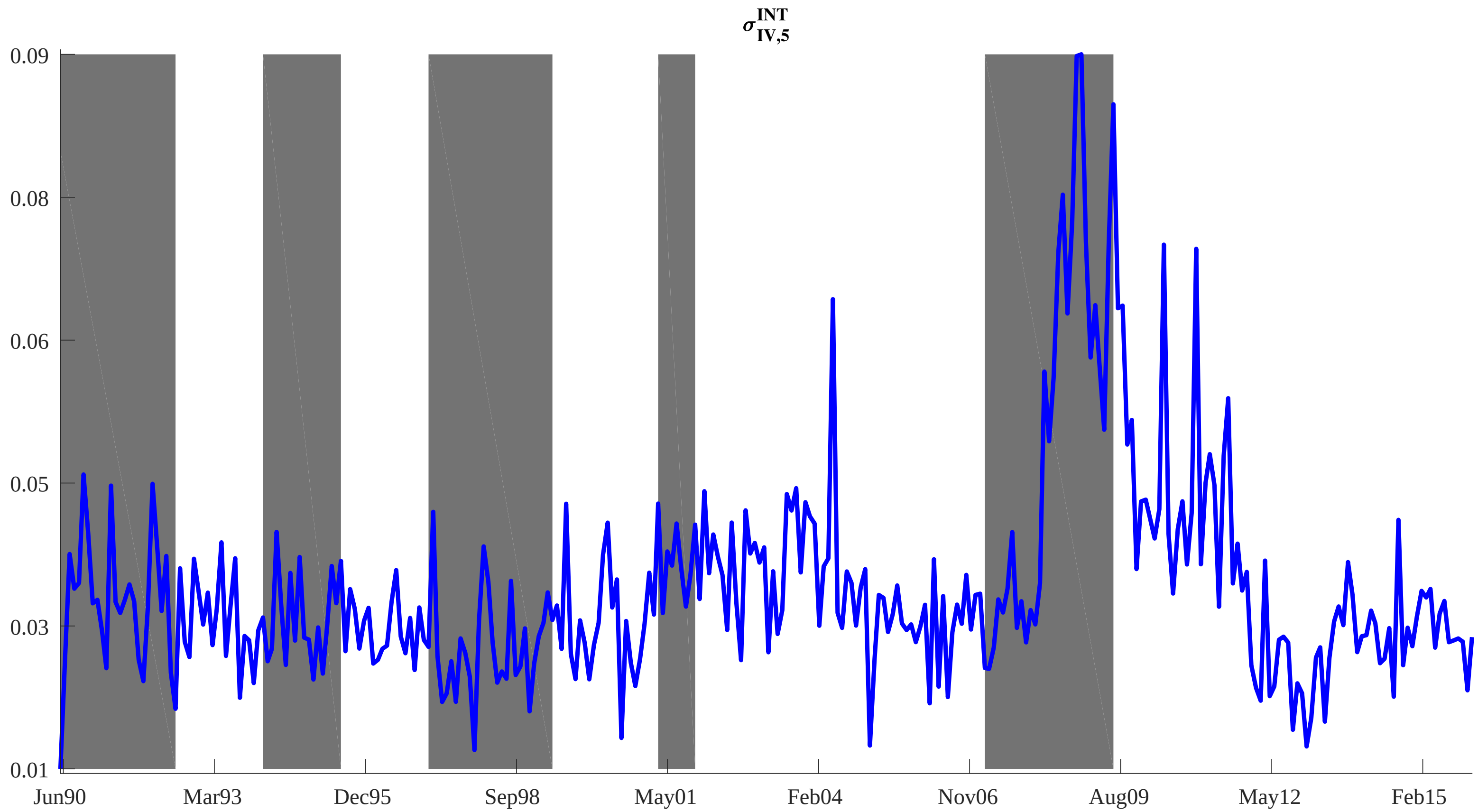
Figure 1. Time series plot for the YIV.

Notes: This figure plots the YIV. The grey shaded regions represent NBER recessions and financial crisis. The NBER recession dates are published by the NBER Business Cycle Dating Committee. The dates for financial crisis are obtained from Kho, Lee, and Stulz (2000), Romer and Romer (2015), and the FDIC. Monthly data, 1990 - 2015.



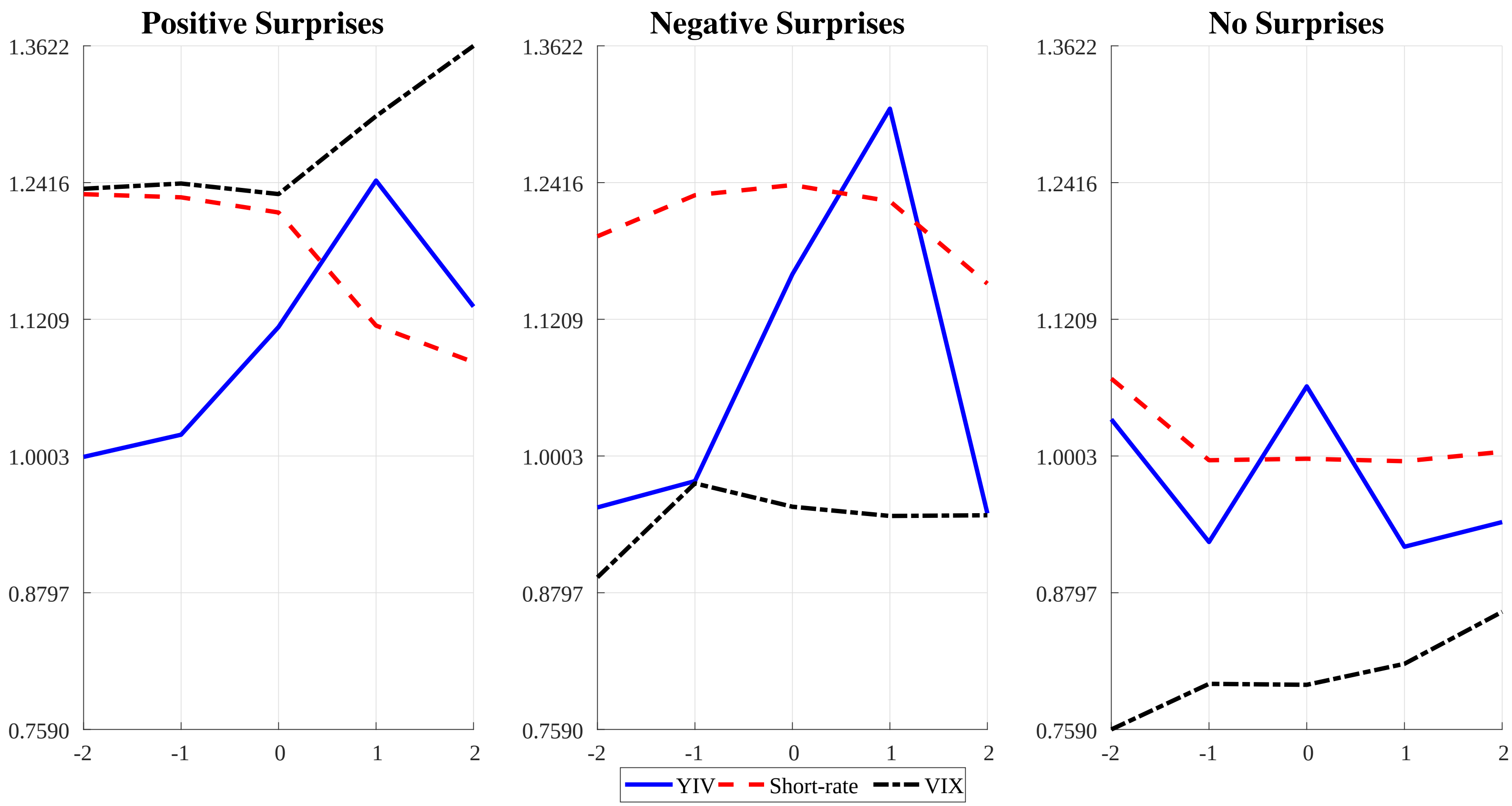


Figure 2. Response of implied volatility to monetary policy surprises.
This figure plots the YIV, the short rate (yield-to-maturity on the 1-year note), and the stock market implied volatility (VIX) over a 5-day window around U.S. Federal Reserve's announcements regarding changed in the Federal Funds rate. We categorize all announcements into three categories: Positive surprises, Negative surprises, or No surprises. Surprises are computed by comparing the actual change in the Federal Funds rate to the market expectation before the announcement. A negative surprise is when the U.S. Federal Reserve cuts the Federal Funds rate to a level that is below expected by market participants, indicating that macroeconomic risk may be higher than anticipated by market participants prior to announcements. Each panel shows the results for a different type of announcement. The left panel shows how the YIV, the short rate, and the VIX react to positive surprises in the Federal Funds rate. In each panel, The solid (blue) line refers to the YIV, the long-dashed (red) line refers to the short rate, and the short-dashed (black) line refers to the VIX. The date of announcement is normalized to zero, with negative (positive) days indicating days before (after) the announcement. Daily data, 1990 - 2016.

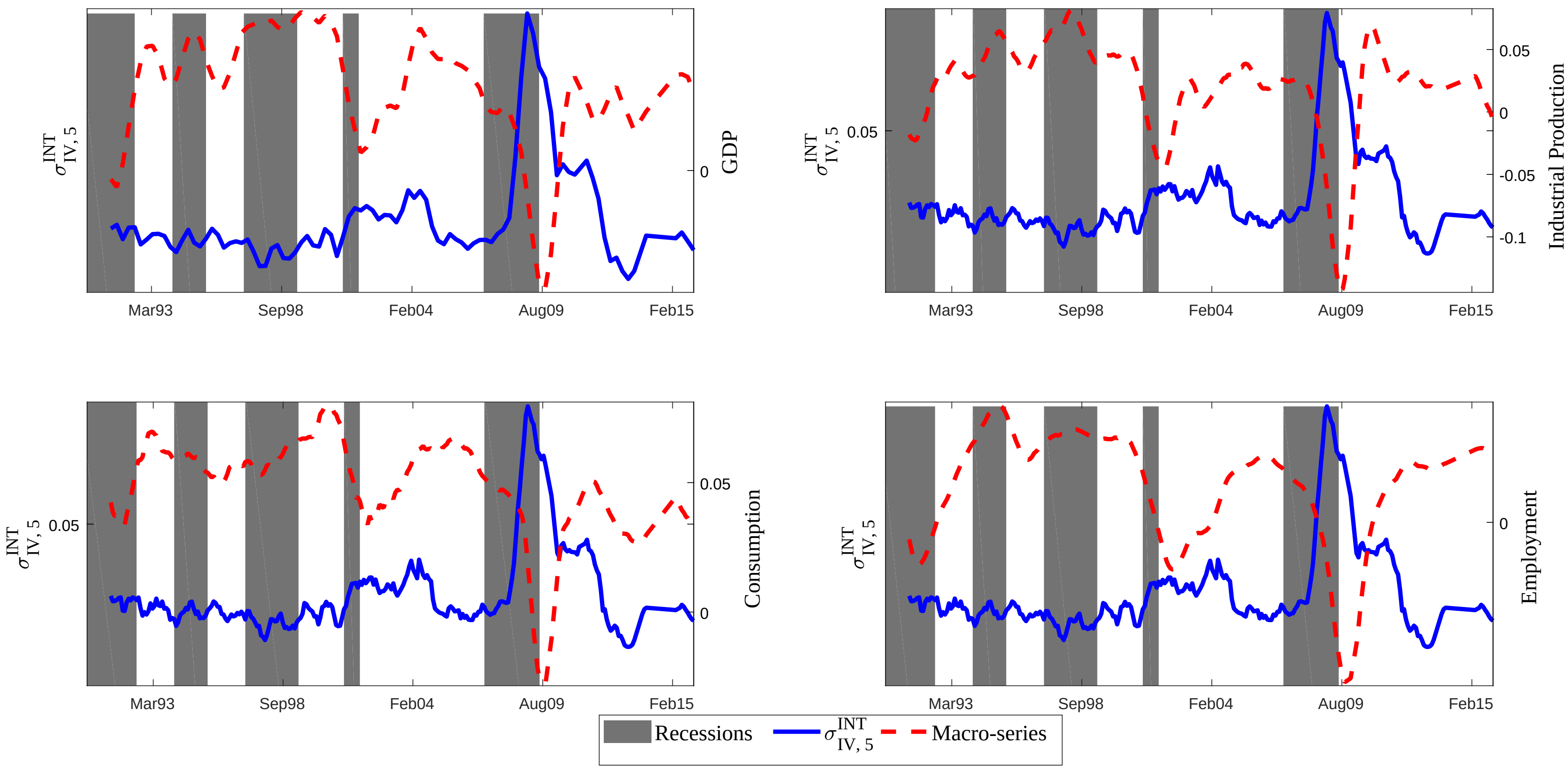


Figure 3. Moving averages of YIV and macroeconomic variables
This figure plots the 12-month lagged (backward-looking) moving average (months t-12 through t) of the YIV and various macroeconomic variables. The months are indicated on the x-axis. Each panel shows the results for a different macroeconomic variable. The top-left panel shows the results for gross domestic product. In each panel, the solid blue line is the YIV and the red dashed line is the macroeconomic variable. The grey shaded regions represent NBER recessions and financial crises. The NBER recession dates are published by the NBER Business Cycle Dating Committee. The dates for financial crisis are obtained from Kho, Lee, and Stulz (2000) and Romer and Romer (2015). Data for gross domestic product is quarterly. For other variables we use monthly data, 1990 - 2016.

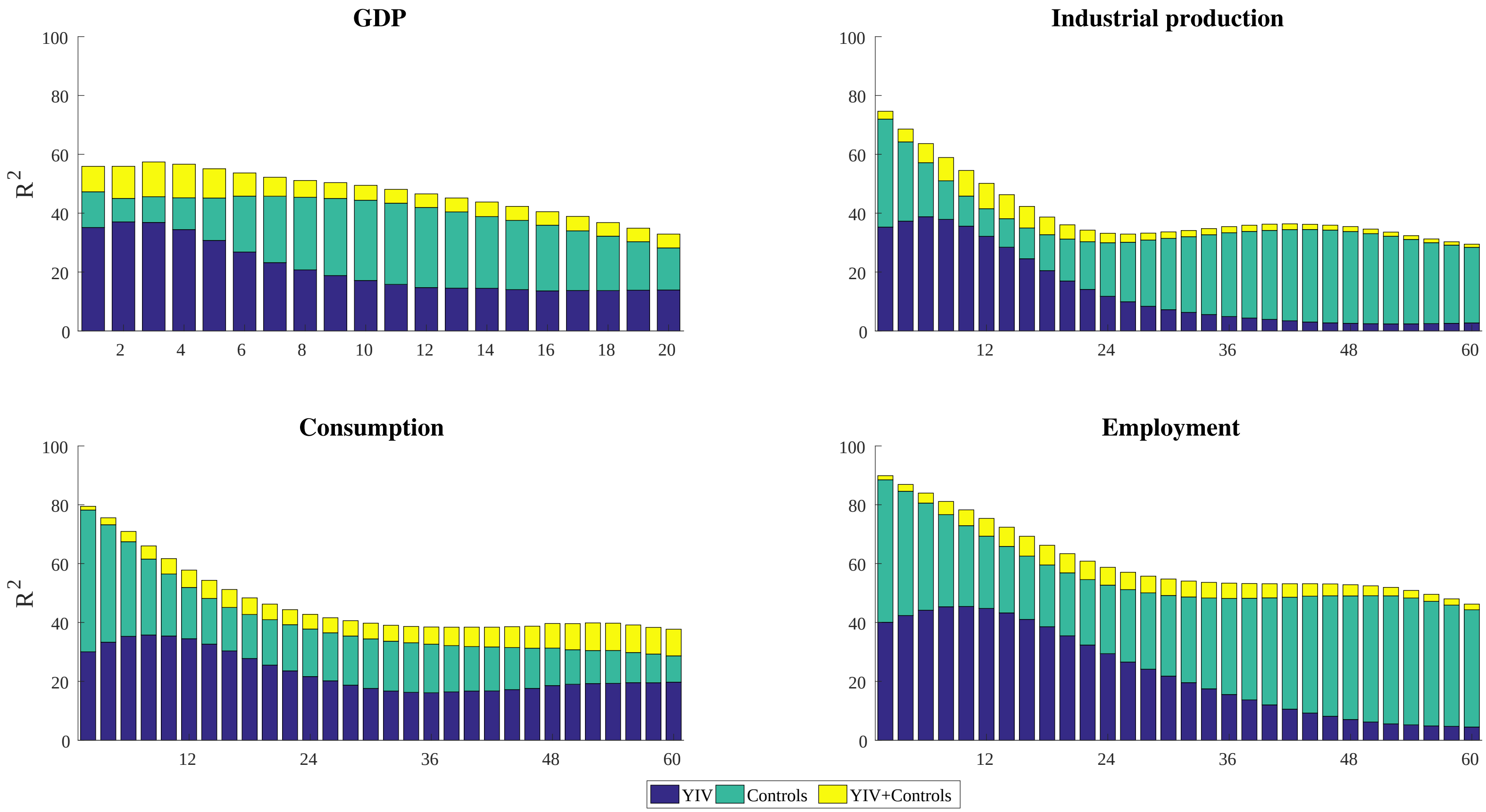


Figure 4. R-squared for predictive regressions of growth rates
This figure plots the value of the R^2 for the predictive regressions of various macroeconomic variables. The months are indicated on the x-axis. Each panel shows the results for a different macroeconomic variable. The top-left panel shows the results when the year-on-year growth rate of gross domestic product is used as the dependent variable. In each panel, for each month, the blue bar shows the R-squared achieved in a predictive regression with only the control variables (the term spread, the short rate, the Treasury bond index, the corporate bond index, the value-weighted stock returns index, the CBOE volatility index, and the economic uncertainty index from Baker, Bloom, and Davis (2015)), and the yellow bar shows the marginal additional R-squared achieved by including the YIV. Data for gross domestic product is quarterly. For all other variables we use monthly data, 1990 - 2016.

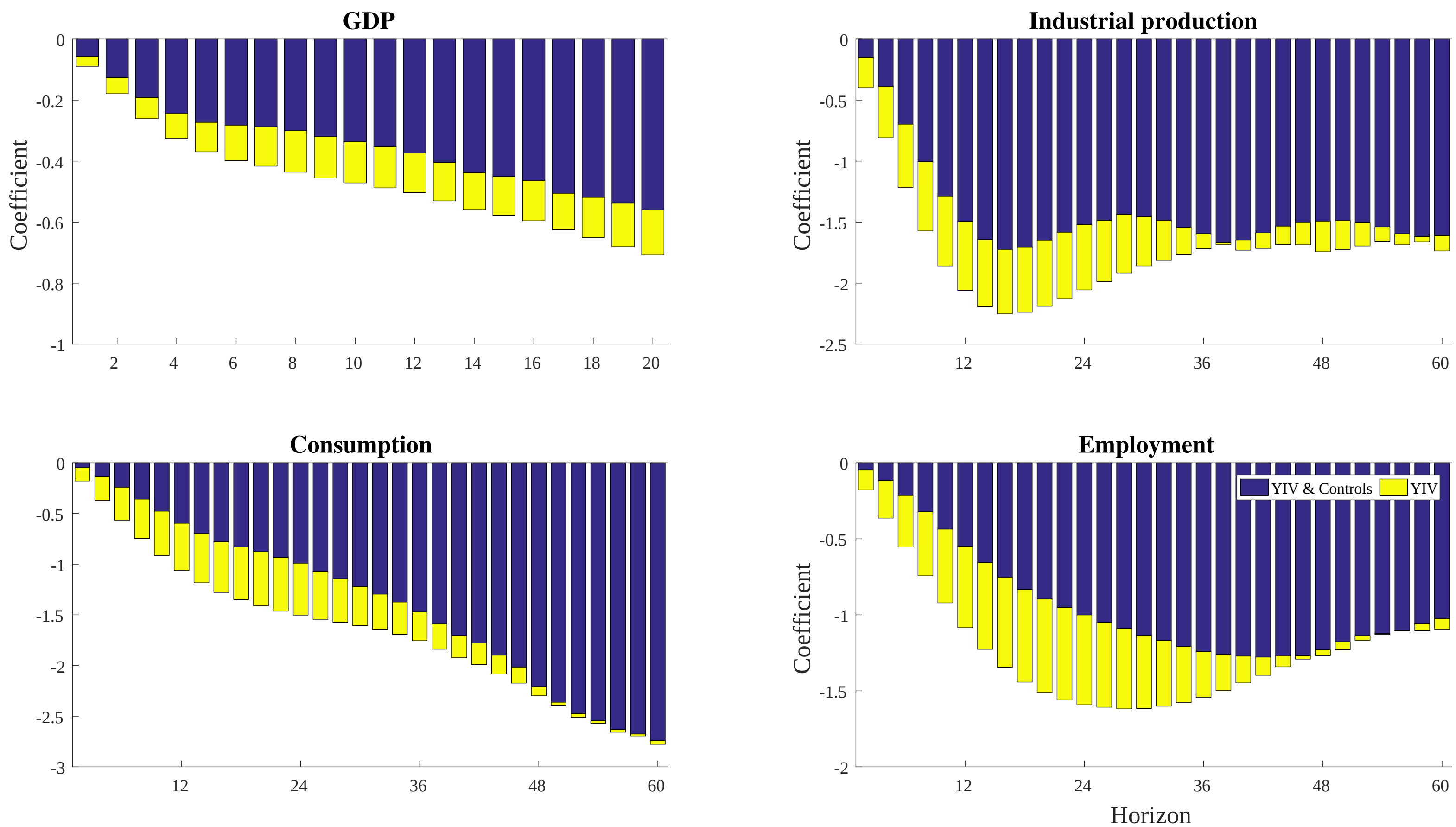


Figure 5. Coefficients for predictive regressions of growth rates

This figure plots the value of the coefficients on the YIV for the predictive regression of various macroeconomic variables. The months are indicated on the x-axis. Each panel shows the results for a different macroeconomic variable. The top-left panel shows the results when the year-on-year growth rate of gross domestic product is used as the dependent variable. In each panel, for each month, the blue bar shows the coefficient on the YIV with the control variables (the term spread, the short rate, the Treasury bond index, the corporate bond index, the value-weighted stock returns index, the CBOE volatility index, and the economic uncertainty index from Baker, Bloom, and Davis (2015)). The yellow bar shows the additional coefficient on the YIV when it is the only predictive variable in the regression. Data for gross domestic product is quarterly. For all other variables we use monthly data, 1990 - 2016.

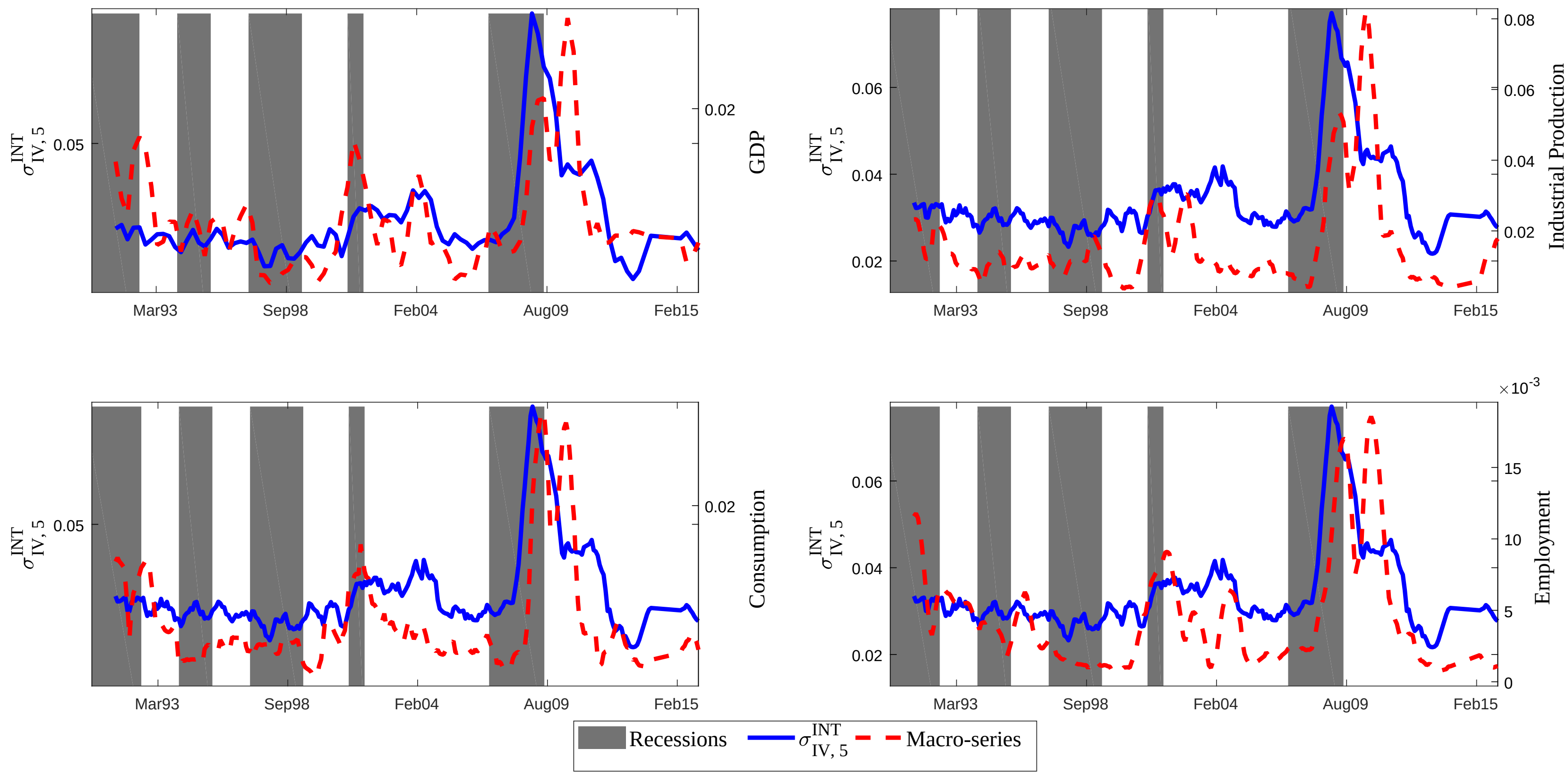


Figure 6. Moving standard deviation of YIV and macroeconomic variables
This figure plots the 12-month lagged (backward-looking) moving standard deviation (months t-12 through t) of the YIV and various macroeconomic variables. The months are indicated on the x-axis. Each panel shows the results for a different macroeconomic variable. The top-left panel shows the results for gross domestic product. In each panel, the solid blue line is the YIV and the red dashed line is the macroeconomic variable. The grey shaded regions represent NBER recessions and financial crisis. The NBER recession dates are published by the NBER Business Cycle Dating Committee. The dates for financial crisis are obtained from Kho, Lee, and Stulz (2000) and Romer and Romer (2015). Data for gross domestic product is quarterly. For other variables we use monthly data, 1990 - 2016..

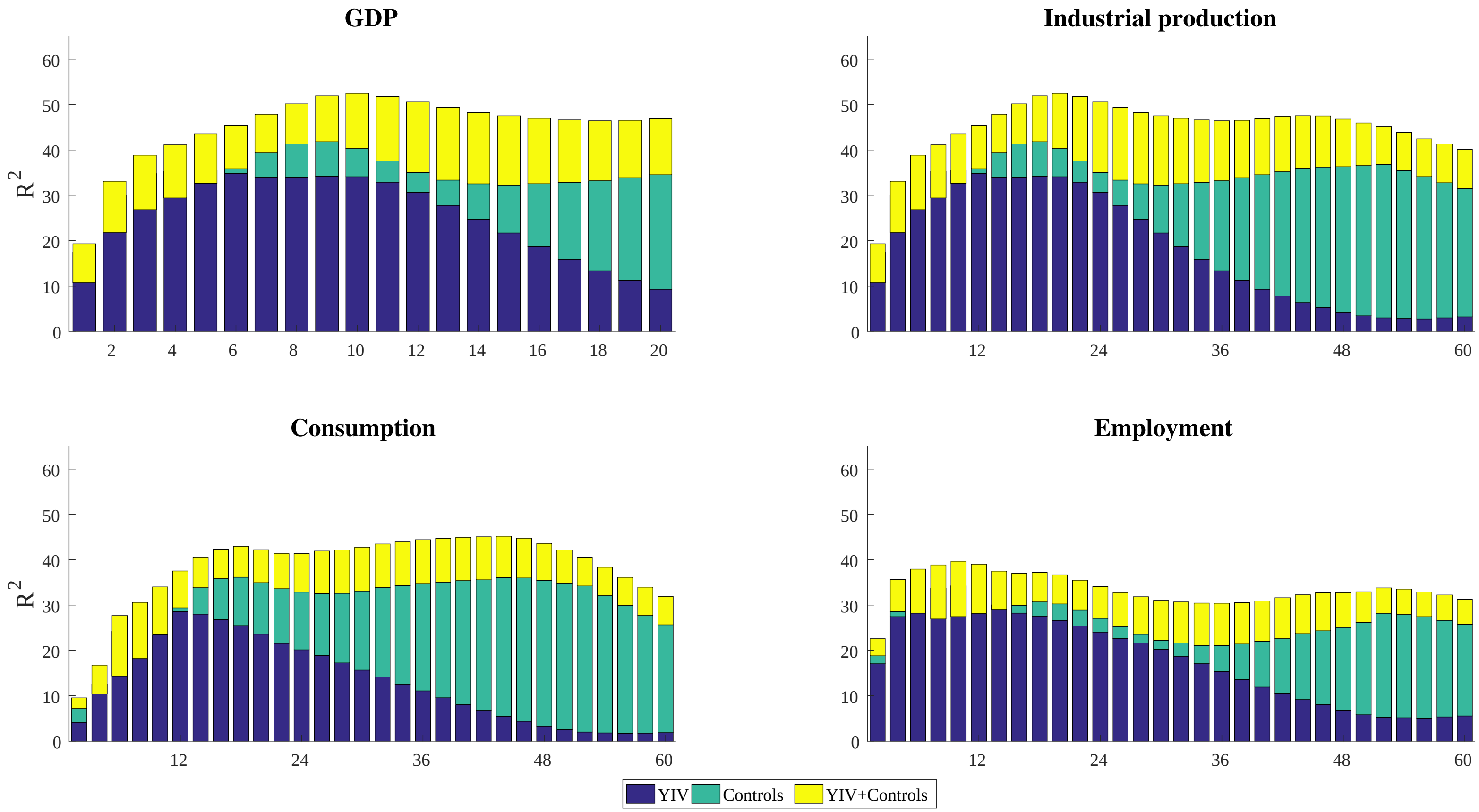


Figure 7. R-squared for predictive regressions of volatility
This figure plots the value of the R^2 for the predictive regressions of various macroeconomic variables. The months are indicated on the x-axis. Each panel shows the results for a different macroeconomic variable. The top-left panel shows the results when the volatility of the year-on-year growth rate of gross domestic product is used as the dependent variable. In each panel, for each month, the blue bar shows the R-squared achieved in a predictive regression with only the control variables (the term spread, the short rate, the Treasury bond index, the corporate bond index, the value-weighted stock returns index, the CBOE volatility index, and the economic uncertainty index from Baker, Bloom, and Davis (2015)), and the yellow bar shows the marginal additional R-squared achieved by including the YIV. Data for gross domestic product is quarterly. For all other variables we use monthly data, 1990 - 2016.

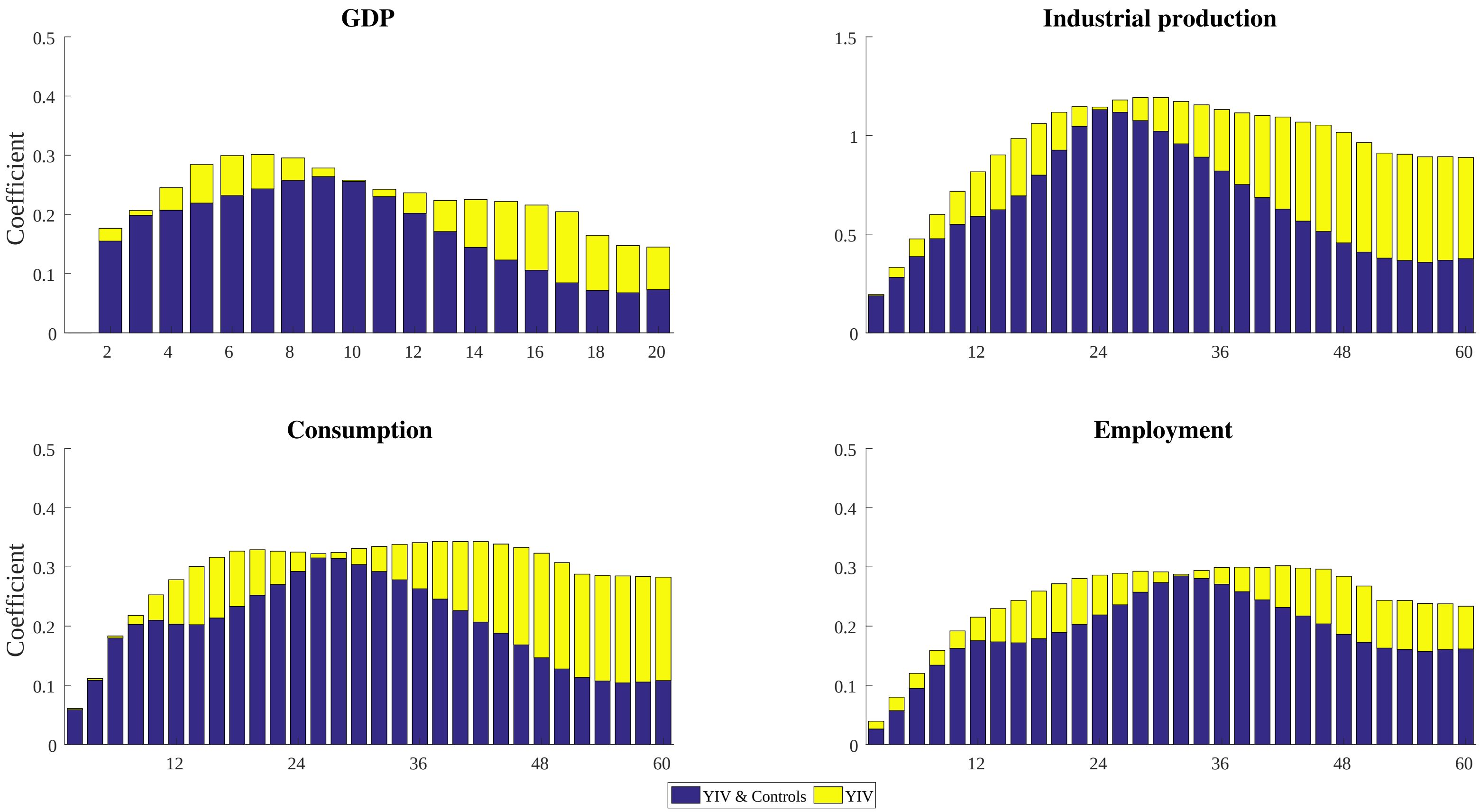


Figure 8. Coefficients for predictive regressions of volatility
This figure plots the value of the coefficients on the YIV for the predictive regression of various macroeconomic variables. The months are indicated on the x-axis. Each panel shows the results for a different macroeconomic variable. The top-left panel shows the results when the volatility of the year-on-year growth rate of gross domestic product is used as the dependent variable. In each panel, for each month, the blue bar shows the coefficient on the YIV with the control variables (the term spread, the short rate, the Treasury bond index, the corporate bond index, the value-weighted stock returns index, the CBOE volatility index, and the economic uncertainty index from Baker, Bloom, and Davis (2015)). The yellow bar shows the additional coefficient on the YIV when it is the only predictive variable in the regression. Data for gross domestic product is quarterly. For all other variables we use monthly data, 1990 - 2016.

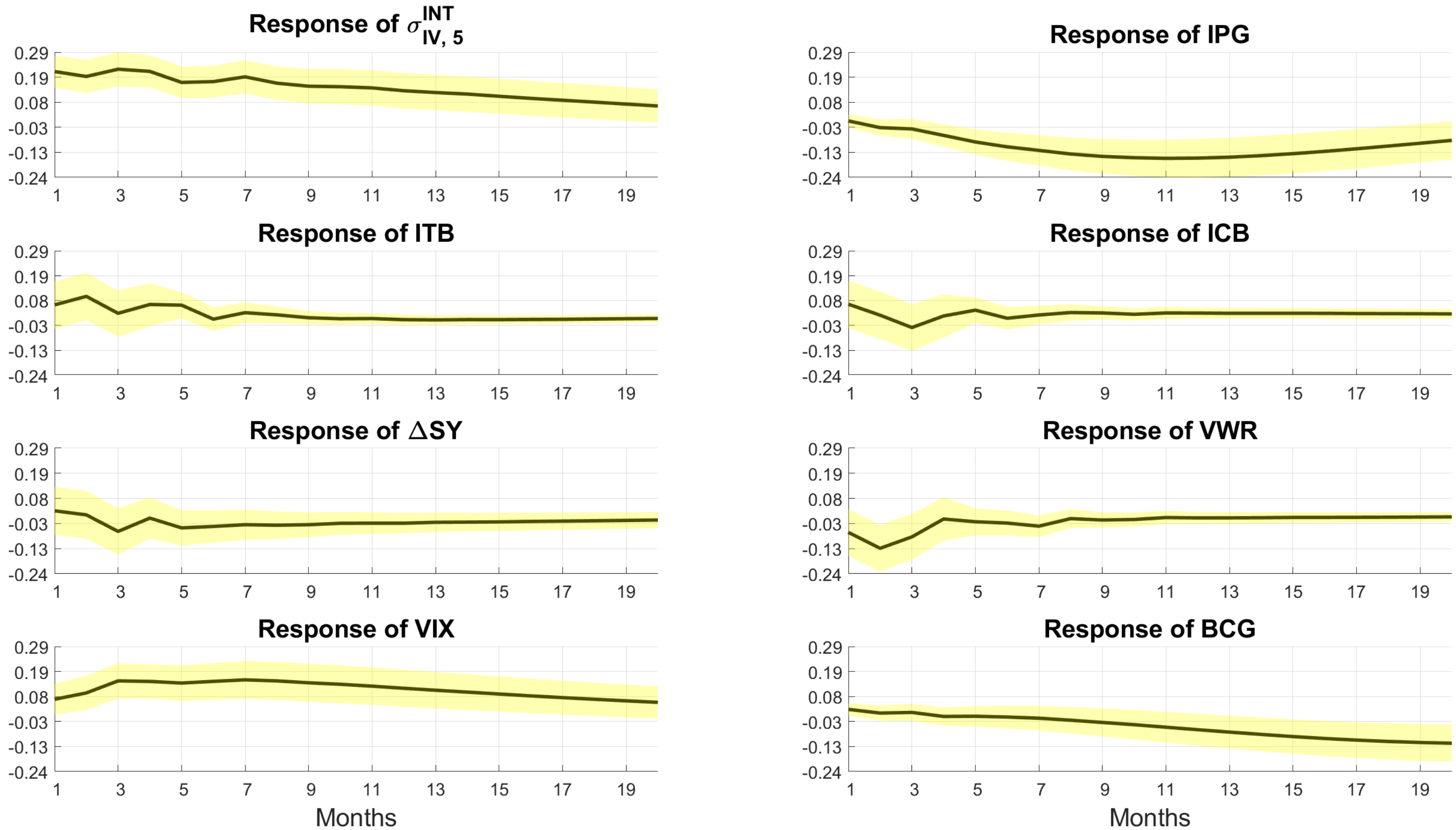


Figure 9. Impulse response function of macroeconomic, bond, and stock market variables.
This figure plots the response of macroeconomic, bond, and stock market variables to a one-standard-deviation shock to the YIV. Each panel shows the response for a separate variable. The top-left panel shows the response of YIV itself and the top-right panel shows the response of an index of Treasury bonds to a one-standard-deviation-shock to the YIV. Bands around the plots indicate the confidence bounds at the 95% confidence levels.

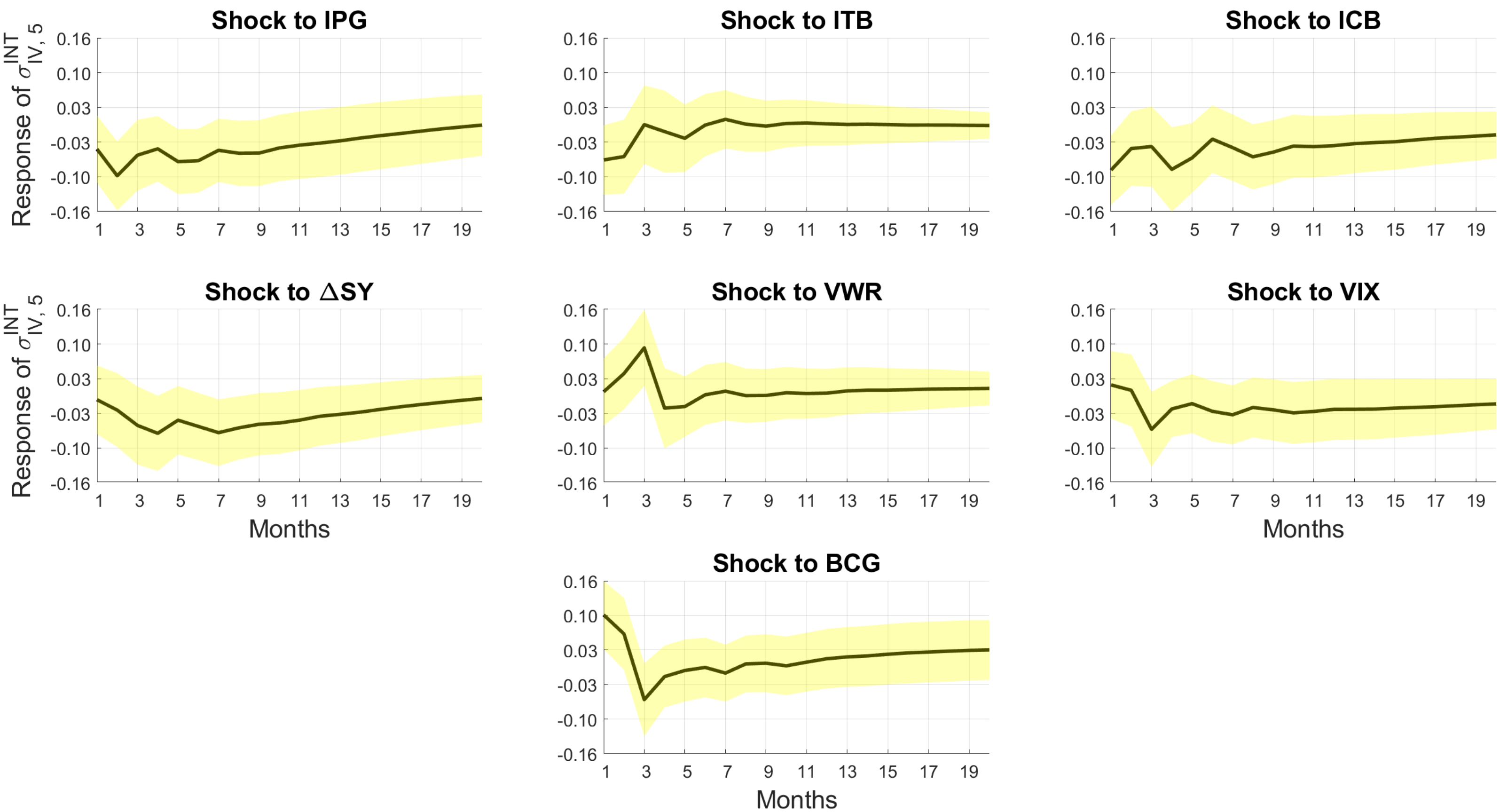


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Figure 10. Impulse response function of YIV.
This figure plots the response of YIV to a one-standard deviation shock to macroeconomic, bond, and stock market variables. Each panel shows the response of YIV for shock to a separate variable. The top-left panel shows the response of YIV to a one-standard deviation shock to the year-on-year growth rate of industrial production, and the top-right panel shows the response of YIV to a shock to returns on an index of U.S. investment grade corporate bonds. Bands around the plots indicate the confidence bounds at the 95% confidence levels.

Table 1. Summary statistics.

Notes: This Table shows the summary statistics for the YIV and various dependent and control variables. Column 1 indicates the variable for which summary statistics are computed. Columns 2-8 report the mean, the standard deviation, the minimum, the 25^{th}-percentile, the 50^{th}-percentile, the 75^{th}-percentile, and maximum values. The last column shows the first-order auto-correlation. GDP, IND, CON, EMP, and BCG are the year-on-year growth rate in gross domestic product, industrial production, consumption, non-farm payroll, and bank credit, respectively. TRM is the term spread as measured by the difference in the yield-to-maturity on the 10-year bond and the 1-year note issued by the U.S. Treasury, ΔSY is the change in the short-rate or the yield-to-maturity on the 1-year note issued by the U.S. Treasury, ITB is the return on an index of all U.S. Treasury bonds, ICB is the return on an index of all U.S. investment grade bonds, VWR is the value weighted return on an index of all stocks in the CRSP database, σ_{IV}^{VIX} is the CBOE volatility index, and UNC is the equity market-related economic uncertainty index from Baker, Bloom, and Davis (2015). All values are multiplied by 100 and are expressed in percentages. In addition, data for ITB, ICB, and VWR is annualized by multiplying by 12. Monthly data, 1990 - 2015.

Sample	Mean	σ	Min	25^{th}	Median	75^{th}	Max	ρ
Panel A: YIVs								
$\sigma_{IV,5}^{INT}$	3.38	1.17	1.37	2.71	3.12	3.67	9.21	0.71
Panel B: Dependent variables								
GDP	2.44	1.80	-4.06	1.65	2.63	3.71	5.27	0.90
IND	2.03	4.04	-15.68	1.29	2.69	4.31	9.03	0.97
CON	4.83	1.99	-3.37	3.87	5.10	6.24	9.01	0.95
EMP	1.06	1.68	-5.01	0.20	1.59	2.17	3.53	0.99
BCG	5.77	4.50	-7.96	2.73	6.63	9.39	12.85	0.98
Panel C: Control variables								
TRM	1.76	1.16	-0.38	0.72	1.84	2.77	3.70	0.98
ΔSY	-0.02	0.20	-0.70	-0.11	-0.01	0.07	0.67	0.48
ITB	2.71	33.67	-111.84	-16.02	2.88	23.61	142.84	0.02
ICB	1.34	18.22	-77.18	-8.49	2.17	10.41	91.51	0.12
VWR	10.35	52.25	-221.56	-21.60	15.79	45.85	138.42	0.09
σ_{IV}^{VIX}	19.81	7.69	10.82	14.20	17.73	23.62	62.64	0.89
UNC	75.81	60.08	13.09	38.63	57.20	90.95	496.03	0.67

Table 2. Correlation with macroeconomic, bond, and stock market variables.

Notes: This Table shows the correlation between YIV and various macroeconomic, bond, and stock market variables. In the Table, GDP refers to gross domestic product, IND refers to the index of industrial production, CON refers to personal consumption expenditure, EMP refers to total non-farm payroll, TRM refers to the changes in the term spread as measured by the difference between the yield-to-maturity on the 10-year bond and the 1-year note issued by the U.S. Treasury, ΔSY measures the changes in the short-rate (yield-to-maturity on 1-year note), ITB measures the return on an index of all U.S. Treasury bonds, ICB measures the return on an index of all investment grade U.S. corporate bonds, VWR and EWR refer to value-weighted and equal-weighted returns of all stocks in Center for Research on Security Prices (CRSP), respectively, VIX is the Chicago Board of Options Exchange Volatility Index, and UNC is the equity market-related economic uncertainty index from Baker, Bloom, and Davis (2015). The numbers in parenthesis are the *p*-values. All data is monthly data except for gross domestic product which is quarterly. Correlations are computed over longest available sample for each paired variable.

Panel A: Macroeconomic variables

Variable	$\sigma_{IV,5}^{INT}$	GDP	IND	CON	EMP
GDP	-0.54***	1.00			
	(0.01)				
IND	-0.45***	0.89***	1.00		
	(0.01)	(0.01)			
CON	-0.41***	0.47***	0.38***	1.00	
	(0.01)	(0.01)	(0.01)		
EMP	-0.57***	0.85***	0.81***	0.53***	1.00
	(0.01)	(0.01)	(0.01)	(0.01)	

Panel B: Bond market variables

Variable	$\sigma_{IV,5}^{INT}$	TRM	ΔSY	ITB	ICB
TRM	0.18***	1.00			
	(0.01)				
ΔSY	-0.12**	-0.38***	1.00		
	(0.04)	(0.01)			
ITB	0.04	-0.39***	-0.34***	1.00	
	(0.47)	(0.01)	(0.01)		
ICB	0.00	-0.22***	-0.41***	0.62***	1.00
	(0.97)	(0.01)	(0.01)	(0.01)	

Panel C: Stock market variables

Variable	$\sigma_{IV,5}^{INT}$	VWR	EWR	σ_{IV}^{VIX}	UNC
VWR	-0.16***	1.00			
	(0.00)				
EWR	-0.08	0.86***	1.00		
	(0.18)	(0.00)			
σ_{IV}^{VIX}	0.49***	-0.27***	-0.24***	1.00	
	(0.00)	(0.00)	(0.00)		
UNC	0.12**	-0.22***	-0.21***	0.57***	1.00
	(0.03)	(0.00)	(0.00)	(0.00)	

Table 3. Predicting interest rates.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$INT_{i,t+j} = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is the YIV measured at time t and $INT_{i,t+j}$ is either the volatility of the 2-year, 5-year, or the 10-year nominal risk-free rate measured at time $t+j$. The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H=$	12	18	24	30	36	12	18	24	30	36
	Panel A: Volatility 2-year rate					Panel B: Volatility 2-year rate with lags				
$\sigma^{INT}_{IV,5}$	1.45**	1.06*	0.63	0.27	-0.26	1.30**	1.51*	1.63	1.90	1.41
	(1.98)	(1.75)	(0.84)	(0.29)	(-0.23)	(2.20)	(1.66)	(1.50)	(1.46)	(1.02)
Lag Vol 2-year						1.23	0.84	0.25	0.14	0.24
						(1.16)	(0.80)	(0.19)	(0.08)	(0.14)
R^2-ord	6.02	2.33	0.61	0.09	0.07	14.94	9.21	7.97	10.55	13.56
	Panel C: Volatility 5-year rate					Panel D: Volatility 5-year rate with lags				
$\sigma^{INT}_{IV,5}$	1.22***	1.11**	1.02**	1.34***	1.66***	0.88*	0.83*	0.59	1.22*	1.39***
	(2.33)	(2.24)	(2.06)	(2.43)	(2.49)	(1.95)	(1.72)	(1.03)	(1.91)	(2.52)
Lag Vol 5-year						-0.24	-0.53	-0.88	-1.08*	-1.21**
						(-0.38)	(-0.96)	(-1.58)	(-1.83)	(-2.22)
R^2-ord	8.01	6.01	4.71	7.43	10.08	12.86	10.75	12.37	18.56	28.44
	Panel E: Volatility 10-year rate					Panel F: Volatility 10-year rate with lags				
$\sigma^{INT}_{IV,5}$	0.63	0.66	0.72	1.17**	1.73***	0.11	-0.12	-0.41	0.14	0.62*
	(1.57)	(1.38)	(1.48)	(2.23)	(3.20)	(0.29)	(-0.34)	(-1.01)	(0.34)	(1.69)
Lag Vol 10-year						0.35	0.46	0.42	0.32	0.32
						(1.11)	(1.47)	(0.95)	(0.77)	(1.04)
R^2-ord	4.28	3.75	3.91	9.12	17.91	16.09	20.21	22.28	24.78	34.15

Table 4. Predicting growth rates of macroeconomic quantities.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + MACRO_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $MACRO_{i,t+j}$ is the year-on-year growth rate in the gross domestic product (GDP), industrial production (IND), consumption (CON), or employment (EMP) measured at time $t+j$. The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Quarterly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: GDP					Panel B: GDP with lags				
$\sigma_{IV,5}^{INT}$	-0.08***	-0.07***	-0.05***	-0.05***	-0.04***	-0.07***	-0.06***	-0.05***	-0.04***	-0.04***
	(-3.61)	(-3.46)	(-3.83)	(-3.99)	(-3.72)	(-2.89)	(-2.82)	(-3.28)	(-3.70)	(-3.79)
Lag GDP						0.02	0.02	0.01	0.01	0.01
						(1.05)	(0.90)	(0.80)	(0.64)	(0.48)
$R^2 - ord$	34.42	26.80	20.72	17.12	14.72	36.05	28.06	21.77	17.77	15.05
	Panel C: IND					Panel D: IND with lags				
$\sigma_{IV,5}^{INT}$	-0.17***	-0.12***	-0.09***	-0.06***	-0.05**	-0.13**	-0.10*	-0.07*	-0.04*	-0.03*
	(-2.90)	(-2.61)	(-2.66)	(-2.48)	(-2.00)	(-2.05)	(-1.79)	(-1.72)	(-1.85)	(-1.83)
Lag IND						0.07	0.04	0.03	0.03	0.03
						(1.28)	(0.73)	(0.75)	(0.82)	(0.75)
$R^2 - ord$	32.13	20.47	11.75	7.20	4.87	35.76	21.81	13.12	8.81	6.13
	Panel E: CON					Panel F: CON with lags				
$\sigma_{IV,5}^{INT}$	-0.09***	-0.07***	-0.06***	-0.05***	-0.05***	-0.06*	-0.05*	-0.04*	-0.04**	-0.03**
	(-3.31)	(-3.19)	(-3.36)	(-3.52)	(-3.76)	(-1.86)	(-1.84)	(-1.89)	(-1.99)	(-2.30)
Lag CON						0.07***	0.05**	0.04*	0.03*	0.03**
						(3.02)	(2.23)	(1.92)	(1.89)	(2.17)
$R^2 - ord$	34.48	27.76	21.63	17.58	16.11	49.70	37.62	28.65	22.75	19.51
	Panel G: EMP					Panel H: EMP with lags				
$\sigma_{IV,5}^{INT}$	-0.09***	-0.08***	-0.07***	-0.05***	-0.04***	-0.05***	-0.05***	-0.05***	-0.04***	-0.04***
	(-6.25)	(-5.36)	(-4.97)	(-4.71)	(-4.06)	(-2.88)	(-2.74)	(-2.82)	(-3.07)	(-3.25)
Lag EMP						0.07***	0.05***	0.03**	0.02	0.01
						(4.57)	(3.02)	(2.09)	(1.32)	(0.74)
$R^2 - ord$	44.77	38.55	29.40	21.78	15.52	61.80	47.71	34.44	24.15	16.42

Table 5. Predicting volatility of macroeconomic quantities.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sigma(MACRO_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $MACRO_{i,t+j}$ is either the year-on-year growth rate in gross domestic product (Panels A and B), the index of industrial production (Panels C and D), the year-on-year growth rate in consumption (Panels E and F), or the year-on-year growth rate in employment (Panels G and H) measured at time $t+j$. The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Data for gross domestic product is quarterly. For other variables we use monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: GDP					Panel B: GDP with lags				
$\sigma_{IV,5}^{INT}$	0.25***	0.30***	0.30**	0.26**	0.20**	0.25***	0.33***	0.36***	0.35***	0.32***
	(2.95)	(2.71)	(2.30)	(2.12)	(2.03)	(3.30)	(3.22)	(3.06)	(3.27)	(3.71)
Lag σGDP						-0.01	-0.09	-0.19**	-0.28***	-0.34***
						(-0.22)	(-1.21)	(-2.12)	(-2.55)	(-2.75)
$R^2 - ord$	25.29	25.13	19.93	14.05	8.86	25.35	26.99	27.45	29.19	30.60
	Panel C: IND					Panel D: IND with lags				
$\sigma_{IV,5}^{INT}$	0.82***	1.06***	1.14***	1.02***	0.82***	0.71***	1.03***	1.25***	1.22***	1.05***
	(3.60)	(3.31)	(3.04)	(2.84)	(2.49)	(3.82)	(3.61)	(3.06)	(2.74)	(2.42)
Lag σIND						0.20	0.06	-0.21	-0.38	-0.44
						(0.83)	(0.25)	(-0.88)	(-1.25)	(-1.34)
$R^2 - ord$	34.80	34.21	30.66	21.69	13.35	36.33	34.29	31.41	23.86	16.21
	Panel E: CON					Panel F: CON with lags				
$\sigma_{IV,5}^{INT}$	0.28***	0.33***	0.33***	0.30***	0.26***	0.24***	0.32***	0.34***	0.34***	0.32***
	(4.06)	(3.37)	(3.08)	(2.90)	(2.53)	(3.03)	(3.03)	(2.87)	(2.80)	(2.65)
Lag σCON						0.09	0.02	-0.04	-0.08	-0.13
						(0.85)	(0.18)	(-0.40)	(-0.85)	(-1.17)
$R^2 - ord$	28.60	25.47	20.13	15.65	11.07	30.69	25.53	20.34	16.58	13.10
	Panel G: EMP					Panel H: EMP with lags				
$\sigma_{IV,5}^{INT}$	0.22***	0.26***	0.29***	0.29***	0.27***	0.18***	0.21***	0.27***	0.31***	0.31***
	(5.04)	(4.19)	(3.74)	(3.52)	(3.13)	(4.15)	(4.57)	(4.06)	(3.67)	(3.31)
Lag σEMP						0.07	0.09	0.04	-0.03	-0.08
						(1.22)	(1.10)	(0.46)	(-0.28)	(-0.84)
$R^2 - ord$	32.70	27.58	24.05	20.23	15.37	35.48	29.74	24.36	20.34	16.47

Table 6. Out of sample forecasts.

Notes: This Table presents the root mean squared errors (RMSE) when the YIV and 20-year YIV are used to predict the year-on-year growth rate of industrial production, consumption, employment, and consumer confidence out of sample. A 10-year rolling window is used to estimate the model. The estimated model is then used to predict the growth rates of the macroeconomic variables 12-, 18-, 24-, 30-, and 36-months ahead. The Table reports the RMSEs for each macroeconomic variable and for each horizon. The RMSE are multiplied by 100 and expressed in percentages.

$H =$	12	18	24	30	36
		Panel A: Model with just YIV			
IND	5.76	5.62	5.30	5.35	6.53
CON	2.91	3.11	3.02	3.13	3.86
EMP	2.90	3.53	3.59	3.31	3.05
		Panel B: Model with just Lags			
IND	6.40	6.41	6.10	9.81	14.99
CON	2.06	3.79	5.22	5.23	6.61
EMP	2.14	3.24	4.55	5.62	6.08

Table 7. .

Notes: This Table presents the estimates for regressing the actual future growth rates and volatility of macroeconomic variables on their predicted values. A 10-year rolling window is used to estimate the model. The estimated model is then used to predict the growth rates of the macroeconomic variables 12-, 18-, 24-, 30-, and 36-months ahead. We regress the predicted value on the actual values for each horizon. The Table reports the coefficient and R^2.

	$H =$	12	18	24	30	36
Panel A: Predicting growth rates with just YIV						
	Coeff	-0.61***	-0.05	0.25	0.35*	0.42**
IND	t-stat	(−3.71)	(−0.26)	(1.39)	(1.91)	(2.30)
	R^2	7.90	0.04	1.19	2.21	3.19
	Coeff	-0.22***	0.06	0.19***	0.22***	0.17***
CON	t-stat	(-3.57)	(0.91)	(3.10)	(3.50)	(2.65)
	R^2	7.34	0.51	5.64	7.05	4.19
	Coeff	-0.80***	-0.58***	-0.28**	-0.05	0.11
EMP	t-stat	(-6.85)	(-4.58)	(-2.06)	(-0.32)	(0.75)
	R^2	22.59	11.54	2.57	0.07	0.34
Panel B: Predicting growth rates with just lagged values						
	Coeff	0.51***	0.01	-0.52***	-1.04***	-1.48***
IND	t-stat	(5.04)	(0.06)	(-3.42)	(-6.50)	(-9.43)
	R^2	13.64	0.00	6.77	20.80	35.58
	Coeff	0.25***	0.06	-0.03	-0.03	0.02
CON	t-stat	(3.52)	(0.84)	(-0.46)	(-0.41)	(0.28)
	R^2	7.16	0.43	0.13	0.10	0.05
	Coeff	0.51***	0.01	-0.52***	-1.04***	-1.48***
EMP	t-stat	(5.04)	(0.06)	(-3.42)	(-6.50)	(-9.43)
	R^2	13.64	0.00	6.77	20.80	35.58
Panel C: Predicting volatility with just YIV						
	Coeff	1.09***	0.83***	0.60***	0.34*	0.10
IND	t-stat	(6.02)	(4.28)	(2.97)	(1.62)	(0.48)
	R^2	18.37	10.23	5.19	1.59	0.14
	Coeff	1.10***	0.83***	0.61***	0.44***	0.33**
CON	t-stat	(7.15)	(5.07)	(3.78)	(2.91)	(2.27)
	R^2	24.12	13.75	8.15	4.99	3.10
	Coeff	1.23***	0.95***	0.77***	0.64***	0.53***
EMP	t-stat	(7.25)	(5.45)	(4.52)	(3.90)	(3.35)
	R^2	24.62	15.55	11.26	8.63	6.52
Panel D: Predicting volatility with just lagged values						
	Coeff	1.46***	1.17***	0.64**	0.16	-0.27
IND	t-stat	(5.31)	(3.72)	(1.97)	(0.47)	(-0.85)
	R^2	14.89	7.93	2.35	0.14	0.45
	Coeff	1.26***	0.71*	0.28	-0.14	-0.66*
CON	t-stat	(3.70)	(1.91)	(0.76)	(-0.38)	(-1.78)
	R^2	7.83	2.22	0.36	0.09	1.92
	Coeff	1.45***	1.31***	0.94***	0.61*	0.24
EMP	t-stat	(5.85)	(4.84)	(3.24)	(1.94)	(0.70)
	R^2	17.54	12.71	6.11	2.29	0.31

Table 8. Predicting bank deposit.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + DEP_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is the YIV measured at time t and $DEP_{i,t+j}$ is either the year-on-year growth rate or volatility of total deposits at all commercial banks in the U.S. at time $t + j$. The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Deposits					Panel B: Deposits with lags				
$\sigma^{INT}_{IV,5}$	-0.32***	-0.33***	-0.33***	-0.33***	-0.33***	-0.25***	-0.27***	-0.28***	-0.28***	-0.29***
	(-4.84)	(-4.66)	(-4.69)	(-4.77)	(-4.80)	(-3.31)	(-4.19)	(-4.70)	(-4.66)	(-4.36)
Lag Dep						0.62***	0.55***	0.48***	0.41***	0.33***
						(7.45)	(5.78)	(5.08)	(4.59)	(3.77)
$R^2 - ord$	12.72	14.62	15.83	16.79	18.22	59.54	54.00	48.32	42.04	36.33
	Panel C: Volatility - Deposits					Panel D: Volatility - Deposits with lags				
$\sigma^{INT}_{IV,5}$	0.57***	0.35*	0.11	-0.00	-0.10	0.62***	0.45***	0.25*	0.18	0.12
	(2.47)	(1.74)	(0.49)	(-0.00)	(-0.40)	(2.64)	(2.68)	(1.64)	(0.98)	(0.62)
Lag σDEP						-0.23	-0.40*	-0.63***	-0.81***	-0.84***
						(-1.08)	(-1.70)	(-2.69)	(-3.54)	(-3.68)
$R^2 - ord$	6.86	1.99	0.17		0.18	7.93	4.41	5.88	9.82	11.36

Table 9. Predicting bank and market expected returns.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$COC_{i,t+j} = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $COC_{i,t+j}$ is either the the LIBOR-OIS spread, or the dividend yield on an index of bank stocks measured at time $t+j$. The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Libor-OIS spread					Panel B: Libor-OIS spread with lags				
$\sigma_{IV,5}^{INT}$	0.30**	0.24*	0.15	0.05	-0.07	0.27**	0.35***	0.50***	0.65***	0.65***
	(2.00)	(1.82)	(0.99)	(0.28)	(-0.29)	(2.04)	(2.78)	(3.51)	(3.93)	(3.80)
Lag Libor-OIS						0.29	0.12	-0.07	-0.20	-0.16
						(1.46)	(0.84)	(-0.55)	(-1.24)	(-0.87)
$R^2 - ord$	13.10	4.62	1.26	0.13	0.18	45.08	46.72	54.39	65.35	77.20
	Panel C: Bank dividend yield					Panel D: Bank dividend yield with lags				
$\sigma_{IV,5}^{INT}$	0.07	0.12	0.21*	0.27**	0.32**			0.01*	0.01*	0.01*
	(1.06)	(1.39)	(1.87)	(2.06)	(2.25)	(0.70)	(1.18)	(1.78)	(1.94)	(1.90)
Lag DY						0.04***	0.03***	0.02***	0.02***	0.02***
						(5.20)	(5.32)	(5.39)	(5.33)	(5.29)
$R^2 - ord$	1.24	2.37	4.94	6.26	6.84	60.99	51.99	45.74	40.70	37.42

Table 10. Predicting bank credit.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$BC_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is the YIV measured at time t and $BC_{i,t+j}$ is either the year-on-year growth rate in total loans extended by all commercial banks in the U.S. at time $t+j$ or the lagged 12-month rolling volatility of bank credit growth. The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Bank credit growth					Panel B: Bank credit growth with lags				
$\sigma^{INT}_{IV,5}$	-0.13***	-0.14***	-0.14***	-0.14***	-0.14***	-0.11***	-0.13***	-0.13***	-0.13***	-0.13***
	(-3.07)	(-4.30)	(-4.42)	(-4.51)	(-5.06)	(-3.53)	(-3.64)	(-3.49)	(-3.59)	(-3.98)
Lag BC						0.24***	0.20***	0.17***	0.14***	0.11***
$R^2 - ord$	13.36	17.67	19.62	20.92	23.02	59.49	53.27	47.02	41.39	37.31
	Panel C: Bank credit volatility					Panel D: Bank credit volatility and lags				
$\sigma^{INT}_{IV,5}$	0.61***	0.73***	0.60***	0.46***	0.33***	0.56***	0.72***	0.64***	0.52***	0.42***
	(7.02)	(5.47)	(4.75)	(4.51)	(3.52)	(5.68)	(4.77)	(4.51)	(4.94)	(4.81)
Lag σBCG						0.15**	0.01	-0.12	-0.22	-0.32*
						(2.32)	(0.07)	(-0.76)	(-1.24)	(-1.81)
$R^2 - ord$	45.79	44.31	25.19	12.73	6.17	48.49	44.31	26.09	15.33	11.50

Table 11. Predicting bank credit sorted by interest rate exposure.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + BCG_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $BCG_{i,t+j}$ is the year-on-year growth rate in total loans extended by all commercial banks in the U.S. at time $t+j$. The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
Panel A: Small, Low										
$\sigma_{IV,5}^{INT}$	-0.26***	-0.28***	-0.28***	-0.28***	-0.25***	-0.23***	-0.26***	-0.27***	-0.27***	-0.24***
	(-2.79)	(-3.90)	(-4.40)	(-4.90)	(-4.16)	(-2.62)	(-3.71)	(-4.43)	(-5.43)	(-4.56)
Lag BCG						0.14**	0.07	0.06	0.06	0.07
						(2.09)	(1.05)	(0.76)	(0.67)	(0.67)
$R^2 - ord$	12.82	19.01	23.71	29.24	26.89	16.39	20.19	24.60	30.42	29.03
Panel B: Small, High										
$\sigma_{IV,5}^{INT}$	-1.66**	-1.99**	-2.16**	-2.36**	-2.56***	-1.54**	-1.91*	-2.13**	-2.40**	-2.66***
	(-2.01)	(-1.99)	(-2.08)	(-2.20)	(-2.35)	(-1.99)	(-1.89)	(-1.99)	(-2.17)	(-2.41)
Lag BCG						1.54	0.90	0.26	-0.45	-0.99
						(1.25)	(0.78)	(0.26)	(-0.50)	(-1.14)
$R^2 - ord$	2.25	4.48	6.53	9.10	12.70	4.17	5.39	6.63	9.43	14.57
Panel C: Large, Low										
$\sigma_{IV,5}^{INT}$	-0.18	-0.07	-0.00	-0.02	0.01	-0.19	-0.07	0.01	0.01	0.04
	(-0.59)	(-0.28)	(-0.01)	(-0.09)	(0.03)	(-0.60)	(-0.25)	(0.05)	(0.04)	(0.24)
Lag BCG						0.08	-0.07	-0.16	-0.26	-0.34
						(0.24)	(-0.18)	(-0.46)	(-0.87)	(-1.29)
$R^2 - ord$	0.83	0.17		0.02		1.01	0.33	1.14	3.69	7.68
Panel D: Large, High										
$\sigma_{IV,5}^{INT}$	-0.31***	-0.37***	-0.39***	-0.38***	-0.35**	-0.33***	-0.40***	-0.42***	-0.39***	-0.35**
	(-2.59)	(-2.76)	(-2.60)	(-2.46)	(-2.16)	(-2.76)	(-3.03)	(-2.75)	(-2.48)	(-2.08)
Lag BCG						-0.12	-0.20*	-0.16	-0.09	-0.02
						(-1.03)	(-1.72)	(-1.11)	(-0.55)	(-0.13)
$R^2 - ord$	3.79	7.11	10.53	12.43	13.27	4.35	9.14	12.27	13.13	13.32

Table 12. Predicting investment growth of bank dependent firms.
Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + INV_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $INV_{i,t+j}$ is the year-on-year growth rate in investments at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
Panel A: Bank dependent firms										
$\sigma_{IV,5}^{INT}$	-0.53**	-0.44	-0.38	-0.39	-0.33	-0.38***	-0.29*	-0.25	-0.27	-0.22
	(-2.12)	(-1.61)	(-1.42)	(-1.43)	(-1.20)	(-2.65)	(-1.64)	(-1.23)	(-1.21)	(-0.96)
Lag INV						1.98***	1.76***	1.66***	1.51***	1.30***
						(2.63)	(2.65)	(2.68)	(2.78)	(2.85)
$R^2 - ord$	1.72	1.32	1.16	1.33	1.02	25.20	22.90	23.08	20.93	16.75
Panel B: Non-bank dependent firms										
$\sigma_{IV,5}^{INT}$	0.00	-0.01	-0.01	-0.01	-0.01	0.00	0.00	-0.01	-0.03	-0.05
	(0.00)	(-0.01)	(-0.01)	(-0.03)	(-0.03)	(0.00)	(0.01)	(-0.14)	(-0.37)	(-0.48)
Lag INV	0.08	0.14	0.24***	0.24***	0.19***	0.08	0.14	0.24***	0.24***	0.19***
	(0.73)	(1.40)	(2.63)	(2.97)	(2.62)	(0.73)	(1.41)	(2.66)	(3.01)	(2.66)
$R^2 - ord$	6.78	8.73	10.91	13.18	13.97	9.82	14.55	23.23	26.43	23.70

Table 13. Granger causality tests.

Notes: This Table shows the results for the Granger causality test for the estimation of the following reduced-form VAR system:

$$Y_t = \alpha + \sum_{i=1}^{i=4} \beta_i Y_{t-i} + \epsilon_t$$

The Y_t variables are the YIV, the year-on-year growth rate of industrial production (IND), the rate of return on an index of Treasury bonds (ITB), the rate of return on an index of U.S. investment grade corporate bonds (ICB), the change in the yield-to-maturity on the 1-year note issued by the U.S. Treasury (ΔSY), the value-weighted return on an index of all stocks (VWR), the CBOE Volatility Index (VIX), and bank credit growth (BCG). Each VAR equation is estimated with up to 4 lags. The 4-month lag structure for the VAR is suggested by the data and is consistent with the minimum Akaike Information Criterion (AIC). The Table shows the *p*-values for the χ^2 test that the column variable has marginal predictive power for the row variable. Monthly data, 1990 - 2016.

Predictors →	$\sigma_{IV,5}^{INT}$	IND	ITB	ICB	ΔSY	VWR	VIX	BCG
$\sigma_{IV,5}^{INT}$	–	0.15	0.74	0.06*	0.29	0.13	0.97	0.20
IND	0.01***	–	0.56	0.66	0.01***	0.01***	0.25	0.01***
ITB	0.32	0.44	–	0.65	0.29	0.20	0.06*	0.03**
ICB	0.51	0.69	0.36	–	0.68	0.39	0.01***	0.19
ΔSY	0.82	0.41	0.04**	0.52	–	0.05**	0.69	0.04**
VWR	0.02**	0.12	0.20	0.01***	0.26	–	0.03**	0.03 ˆ**
VIX	0.02**	0.44	0.33	0.02**	0.13	0.01***	–	0.04**
BCG	0.04**	0.01***	0.02**	0.13	0.09*	0.20	0.17	—

Appendix
Interest Rate Implied Volatility and Real Activity

A Additional summary statistics

Table A1 reports the average trading volume and open interest in interest rate futures and options markets. We collect data for trading volume and open interest from Bloomberg (Screen code: FV1). To construct Table A1, we first average the daily volume and open interest for futures, call, and put options within each month. Table A1 then reports the time-series mean for these within month averages over our entire sample. The first column indicates the maturity. Columns 2-4 report the average daily volume of the futures, call options, and put options. Finally, columns 5-6 report the open interest for the call and put options. Figures in parenthesis below each maturity report standard errors.

Figure A1 plots the volume and open interest for futures and options contracts on U.S. Treasury bonds and notes traded on the CME.

Table A2 reports the trading activity of financial institutions in the interest rate derivatives markets. Data for trading activity of financial institutions is from the "Central Bank Survey of Foreign Exchange and Derivatives Market Activity" conducted by the Bank of International Settlements. Panels A and B of the Table report the notional amounts and market value (in dollar billions) of the interest rate derivatives bought and sold by financial institutions. The information regarding notional and market values of interest rate derivatives bought and sold is reported by the underlying (reference) interest rates and by counter-party. Panel C of Table A2 provides information regarding the maturity structure of the interest rate derivatives contracts traded by the financial institutions. Panel C indicates that a vast majority of the interest rate derivatives contracts bought and sold by financial institutions (nearly 85%) are of maturity 5-years or less.

B Additional results

This section tabulates additional results and robustness tests. Tables A3 - A6 show the results for predicting growth rates of macroeconomic variables with standard forecasting variables added as controls.

Tables A8 - A10 show the results for predicting volatility of macroeconomic variables with standard forecasting variables added as controls. In all cases, the dependent variable is the one-year rolling window volatility of the growth rate of a macroeconomic variable (either gross domestic product, industrial production, consumption, or employment).

Table A11 compares the performance of the YIV with other measures of implied volatility from the Treasury markets, namely the implied volatility on options on the 20-year Treasury bond futures contract, the Treasury Implied Volatility (TIV) from Choi, Mueller, and Vedolin (2016) and the CBOE/CBOT US Treasury Volatility Index (TYVIX).

Table A12 uses alternative measures of implied volatility from the Treasury derivatives market such as the TIV, TYVIX, and the 20-year YIV to forecast the volatility of macroeconomic variables. We control for the implied volatility of at the money options contract that reference futures contract on the 20-year Treasury bond (20-year YIV), the CBOE 10-year U.S. Treasury note volatility index (TYVIX), and the Treasury implied volatility from Choi, Mueller, and Vedolin (2016) (TIV).

Tables A13 and A14 present the results for additional robustness tests. In Table A13, we use the YIV to predict growth rates of macroeconomic quantities with non-overlapping observations. In Table A14, we exclude the data from the financial crisis.

Tables A15 - A16 show the results for predicting growth rate and volatility of bank deposit growth with standard forecasting variables added as controls.

Tables A17 - A18 show the results for predicting volatility of bank credit growth with standard forecasting variables added as controls.

Figure A1. Time-series plot for volume and open interest.

Notes: This figure plots the volume and open interest (number of contracts) for futures and options contract on U.S. Treasury bonds and notes on the CME Floor, PNT, over-the-counter, and Globex exchange for futures and options contracts on U.S. Treasury bonds and notes of 5-year maturity. The continuous blue line references the volume of futures contracts, the dashed red line references the volume of options contracts, and the dashed-dotted black line references the open interest of options contracts. The grey shaded regions represent NBER recessions and financial crisis. The NBER recession dates are published by the NBER Business Cycle Dating Committee. The dates for financial crisis are obtained from Kho, Lee, and Stulz (2000), Romer and Romer (2015), and the FDIC. Daily data, 1990 - 2016.

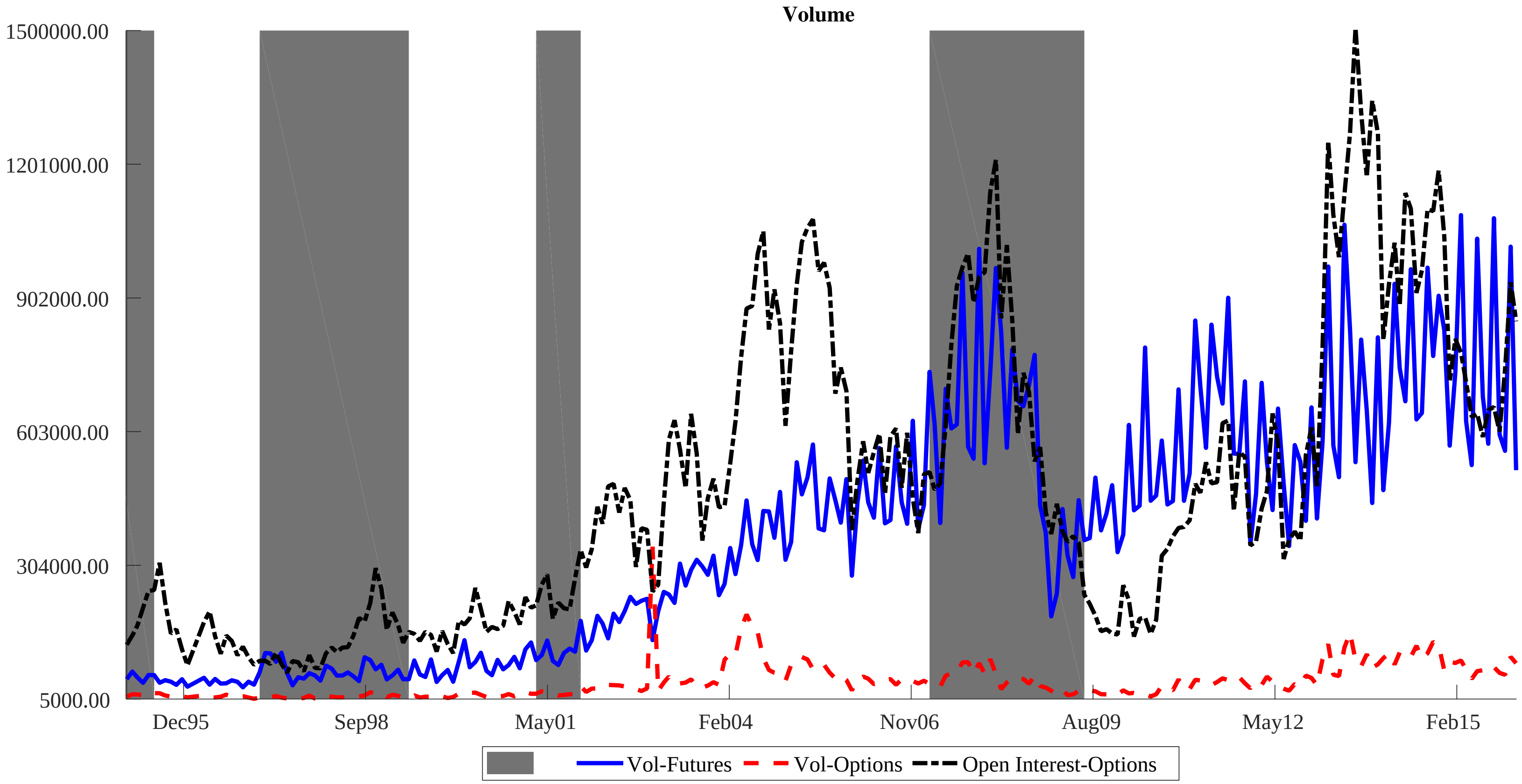

Table A1. Trading volume and open interest.

Notes: This Table shows the average daily trading volume and open interest (number of contracts) for futures and options contract on U.S. Treasury bonds and notes on the CME Floor, PNT, over-the-counter, and Globex exchange. Column 1 indicates the maturity of the contract. Columns 2-4 report the average daily volume for the futures, call options, and put options. Columns 5-6 report the open interest for the call and put options. Figures in parenthesis report standard errors. Daily data, 1990 - 2016.

Maturity	Vol-Futures	Vol-Call	Vol-Put	OI-Call	OI-Put
5-yrs	371,432	19,181	24,331	208,637	274,329
	(17,617)	(1,518)	(1,473)	(8,941)	(13,948)

Table A2. Trading activity for financial institutions.

Notes: This Table shows the trading activity for financial institutions in the interest rate derivatives markets. Data for this Table is from the Central Bank Survey of Foreign Exchange and Derivatives Market Activity conducted by the Bank of International Settlements. Panel A reports the notional amounts and Panel B reports the market value of interest rate derivatives bought and sold by financial institutions in dollar billions. This information is reported by the underlying interest rates (U.S. dollar interest rates or other interest rates) and by counter-party (financial institutions trading with another financial institution or non-financial customers). Panel C reports the maturity structure of interest rate derivatives bought and sold by financial institutions.

Panel A: Notional amounts reported by financial institutions

	Options bought			Options sold		
Contracts with	*U.S.D*	*Other*	*Total*	*U.S.D*	*Others*	*Total*
Other FIs	529.40	726.50	1255.90	576.10	681.90	1258.10
Customers	431.60	340.60	772.20	690.40	398.10	1088.40
Total	961.10	1067.10	2028.10	1266.50	1080.00	2346.50

Panel B: Market values reported by financial institutions

	Options bought			Options sold		
Contracts with	*U.S.D*	*Others*	*Total*	*U.S.D*	*Others*	*Total*
Other FIs	–	–	22.40	–	–	21.60
Customers	–	–	15.20	–	–	14.60
Total	20.80	16.70	37.60	19.40	16.80	36.20

Panel C: Maturity distributions

	Options bought	Options sold
Up to 1-year	30.00	29.00
> 1-year, < 5-years	58.00	56.00
> 5-years	12.00	15.00

Table A3. Predicting GDP growth.
Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + GDP_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $GDP_{i,t+j}$ is the year-on-year growth rate in the gross domestic product measured at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Quarterly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Controls only					Panel B: YIV and controls				
$\sigma_{IV,5}^{INT}$						-0.06***	-0.05***	-0.04***	-0.03***	-0.03***
						(-4.25)	(-3.78)	(-3.70)	(-3.81)	(-3.71)
Lag GDP	0.07***	0.07***	0.06***	0.06***	0.06***	0.06***	0.06***	0.06***	0.06***	0.06***
	(2.83)	(3.00)	(2.85)	(2.69)	(2.75)	(2.64)	(2.87)	(2.73)	(2.57)	(2.65)
TRM	0.04**	0.04***	0.05***	0.06**	0.06**	0.05***	0.05***	0.06***	0.06***	0.06***
	(2.25)	(2.83)	(2.56)	(2.23)	(2.12)	(2.97)	(3.40)	(3.07)	(2.61)	(2.38)
ΔSY	0.05***	0.05***	0.05***	0.05***	0.04***	0.04***	0.04***	0.04***	0.04***	0.03***
	(3.59)	(3.46)	(3.44)	(3.51)	(3.57)	(3.18)	(3.22)	(3.17)	(3.17)	(3.06)
ITB	-0.01	-0.00				-0.01	-0.00			
	(-0.50)	(-0.12)	(0.25)	(0.28)	(0.26)	(-0.54)	(-0.02)	(0.44)	(0.45)	(0.44)
ICB	0.04***	0.04***	0.03***	0.03***	0.03***	0.03***	0.03***	0.03***	0.02***	0.02***
	(2.38)	(3.16)	(3.94)	(4.00)	(3.72)	(2.34)	(3.00)	(3.33)	(3.22)	(3.00)
VWR	0.03**	0.03***	0.03***	0.02***	0.02**	0.03***	0.03***	0.03***	0.02***	0.02***
	(2.31)	(2.39)	(2.46)	(2.38)	(1.98)	(2.91)	(3.03)	(3.01)	(2.95)	(2.40)
σ_{IV}^{VIX}	-0.04*	-0.04*	-0.03*	-0.03*	-0.03*	-0.01	-0.01	-0.01	-0.01	-0.01
	(-1.71)	(-1.74)	(-1.75)	(-1.74)	(-1.63)	(-0.68)	(-0.76)	(-0.76)	(-0.73)	(-0.65)
UNC	0.03*	0.04***	0.04***	0.04***	0.04***	0.01	0.02*	0.03**	0.03***	0.03***
	(1.96)	(2.49)	(2.94)	(3.37)	(3.43)	(0.73)	(1.76)	(2.09)	(2.35)	(2.36)
$R^2 - ord$	45.22	45.79	45.40	44.40	41.93	56.64	53.67	51.11	49.46	46.55

Table A4. Predicting industrial production.
Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + IND_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $IND_{i,t+j}$ is the year-on-year growth rate in the index of industrial production measured at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Controls only					Panel B: YIV and controls				
$\sigma_{IV,5}^{INT}$						-0.12***	-0.09**	-0.06**	-0.05**	-0.04**
						(-2.34)	(-2.09)	(-2.15)	(-2.07)	(-2.03)
Lag IND	0.12***	0.09*	0.08*	0.09*	0.08*	0.09*	0.06	0.06	0.07	0.07
	(2.39)	(1.90)	(1.76)	(1.70)	(1.64)	(1.83)	(1.35)	(1.43)	(1.50)	(1.46)
TRM	0.04*	0.05**	0.07***	0.09***	0.11***	0.07***	0.07***	0.09***	0.11***	0.12***
	(1.87)	(2.14)	(2.40)	(2.43)	(2.45)	(2.97)	(2.98)	(2.83)	(2.65)	(2.62)
ΔSY	0.07***	0.08***	0.07**	0.06*	0.04*	0.06***	0.07***	0.07*	0.05*	0.04*
	(4.41)	(2.73)	(2.06)	(1.93)	(1.77)	(3.81)	(2.53)	(1.95)	(1.84)	(1.65)
ITB	0.01	0.00	-0.00	-0.00	0.00	0.01	0.00	0.00	-0.00	0.00
	(0.23)		(-0.05)	(-0.12)	(0.06)	(0.45)	(0.12)	(0.06)	(-0.05)	(0.14)
ICB	0.02	0.03	0.03	0.03*	0.02	0.01	0.02	0.03	0.03*	0.02
	(0.62)	(1.05)	(1.40)	(1.70)	(1.60)	(0.52)	(1.14)	(1.50)	(1.77)	(1.61)
VWR	0.04***	0.04***	0.03***	0.03***	0.02**	0.03***	0.04***	0.03***	0.02***	0.02***
	(3.17)	(3.43)	(3.08)	(2.60)	(2.32)	(3.45)	(3.96)	(3.46)	(2.81)	(2.44)
σ_{IV}^{VIX}	-0.09**	-0.08**	-0.06**	-0.05*	-0.04	-0.03	-0.03	-0.03	-0.03	-0.02
	(-2.06)	(-2.09)	(-2.01)	(-1.77)	(-1.48)	(-1.03)	(-0.97)	(-0.89)	(-0.74)	(-0.60)
UNC	0.02	0.04	0.04	0.04	0.04	-0.01	0.01	0.03	0.03	0.03
	(0.71)	(1.04)	(1.24)	(1.47)	(1.51)	(-0.52)	(0.36)	(0.81)	(1.08)	(1.08)
$R^2 - ord$	41.52	32.69	29.96	31.44	33.36	50.14	38.68	33.18	33.64	35.43

Table A5. Predicting consumption growth.
Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + CON_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $CON_{i,t+j}$ is the year-on-year growth rate in consumption measured at time $t + j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Controls only					Panel B: YIV and controls				
$\sigma_{IV,5}^{INT}$						-0.05*	-0.05*	-0.04**	-0.04**	-0.04***
						(-1.90)	(-1.92)	(-2.05)	(-2.29)	(-2.58)
Lag CON	0.09***	0.07***	0.06***	0.06***	0.06***	0.08***	0.07***	0.06***	0.05***	0.05***
	(4.15)	(3.60)	(3.15)	(2.96)	(2.92)	(3.45)	(2.92)	(2.63)	(2.57)	(2.63)
TRM	0.01	0.02	0.02	0.03	0.03	0.03**	0.03**	0.04*	0.04	0.04
	(1.01)	(1.05)	(1.06)	(1.07)	(1.05)	(2.23)	(2.15)	(1.78)	(1.61)	(1.50)
ΔSY	0.02***	0.03***	0.03**	0.03**	0.03*	0.02***	0.03**	0.03*	0.03*	0.02
	(2.67)	(2.43)	(2.13)	(1.99)	(1.82)	(2.52)	(2.24)	(1.96)	(1.80)	(1.56)
ITB	-0.00	-0.00	-0.01	-0.01	-0.01*	-0.00	-0.00	-0.01	-0.01*	-0.01*
	(-0.40)	(-0.50)	(-0.91)	(-1.55)	(-1.73)	(-0.57)	(-0.71)	(-1.13)	(-1.84)	(-1.89)
ICB	0.01	0.01	0.01	0.02*	0.01	0.01	0.01	0.01	0.01*	0.01*
	(0.78)	(1.06)	(1.38)	(1.66)	(1.60)	(0.87)	(1.22)	(1.58)	(1.88)	(1.68)
VWR	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***
	(3.46)	(3.40)	(3.22)	(2.98)	(2.79)	(3.67)	(3.65)	(3.51)	(3.28)	(2.94)
σ_{IV}^{VIX}	-0.04*	-0.04	-0.03	-0.02	-0.02	-0.02	-0.01	-0.01	-0.00	0.00
	(-1.69)	(-1.49)	(-1.31)	(-1.06)	(-0.87)	(-0.81)	(-0.55)	(-0.36)	(-0.04)	(0.13)
UNC	0.02	0.03*	0.04**	0.04***	0.04***	0.01	0.02	0.03*	0.03*	0.03*
	(1.48)	(1.86)	(2.19)	(2.39)	(2.46)	(0.74)	(1.38)	(1.70)	(1.81)	(1.80)
$R^2 - ord$	51.90	42.71	37.77	34.42	32.62	57.80	48.36	42.75	39.77	38.47

Table A6. Predicting employment growth.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + EMP_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $EMP_{i,t+j}$ is the year-on-year growth rate in non-farm payroll measured at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Controls only					Panel B: YIV and controls				
$\sigma_{IV,5}^{INT}$						-0.05***	-0.05***	-0.04***	-0.04***	-0.03***
						(-3.43)	(-3.21)	(-3.48)	(-3.91)	(-4.20)
Lag EMP	0.10***	0.09***	0.08***	0.08***	0.08***	0.09***	0.08***	0.07***	0.07***	0.07***
	(5.20)	(4.32)	(3.88)	(3.49)	(3.32)	(5.05)	(4.20)	(3.80)	(3.47)	(3.30)
TRM	0.03***	0.04***	0.05***	0.07***	0.08***	0.04***	0.05***	0.06***	0.08***	0.09***
	(3.27)	(3.69)	(4.09)	(4.18)	(4.24)	(4.38)	(4.87)	(5.34)	(5.20)	(5.02)
ΔSY	0.02***	0.03***	0.03***	0.03**	0.02*	0.02***	0.03***	0.03***	0.02*	0.02
	(5.36)	(3.80)	(2.68)	(2.17)	(1.85)	(4.77)	(3.35)	(2.38)	(1.91)	(1.58)
ITB	0.01	0.01	0.01	0.01	0.00	0.01**	0.01	0.01	0.00	0.00
	(1.46)	(1.04)	(0.94)	(0.80)	(0.81)	(2.01)	(1.41)	(1.28)	(1.02)	(0.99)
ICB	-0.00	0.00	0.01	0.01	0.01*	-0.00	0.00	0.01	0.01	0.01*
	(-0.17)	(0.49)	(0.95)	(1.29)	(1.63)	(-0.83)	(0.28)	(0.92)	(1.29)	(1.63)
VWR	0.01***	0.01***	0.01***	0.01***	0.01***	0.01*	0.01***	0.01***	0.01***	0.01***
	(2.48)	(3.04)	(3.07)	(2.98)	(2.92)	(1.92)	(2.67)	(2.92)	(3.00)	(3.03)
σ_{IV}^{VIX}	-0.04***	-0.04***	-0.04***	-0.03**	-0.03**	-0.02*	-0.02*	-0.02	-0.01	-0.01
	(-2.38)	(-2.38)	(-2.35)	(-2.28)	(-2.16)	(-1.76)	(-1.64)	(-1.38)	(-1.12)	(-0.88)
UNC	0.00	0.01	0.01	0.01	0.01	-0.01	-0.00	-0.00	0.00	0.00
	(0.38)	(0.71)	(0.88)	(0.98)	(1.11)	(-1.24)	(-0.57)	(-0.06)	(0.14)	(0.29)
$R^2 - ord$	69.33	59.54	52.69	49.17	48.16	75.37	66.24	58.74	54.77	53.38

Table A7. Predicting GDP volatility.
Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sigma(GDP_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is the YIV measured at time t and $GDP_{i,t+j}$ is the year-on-year growth rate in the gross domestic product measured at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Quarterly data, 1990 - 2016.

$H=$	12	18	24	30	36	12	18	24	30	36
	Panel A: Controls only					Panel B: YIV and controls				
$\sigma^{INT}_{IV,5}$						0.21***	0.23***	0.26***	0.26***	0.24***
						(3.30)	(4.02)	(3.69)	(3.74)	(4.25)
Lag σGDP	-0.00	-0.06	-0.15	-0.21*	-0.22*	-0.02	-0.07	-0.15	-0.21*	-0.21**
	(-0.05)	(-0.61)	(-1.29)	(-1.82)	(-1.93)	(-0.27)	(-0.78)	(-1.39)	(-1.90)	(-2.10)
TRM	0.06	0.06	0.05	0.03	-0.04	-0.00	-0.03	-0.05	-0.08	-0.15
	(0.91)	(0.56)	(0.40)	(0.19)	(-0.34)	(-0.05)	(-0.35)	(-0.42)	(-0.61)	(-1.24)
ΔSY	-0.08	-0.13	-0.15	-0.18*	-0.22***	-0.04	-0.08	-0.10	-0.13	-0.16**
	(-1.46)	(-1.60)	(-1.57)	(-1.75)	(-2.39)	(-0.66)	(-1.04)	(-1.09)	(-1.34)	(-2.01)
ITB		0.05	0.06	0.04	0.03	-0.00	0.04	0.05	0.04	0.03
	(0.01)	(0.65)	(0.73)	(0.63)	(0.42)	(-0.05)	(0.74)	(0.85)	(0.78)	(0.55)
ICB	0.01	-0.09	-0.18***	-0.21***	-0.22***	0.04	-0.05	-0.14***	-0.17***	-0.19***
	(0.33)	(-1.31)	(-2.52)	(-2.87)	(-3.72)	(0.83)	(-1.15)	(-2.82)	(-2.89)	(-3.30)
VWR	-0.01	-0.03	-0.05	-0.05	-0.04		-0.02	-0.03	-0.03	-0.02
	(-0.10)	(-0.47)	(-0.65)	(-0.63)	(-0.56)	(0.07)	(-0.28)	(-0.56)	(-0.61)	(-0.49)
σ^{VIX}_{IV}	0.21*	0.34***	0.37***	0.35***	0.32***	0.10	0.21**	0.23***	0.21***	0.20***
	(1.87)	(2.38)	(2.56)	(2.78)	(2.89)	(1.27)	(2.11)	(2.39)	(2.61)	(2.73)
UNC	-0.10	-0.18*	-0.23*	-0.23*	-0.23*	-0.00	-0.07	-0.11	-0.10	-0.11
	(-1.17)	(-1.78)	(-1.92)	(-1.75)	(-1.77)	(-0.06)	(-0.93)	(-1.26)	(-1.17)	(-1.25)
R^2-ord	21.07	30.06	29.83	32.07	37.41	32.02	39.12	38.85	40.53	44.49

Table A8. Predicting volatility of industrial production.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sigma(IND_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is either the the YIV or the 20-year YIV measured at time t and $IND_{i,t+j}$ is the year-on-year growth rate in the index of industrial production measured at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Controls only					Panel B: YIV and controls				
$\sigma^{INT}_{IV,5}$						0.59***	0.80***	1.13***	1.19***	1.13***
						(4.21)	(5.43)	(4.11)	(3.73)	(3.90)
Lag σIND	0.24	0.14	0.09	0.09	0.15	0.11	-0.03	-0.13	-0.13	-0.05
	(0.88)	(0.52)	(0.41)	(0.43)	(0.61)	(0.53)	(-0.16)	(-0.88)	(-0.82)	(-0.25)
TRM	0.05	-0.06	-0.29	-0.55*	-0.83**	-0.12	-0.30*	-0.65***	-0.93***	-1.20***
	(0.40)	(-0.34)	(-1.07)	(-1.68)	(-2.16)	(-1.12)	(-1.88)	(-2.49)	(-2.84)	(-2.99)
ΔSY	-0.20	-0.39*	-0.44**	-0.52**	-0.54**	-0.15	-0.33	-0.35*	-0.41*	-0.42
	(-1.57)	(-1.95)	(-2.26)	(-2.12)	(-2.00)	(-1.11)	(-1.58)	(-1.79)	(-1.72)	(-1.62)
ITB	-0.21*	-0.18	-0.16	-0.17	-0.18	-0.20**	-0.17	-0.15	-0.15	-0.16
	(-1.94)	(-1.33)	(-1.04)	(-1.17)	(-1.24)	(-2.12)	(-1.50)	(-1.38)	(-1.54)	(-1.49)
ICB	0.17	0.10	-0.04	-0.09	-0.13	0.20*	0.15	0.02	-0.03	-0.06
	(1.10)	(0.61)	(-0.22)	(-0.55)	(-0.87)	(1.69)	(1.19)	(0.19)	(-0.25)	(-0.64)
VWR	-0.04	-0.12	-0.17*	-0.20*	-0.21*	0.01	-0.05	-0.07	-0.09	-0.11
	(-0.45)	(-1.19)	(-1.65)	(-1.74)	(-1.66)	(0.07)	(-0.51)	(-0.82)	(-1.10)	(-1.16)
σ^{VIX}_{IV}	0.74***	1.19***	1.24***	1.14***	0.98**	0.45***	0.80***	0.69***	0.56**	0.43*
	(2.86)	(2.85)	(2.60)	(2.38)	(2.05)	(2.48)	(2.77)	(2.57)	(2.11)	(1.63)
UNC	-0.43*	-0.69**	-0.80**	-0.84**	-0.81*	-0.25	-0.44*	-0.43*	-0.45*	-0.43
	(-1.95)	(-2.26)	(-2.15)	(-1.97)	(-1.78)	(-1.49)	(-1.91)	(-1.89)	(-1.71)	(-1.47)
$R^2 - ord$	35.86	41.81	35.03	32.26	33.29	45.42	51.93	50.57	47.53	46.43

Table A9. Predicting volatility of consumption growth.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sigma(CON_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is either the the YIV or the 20-year YIV measured at time t and $CON_{i,t+j}$ is the year-on-year growth rate in consumption measured at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Controls only					Panel B: YIV and controls				
$\sigma^{INT}_{IV,5}$						0.20***	0.23***	0.29***	0.33***	0.34***
						(2.81)	(3.56)	(3.56)	(3.37)	(3.33)
Lag σCON	0.12	0.07	0.08	0.10	0.10	0.08	0.02	0.03	0.04	0.05
	(1.06)	(0.63)	(1.07)	(1.49)	(1.32)	(0.77)	(0.24)	(0.40)	(0.68)	(0.65)
TRM	-0.00	-0.05	-0.15*	-0.25**	-0.33**	-0.06	-0.12**	-0.24***	-0.36***	-0.44***
	(-0.06)	(-0.81)	(-1.91)	(-2.05)	(-2.11)	(-1.13)	(-2.08)	(-3.06)	(-2.75)	(-2.64)
ΔSY	-0.09*	-0.17*	-0.17*	-0.16*	-0.15*	-0.07	-0.15*	-0.15	-0.13	-0.12
	(-1.72)	(-1.87)	(-1.79)	(-1.67)	(-1.67)	(-1.35)	(-1.65)	(-1.55)	(-1.41)	(-1.35)
ITB	-0.07***	-0.05	-0.05	-0.04	-0.04	-0.07***	-0.05	-0.05	-0.04	-0.04
	(-2.41)	(-1.38)	(-0.98)	(-0.90)	(-0.89)	(-2.47)	(-1.60)	(-1.19)	(-1.09)	(-1.02)
ICB	0.03	-0.01	-0.04	-0.05	-0.07	0.05	0.01	-0.02	-0.02	-0.04
	(0.85)	(-0.27)	(-0.78)	(-0.95)	(-1.47)	(1.52)	(0.19)	(-0.47)	(-0.61)	(-1.18)
VWR	-0.04	-0.05	-0.05	-0.06	-0.06	-0.02	-0.03	-0.03	-0.03	-0.03
	(-1.20)	(-1.49)	(-1.24)	(-1.31)	(-1.29)	(-0.65)	(-0.90)	(-0.72)	(-0.83)	(-0.87)
σ^{VIX}_{IV}	0.22***	0.37***	0.38***	0.37***	0.35***	0.11**	0.25***	0.23***	0.21**	0.18*
	(3.19)	(3.18)	(2.98)	(2.93)	(2.84)	(2.26)	(2.95)	(2.61)	(2.13)	(1.79)
UNC	-0.14*	-0.23**	-0.27**	-0.29**	-0.30**	-0.08	-0.15*	-0.18*	-0.18**	-0.18**
	(-1.92)	(-2.09)	(-2.15)	(-2.22)	(-2.21)	(-1.56)	(-1.78)	(-1.91)	(-2.05)	(-2.09)
$R^2 - ord$	29.40	36.15	32.84	33.11	34.75	37.52	42.97	41.35	42.77	44.42

Table A10. Predicting volatility of employment growth.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sigma(EMP_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is either the the YIV or the 20-year YIV measured at time t and $EMP_{i,t+j}$ is the year-on-year growth rate in non-farm payroll measured at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: Controls only					Panel B: YIV and controls				
$\sigma^{INT}_{IV,5}$						0.18***	0.18***	0.22***	0.27***	0.30***
						(3.55)	(4.33)	(4.20)	(3.43)	(3.20)
Lag σEMP	0.14*	0.16*	0.15*	0.14	0.12	0.09	0.11	0.09	0.06	0.04
	(1.87)	(1.81)	(1.76)	(1.59)	(1.47)	(1.41)	(1.42)	(1.25)	(0.87)	(0.57)
TRM	0.01	-0.02	-0.06	-0.12	-0.18	-0.03	-0.07	-0.12	-0.18	-0.26*
	(0.17)	(-0.38)	(-0.79)	(-1.00)	(-1.27)	(-0.81)	(-1.21)	(-1.47)	(-1.53)	(-1.71)
ΔSY	-0.08***	-0.10	-0.12	-0.12	-0.12*	-0.07**	-0.09	-0.10	-0.10	-0.10
	(-2.90)	(-1.56)	(-1.45)	(-1.51)	(-1.71)	(-2.31)	(-1.32)	(-1.23)	(-1.22)	(-1.34)
ITB	-0.02	-0.06**	-0.06	-0.07	-0.08*	-0.03	-0.06***	-0.06*	-0.07*	-0.08**
	(-0.93)	(-2.02)	(-1.47)	(-1.47)	(-1.72)	(-1.31)	(-2.39)	(-1.74)	(-1.76)	(-1.99)
ICB	-0.01	0.03	0.01	0.00	-0.01	0.01	0.04	0.03	0.02	0.01
	(-0.13)	(0.74)	(0.26)	(0.04)	(-0.18)	(0.25)	(1.36)	(0.72)	(0.56)	(0.35)
VWR	-0.03	-0.03	-0.04	-0.04	-0.04	-0.01	-0.02	-0.02	-0.02	-0.01
	(-1.33)	(-1.22)	(-1.35)	(-1.13)	(-1.01)	(-0.52)	(-0.62)	(-0.76)	(-0.51)	(-0.42)
σ^{VIX}_{IV}	0.09***	0.18***	0.24***	0.26**	0.27***	0.00	0.09*	0.13*	0.12	0.12
	(2.57)	(2.71)	(2.50)	(2.33)	(2.37)	(0.05)	(1.67)	(1.63)	(1.24)	(1.15)
UNC	-0.09**	-0.13*	-0.16*	-0.17	-0.17	-0.04	-0.08	-0.10	-0.09	-0.07
	(-2.08)	(-1.72)	(-1.63)	(-1.55)	(-1.43)	(-1.20)	(-1.21)	(-1.14)	(-1.02)	(-0.85)
$R^2 - ord$	28.17	30.70	27.08	22.20	21.06	39.03	37.21	34.08	31.03	30.41

Table A11. Controlling for 20-year YIV, TYVIX, TIV.
Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + DEP_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is the YIV measured at time t and $DEP_{i,t+j}$ is either the year-on-year growth rate in the gross domestic product, index of industrial production, employment, or consumption measured at time $t + j$. Controls include the at-the-money implied volatility of options on futures on 20-year Treasury notes or bonds, TYVIX index, the CBOE 10-year U.S. Treasury Note Volatility Index, and the variance risk premia. The variance risk premia is the difference between the realized and implied volatility. The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: GDP and 20-year YIV, TIV, TYVIX					Panel B: GDP and 5-year, 20-year YIV, TIV, TYVIX				
$\sigma^{INT}_{IV,5}$						-0.07**	-0.06*	-0.03	-0.00	-0.04
						(-1.96)	(-1.74)	(-1.07)	(-0.05)	(-1.40)
$\sigma^{INT}_{IV,20}$	-0.15***	-0.15***	-0.18***	-0.10*	-0.03	-0.11***	-0.11***	-0.16***	-0.10**	-0.02
	(-3.22)	(-4.48)	(-3.99)	(-1.87)	(-0.57)	(-2.49)	(-2.73)	(-3.39)	(-2.04)	(-0.56)
TIV	-0.27***	-0.35***	-0.42***	-0.32***	-0.23***	-0.21**	-0.31***	-0.40***	-0.32***	-0.19***
	(-2.56)	(-3.59)	(-11.15)	(-6.77)	(-2.66)	(-2.33)	(-3.04)	(-6.93)	(-8.49)	(-3.12)
TYVIX	0.31***	0.42***	0.56***	0.47***	0.34***	0.26***	0.38***	0.54***	0.47***	0.33***
	(2.63)	(3.76)	(14.02)	(6.44)	(3.21)	(2.66)	(3.55)	(10.58)	(7.77)	(3.75)
VRP	0.06	0.06	0.06	0.12***	0.09***	0.04	0.04	0.05	0.12***	0.09***
	(1.33)	(1.35)	(1.40)	(4.58)	(2.97)	(1.10)	(1.20)	(1.32)	(3.83)	(3.22)
Lag GDP	0.11***	0.10**	0.12***	0.11***	0.10***	0.09***	0.08***	0.11***	0.11***	0.09***
	(2.35)	(2.31)	(5.62)	(7.28)	(6.90)	(2.41)	(2.36)	(8.97)	(10.70)	(16.87)
$R^2 - ord$	55.44	53.26	57.57	68.62	71.33	60.63	57.58	58.99	68.63	73.90
	Panel C: IND and 20-year YIV, TIV, TYVIX					Panel D: IND and 5-year, 20-year YIV, TIV, TYVIX				
$\sigma^{INT}_{IV,5}$						-0.16	-0.15**	-0.13***	-0.12***	-0.05*
						(-1.37)	(-2.03)	(-2.69)	(-3.69)	(-1.73)
$\sigma^{INT}_{IV,20}$	-0.03	0.04	0.01	0.14***	0.15***	0.05	0.10	0.05	0.18***	0.16***
	(-0.39)	(0.47)	(0.06)	(2.79)	(4.95)	(0.45)	(1.24)	(0.63)	(4.21)	(5.72)
TIV	-0.15	-0.17**	-0.13*	-0.05	0.01	-0.10	-0.13**	-0.09	-0.01	0.03
	(-1.30)	(-2.23)	(-1.90)	(-1.07)	(0.40)	(-1.36)	(-2.32)	(-1.23)	(-0.17)	(0.84)
TYVIX	-0.03	-0.02	0.05	0.01	0.02	-0.05	-0.03	0.04	-0.00	0.01
	(-0.32)	(-0.16)	(0.80)	(0.12)	(0.28)	(-0.46)	(-0.25)	(0.53)	(-0.05)	(0.07)
VRP	0.01	-0.04	-0.04	0.10	0.15***	-0.04	-0.08	-0.10	0.06	0.12*
	(0.11)	(-0.57)	(-0.51)	(1.30)	(3.02)	(-0.46)	(-1.50)	(-1.43)	(0.89)	(1.89)
Lag IND	0.09***	0.05**	0.03	0.03**	0.01	0.05	0.01	-0.00		
	(4.16)	(1.99)	(1.31)	(2.06)	(0.62)	(1.23)	(0.47)	(-0.10)	(0.02)	(0.01)
$R^2 - ord$	36.96	24.49	11.46	11.53	37.14	43.06	30.49	17.70	19.08	38.71
	Panel E: CON and 20-year YIV, TIV, TYVIX					Panel F: CON and 5-year, 20-year YIV, TIV, TYVIX				
$\sigma^{INT}_{IV,5}$						-0.11***	-0.10***	-0.08***	-0.08***	-0.06
						(-2.50)	(-2.80)	(-2.39)	(-2.55)	(-1.54)
$\sigma^{INT}_{IV,20}$	-0.02	0.02	0.04	0.12***	0.08***	0.03	0.05	0.08*	0.16***	0.11***
	(-0.38)	(0.31)	(0.83)	(2.49)	(2.90)	(0.53)	(0.94)	(1.66)	(3.73)	(4.22)
TIV	-0.04	-0.05	-0.04		0.05***	-0.01	-0.03	-0.01	0.03	0.06***
	(-0.65)	(-0.95)	(-0.99)	(0.11)	(2.42)	(-0.27)	(-0.78)	(-0.41)	(0.98)	(3.25)
TYVIX	-0.02	-0.01	-0.00	-0.03		-0.02	-0.01	-0.01	-0.04	-0.01
	(-0.34)	(-0.31)	(-0.07)	(-0.37)	(0.03)	(-0.42)	(-0.23)	(-0.26)	(-0.47)	(-0.20)
VRP	0.09*	0.08	0.08	0.15***	0.13***	0.05	0.04	0.05	0.13***	0.12***
	(1.70)	(1.26)	(1.28)	(3.11)	(4.86)	(1.05)	(0.76)	(0.89)	(2.71)	(3.53)
Lag CON	0.05***	0.04**	0.04*	0.04**	0.03	0.02	0.01	0.01	0.02	0.02*
	(3.16)	(1.99)	(1.78)	(2.10)	(1.47)	(0.96)	(0.68)	(0.81)	(1.04)	(1.68)
$R^2 - ord$	47.47	32.48	22.74	40.98	59.57	57.55	40.35	29.31	48.25	64.40
	Panel G: EMP and 20-year YIV, TIV, TYVIX					Panel H: EMP and 5-year, 20-year YIV, TIV, TYVIX				
$\sigma^{INT}_{IV,5}$						-0.07***	-0.08***	-0.07***	-0.07***	-0.06***
						(-2.87)	(-4.66)	(-3.21)	(-3.22)	(-4.83)
$\sigma^{INT}_{IV,20}$	-0.06*	-0.03	-0.03	-0.01	0.01	-0.02		0.01	0.04	0.05***
	(-1.76)	(-1.30)	(-1.14)	(-0.46)	(0.69)	(-0.68)	(0.15)	(0.43)	(1.29)	(2.57)
TIV	-0.05	-0.07*	-0.06*	-0.04	-0.04*	-0.04	-0.05**	-0.04	-0.01	-0.01
	(-1.32)	(-1.69)	(-1.72)	(-1.35)	(-1.91)	(-1.35)	(-1.98)	(-1.46)	(-0.60)	(-0.44)
TYVIX	0.01	0.01	0.02	0.02			0.01	0.01	0.01	-0.01
	(0.23)	(0.30)	(0.90)	(1.04)	(0.13)	(0.11)	(0.20)	(0.42)	(0.32)	(-0.27)
VRP	0.02	-0.00	-0.01	-0.00	-0.03		-0.02	-0.03	-0.01	-0.03
	(1.15)	(-0.12)	(-0.37)	(-0.13)	(-1.04)	(0.17)	(-1.22)	(-1.35)	(-0.20)	(-0.80)
Lag EMP	0.02***	0.01	0.01	0.01	0.02*	-0.00	-0.01***	-0.01***	-0.01***	
	(2.91)	(1.56)	(1.18)	(1.25)	(1.82)	(-0.09)	(-2.75)	(-3.00)	(-2.54)	(0.15)
$R^2 - ord$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table A12. Predicting volatility with 20-year YIV, TYVIX, TYVIX.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sigma(MACRO_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is the YIV measured at time t and $\sigma(MACRO_{i,t+j})$ is either the volatility of the year-on-year growth rate in the index of industrial production, the year-on-year growth rate of employment, the year-on-year growth rate in consumption, or the year-on-year change in the consumer confidence index measured at time $t+j$. Controls include the TYVIX index, or the CBOE 10-year U.S. Treasury Note Volatility Index. The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: IND and 20-year YIV, TIV, TYVIX					Panel B: IND and 5-year, 20-year YIV, TIV, TYVIX				
$\sigma^{INT}_{IV,5}$						0.07***	0.13***	0.17***	0.18***	0.21***
						(2.36)	(3.37)	(4.46)	(6.27)	(5.64)
$\sigma^{INT}_{IV,20}$	0.13*	0.09	0.04	-0.09**	-0.12***	0.09	0.03	-0.03	-0.14***	-0.17***
	(1.73)	(1.46)	(0.62)	(-2.11)	(-6.35)	(1.21)	(0.45)	(-0.43)	(-2.79)	(-5.38)
TIV	0.03	0.07	0.10	0.07	0.02		0.03	0.03	-0.00	-0.06
	(0.58)	(1.18)	(1.52)	(1.34)	(0.52)	(0.08)	(0.67)	(0.57)	(-0.03)	(-0.88)
TYVIX	-0.02	-0.00	-0.04	-0.01	0.01	-0.01		-0.01	0.01	0.06
	(-0.27)	(-0.06)	(-0.80)	(-0.17)	(0.09)	(-0.18)	(0.05)	(-0.13)	(0.16)	(0.44)
VRP	0.02	0.02	0.06	0.15*	0.07	-0.00	-0.01	-0.00	0.07	-0.03
	(0.40)	(0.32)	(0.83)	(1.73)	(1.34)	(-0.07)	(-0.40)	(-0.03)	(0.89)	(-0.39)
Lag σIND	0.02	-0.03*	-0.04*	-0.04	-0.06*	0.03***			0.01	-0.02
	(1.10)	(-1.62)	(-1.76)	(-1.37)	(-1.63)	(2.93)	(0.28)	(0.23)	(0.68)	(-1.44)
$R^2 - ord$	49.93	42.45	26.21	17.74	13.06	54.20	51.48	38.11	29.61	30.28
	Panel C: Cons. and 20-year YIV, TIV, TYVIX					Panel D: Cons. and 5-year, 20-year YIV, TIV, TYVIX				
$\sigma^{INT}_{IV,5}$						0.03***	0.04***	0.05***	0.07***	0.08***
						(2.43)	(2.46)	(2.67)	(4.48)	(12.78)
$\sigma^{INT}_{IV,20}$	0.03	0.03	0.02	-0.02	-0.01	0.02	0.01	-0.00	-0.06***	-0.04***
	(1.34)	(1.19)	(0.72)	(-1.03)	(-1.14)	(0.77)	(0.36)	(-0.08)	(-3.59)	(-2.74)
TIV	0.02	0.04*	0.04	0.03	-0.01	0.01	0.02	0.01	-0.00	-0.06*
	(1.04)	(1.76)	(1.45)	(1.38)	(-0.85)	(0.58)	(1.12)	(0.49)	(-0.17)	(-1.80)
TYVIX		-0.01	-0.02	-0.01	0.01		-0.00	-0.01		0.04
		(-0.27)	(-0.87)	(-0.49)	(0.46)	(0.10)	(-0.13)	(-0.40)	(0.08)	(0.79)
VRP	0.01	-0.00	0.01	0.04	-0.02		-0.01	-0.01	0.03	-0.04***
	(0.58)	(-0.07)	(0.37)	(1.46)	(-1.48)	(0.09)	(-0.89)	(-0.31)	(1.58)	(-2.62)
Lag σCON		-0.01	-0.01	-0.02*	-0.03***	0.01*	0.01			-0.01
	(0.34)	(-0.73)	(-1.17)	(-1.64)	(-2.70)	(1.79)	(1.53)	(0.48)	(0.29)	(-1.45)
$R^2 - ord$	44.06	33.99	16.15	9.85	15.16	48.93	40.96	24.78	26.86	41.05
	Panel E: Emp. and 20-year YIV, TIV, TYVIX					Panel F: Emp. and 5-year, 20-year YIV, TIV, TYVIX				
$\sigma^{INT}_{IV,5}$						0.03***	0.02***	0.03***	0.05***	0.06***
						(5.94)	(2.45)	(2.53)	(3.55)	(10.21)
$\sigma^{INT}_{IV,20}$	0.02*	0.02	0.01		-0.02**	0.01	0.01	-0.00	-0.02*	-0.04***
	(1.76)	(1.15)	(1.01)	(0.22)	(-2.32)	(0.85)	(0.38)	(-0.03)	(-1.92)	(-4.13)
TIV	0.02*	0.02*	0.02	0.01		0.02	0.02	0.01	-0.01	-0.02
	(1.77)	(1.68)	(1.50)	(0.63)	(0.09)	(1.41)	(1.25)	(0.80)	(-0.74)	(-1.34)
TYVIX	-0.01	-0.00	-0.01	-0.01	0.01	-0.01	-0.00	-0.01		0.02
	(-0.81)	(-0.00)	(-0.94)	(-0.54)	(0.42)	(-0.66)	(-0.04)	(-0.61)	(0.02)	(0.72)
VRP	0.01	0.01	0.02*	0.02**	-0.01			0.01	0.01	-0.02***
	(0.70)	(0.72)	(1.84)	(2.17)	(-0.72)	(0.17)	(0.25)	(1.20)	(1.35)	(-2.71)
Lag σEMP		-0.00	-0.00	-0.01**	-0.02***	0.01***	0.01*		0.01	-0.00
	(0.72)	(-0.22)	(-1.31)	(-1.98)	(-2.78)	(3.45)	(1.89)	(1.17)	(1.59)	(-1.32)
$R^2 - ord$	48.75	43.78	28.79	12.53	9.63	58.02	49.17	35.47	26.31	36.71

Table A13. Predicting macroeconomic growth rates with non-overlapping observations.
Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + MACRO_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $MACRO_{i,t+j}$ is either the year-on-year growth rate in gross domestic product, index of industrial production, employment, or consumption measured at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity and auto-correlation using Newey-West correction with up to 36 lags lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: GDP and YIV					Panel B: GDP and YIV and lags				
$\sigma_{IV,5}^{INT}$	-0.06**	-0.03	-0.02	-0.01	-0.01	-0.06**	-0.02	-0.02	-0.02	-0.01
	(-2.31)	(-1.61)	(-1.50)	(-1.24)	(-0.94)	(-2.04)	(-1.11)	(-1.25)	(-1.42)	(-1.20)
Lag							0.01		-0.01	-0.01
						(0.28)	(0.72)	(0.21)	(-0.35)	(-0.37)
$R^2 - ord$	17.79	3.16	1.39	0.88	0.50	17.87	3.61	1.42	0.97	0.64
	Panel C: IND and YIV					Panel D: IND and YIV and lags				
$\sigma_{IV,5}^{INT}$	-0.09**	-0.02	-0.04***	-0.03**	-0.03**	-0.11***	-0.02	-0.06***	-0.04***	-0.03
	(-2.04)	(-0.94)	(-2.45)	(-2.17)	(-2.10)	(-2.47)	(-0.90)	(-3.28)	(-2.37)	(-1.46)
Lag IND						-0.05		0.04***	0.02	-0.01
						(-1.39)	(0.14)	(2.53)	(1.30)	(-0.49)
$R^2 - ord$	6.95	0.39	1.51	0.83	0.97	8.21	0.39	2.46	1.11	1.01
	Panel E: CON and YIV					Panel F: CON and YIV and lags				
$\sigma_{IV,5}^{INT}$	-0.07***	-0.03***	-0.01	-0.01	-0.01	-0.06***	-0.02*	-0.00	-0.00	-0.00
	(-4.39)	(-3.25)	(-1.56)	(-1.21)	(-1.45)	(-3.11)	(-1.90)	(-0.45)	(-0.36)	(-0.60)
Lag CON						0.02*	0.02*	0.02*	0.01	0.02
						(1.64)	(1.90)	(1.94)	(1.56)	(1.41)
$R^2 - ord$	18.02	3.03	0.48	0.33	0.58	19.16	3.97	1.16	0.80	1.15
	Panel G: EMP and YIV					Panel H: EMP and YIV and lags				
$\sigma_{IV,5}^{INT}$	-0.08***	-0.04***	-0.01**	-0.001	-0.01***	-0.07***	-0.04***	-0.02***	-0.01**	-0.00
	(-6.38)	(-4.07)	(-2.12)	(-0.53)	(-2.37)	(-4.28)	(-3.37)	(-3.02)	(-1.97)	(-0.61)
Lag EMP						0.02**	-0.00	-0.02**	-0.03***	-0.03***
						(2.25)	(-0.05)	(-2.09)	(-3.28)	(-3.41)
$R^2 - ord$	30.76	9.28	0.92	0.05	1.09	32.35	9.28	1.84	3.11	5.25

Table A14. Exclude the financial crisis.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + MACRO_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $MACRO_{i,t+j}$ is either the year-on-year growth rate in gross domestic product, industrial production, employment, or consumption measured at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity and auto-correlation using Newey-West correction with 12 lags. Monthly data, 1990 - 2007.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: GDP and YIV					Panel B: GDP and YIV and lags				
$\sigma_{IV,5}^{INT}$	-0.02	-0.02	-0.02	-0.02	-0.01*	-0.02	-0.02	-0.02	-0.02	-0.01*
	(-1.41)	(-1.34)	(-1.44)	(-1.53)	(-1.87)	(-1.27)	(-1.31)	(-1.44)	(-1.53)	(-1.79)
Lag						0.02	0.01	0.00	-0.00	-0.01
						(1.22)	(0.60)	(0.13)	(-0.20)	(-0.44)
$R^2 - ord$	4.87	4.89	5.44	4.22	2.91	8.56	6.03	5.52	4.43	3.90
	Panel C: IND and YIV					Panel D: IND and YIV and lags				
$\sigma_{IV,5}^{INT}$	-0.74***	-0.88**	-1.08**	-1.18**	-1.24**	-0.16**	-0.16*	-0.25**	-0.25**	-0.32**
	(-2.57)	(-2.25)	(-2.25)	(-2.23)	(-2.24)	(-2.11)	(-1.80)	(-2.06)	(-2.08)	(-2.34)
Lag IND						1.48***	1.84***	2.13***	2.36***	2.23***
						(5.23)	(5.15)	(4.43)	(3.42)	(2.34)
$R^2 - ord$	8.05	5.96	5.92	4.98	4.10	35.86	28.27	25.37	21.80	15.08
	Panel E: CON and YIV					Panel F: CON and YIV and lags				
$\sigma_{IV,5}^{INT}$	-0.48***	-0.63***	-0.72***	-0.77***	-0.85***	-0.13**	-0.20**	-0.28**	-0.37***	-0.52***
	(-3.29)	(-2.85)	(-2.62)	(-2.60)	(-3.16)	(-2.32)	(-2.38)	(-2.41)	(-2.57)	(-2.77)
Lag CON						0.92***	1.11***	1.14***	1.04***	0.85
						(8.53)	(5.90)	(3.87)	(2.42)	(1.47)
$R^2 - ord$	13.16	10.91	9.02	7.42	7.18	54.63	40.09	28.16	18.91	13.17
	Panel G: EMP and YIV					Panel H: EMP and YIV and lags				
$\sigma_{IV,5}^{INT}$	-0.48***	-0.63***	-0.72***	-0.77***	-0.85***	-0.13*	-0.20*	-0.28*	-0.37*	-0.52***
	(-3.29)	(-2.85)	(-2.62)	(-2.60)	(-3.16)	(-1.64)	(-1.83)	(-1.64)	(-1.75)	(-2.77)
Lag EMP						0.92***	1.11***	1.14***	1.04***	0.85
						(8.53)	(5.90)	(3.87)	(2.42)	(1.47)
$R^2 - ord$	13.16	10.91	9.02	7.42	7.18	54.63	40.09	28.16	18.91	13.17

Table A15. Predicting bank deposit.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + DEP_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $DEP_{i,t+j}$ is the year-on-year growth rate in total deposits for all commercial banks in the U.S. at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: YIV					Panel B: YIV and lags				
$\sigma_{IV,5}^{INT}$						-0.11	-0.11	-0.11*	-0.14*	-0.18***
						(-1.38)	(-1.61)	(-1.69)	(-1.93)	(-2.41)
Lag DEP	0.51***	0.44***	0.41***	0.39***	0.38***	0.53***	0.46***	0.43***	0.42***	0.42***
	(5.26)	(4.09)	(3.29)	(2.81)	(2.67)	(6.04)	(4.73)	(3.80)	(3.38)	(3.35)
TRM	-0.23**	-0.24*	-0.20	-0.13	-0.04	-0.17*	-0.18	-0.13	-0.05	0.06
	(-2.03)	(-1.80)	(-1.25)	(-0.71)	(-0.21)	(-1.67)	(-1.44)	(-0.84)	(-0.26)	(0.34)
ΔSY	0.13***	0.18***	0.21***	0.24***	0.25***	0.12**	0.17***	0.21***	0.22***	0.23***
	(2.34)	(4.39)	(4.93)	(5.09)	(5.56)	(2.15)	(3.97)	(4.60)	(4.78)	(4.94)
ITB	-0.03	-0.02	-0.01	0.01	0.03	-0.04	-0.03	-0.01	0.01	0.02
	(-1.26)	(-1.05)	(-0.44)	(0.53)	(1.59)	(-1.38)	(-1.24)	(-0.59)	(0.37)	(1.55)
ICB	0.01	0.01	0.03	0.03	0.01	0.01	0.01	0.03	0.03	0.01
	(0.36)	(0.32)	(0.76)	(0.77)	(0.34)	(0.35)	(0.28)	(0.76)	(0.78)	(0.24)
VWR	0.04	0.04*	0.04*	0.04	0.04	0.04	0.03	0.03	0.03	0.03
	(1.60)	(1.68)	(1.63)	(1.61)	(1.60)	(1.35)	(1.31)	(1.22)	(1.14)	(1.13)
σ_{IV}^{VIX}	-0.16***	-0.19***	-0.23***	-0.26***	-0.30***	-0.10	-0.13	-0.17	-0.18	-0.20*
	(-2.45)	(-2.55)	(-2.65)	(-2.73)	(-3.18)	(-1.16)	(-1.40)	(-1.60)	(-1.51)	(-1.67)
UNC	-0.02	0.04	0.09	0.14**	0.18***	-0.05	-0.00	0.05	0.08	0.11*
	(-0.26)	(0.63)	(1.51)	(1.98)	(2.37)	(-0.75)	(-0.00)	(0.92)	(1.38)	(1.76)
$R^2 - ord$	66.39	62.83	57.63	50.97	45.96	67.22	63.70	58.61	52.61	48.75

Table A16. Predicting bank deposit volatility.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sigma(DEP_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is the YIV measured at time t and $DEP_{i,t+j}$ is the year-on-year growth rate in total deposits for all commercial banks in the U.S. at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: YIV					Panel B: YIV and lags				
$\sigma^{INT}_{IV,5}$						0.37	0.08	0.01	0.04	0.02
						(1.19)	(0.31)	(0.03)	(0.21)	(0.10)
Lag σ DEP	-0.31*	-0.58***	-0.80***	-0.92***	-0.83***	-0.34*	-0.58***	-0.80***	-0.92***	-0.83***
	(-1.65)	(-2.78)	(-3.41)	(-3.61)	(-2.64)	(-1.77)	(-2.75)	(-3.38)	(-3.59)	(-2.56)
TRM	0.14	0.03	-0.02	0.10	0.26	-0.00	-0.00	-0.03	0.09	0.25
	(0.72)	(0.13)	(-0.08)	(0.32)	(0.57)	(-0.02)	(-0.00)	(-0.08)	(0.25)	(0.51)
ΔSY	-0.07	-0.24	-0.30	-0.32	-0.30	-0.04	-0.24	-0.29	-0.32	-0.30
	(-0.27)	(-0.57)	(-0.71)	(-0.84)	(-0.89)	(-0.15)	(-0.55)	(-0.70)	(-0.83)	(-0.90)
ITB	-0.01	0.18	0.23	0.17	0.10	-0.00	0.18	0.23	0.17	0.10
	(-0.09)	(1.42)	(1.30)	(0.87)	(0.47)	(-0.02)	(1.40)	(1.30)	(0.86)	(0.47)
ICB	-0.23**	-0.39***	-0.20	0.01	0.03	-0.21**	-0.39***	-0.20	0.01	0.03
	(-1.96)	(-2.90)	(-1.28)	(0.12)	(0.18)	(-2.09)	(-2.84)	(-1.26)	(0.13)	(0.19)
VWR	0.01	0.21*	0.22*	0.13	0.03	0.04	0.22*	0.23*	0.14	0.03
	(0.12)	(1.83)	(1.81)	(1.07)	(0.23)	(0.38)	(1.96)	(1.85)	(1.13)	(0.24)
σ^{VIX}_{IV}	0.90***	1.00***	0.68*	0.32	-0.04	0.69***	0.96***	0.67*	0.30	-0.05
	(3.97)	(3.21)	(1.90)	(0.82)	(-0.10)	(2.36)	(2.67)	(1.78)	(0.77)	(-0.13)
UNC	-0.87***	-0.76**	-0.50	-0.45	-0.32	-0.75***	-0.74*	-0.50	-0.44	-0.32
	(-3.20)	(-2.09)	(-1.41)	(-1.30)	(-0.88)	(-2.83)	(-1.94)	(-1.36)	(-1.34)	(-0.98)
$R^2 - ord$	15.06	13.29	11.10	13.44	14.44	16.69	13.35	11.10	13.45	14.44

Table A17. Predicting bank credit.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sum_{j=1}^{j=H} \log(1 + BCG_{i,t+j}) = \alpha_H + \beta_H \sigma_{IV,t}^{INT} + Controls + \epsilon_{t+H}$$

Here, $\sigma_{IV,t}^{INT}$ is the YIV measured at time t and $BCG_{i,t+j}$ is the year-on-year growth rate in total loans extended by all commercial banks in the U.S. at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: YIV					Panel B: YIV and lags				
$\sigma_{IV,5}^{INT}$						-0.10***	-0.12***	-0.13***	-0.13***	-0.14***
						(-4.22)	(-4.08)	(-4.08)	(-4.70)	(-6.16)
Lag BCG	0.22***	0.20***	0.18***	0.17***	0.15**	0.25***	0.25***	0.23***	0.22***	0.20***
	(4.59)	(3.47)	(2.75)	(2.44)	(2.27)	(5.85)	(5.16)	(4.24)	(3.83)	(3.93)
TRM	-0.05	-0.02		0.02	0.03	0.02	0.06	0.09	0.11*	0.13**
	(-0.97)	(-0.29)		(0.23)	(0.43)	(0.37)	(1.26)	(1.40)	(1.63)	(2.13)
ΔSY	0.08***	0.09***	0.09***	0.09***	0.09***	0.07***	0.08***	0.08***	0.08***	0.07***
	(2.83)	(3.67)	(5.32)	(5.38)	(4.94)	(2.86)	(3.74)	(5.43)	(4.80)	(3.98)
ITB	0.06***	0.05***	0.04***	0.04***	0.03***	0.06***	0.05***	0.04***	0.04***	0.03***
	(3.81)	(3.02)	(2.68)	(2.72)	(2.52)	(4.36)	(3.94)	(3.92)	(4.05)	(3.97)
ICB	-0.03	-0.03	-0.02	-0.01	-0.00	-0.03*	-0.03**	-0.03*	-0.02	-0.01
	(-1.40)	(-1.35)	(-1.11)	(-0.70)	(-0.19)	(-1.75)	(-2.02)	(-1.77)	(-1.27)	(-0.76)
VWR		0.01	0.02	0.02	0.02	-0.00		0.01	0.01	0.01
	(0.13)	(0.79)	(1.04)	(0.95)	(1.04)	(-0.22)	(0.29)	(0.49)	(0.38)	(0.40)
σ_{IV}^{VIX}	-0.08*	-0.11**	-0.12***	-0.13***	-0.14***	-0.03	-0.04	-0.05	-0.07**	-0.07**
	(-1.89)	(-2.26)	(-2.73)	(-3.19)	(-3.51)	(-0.81)	(-1.06)	(-1.51)	(-2.01)	(-2.30)
UNC	0.04	0.05	0.08**	0.09***	0.10***	0.01	0.01	0.03	0.05*	0.06*
	(0.86)	(1.27)	(1.98)	(2.43)	(2.69)	(0.16)	(0.31)	(1.12)	(1.65)	(1.90)
$R^2 - ord$	61.63	55.83	50.84	47.39	44.06	65.31	62.25	58.41	55.82	55.03

Table A18. Predicting bank credit volatility.

Notes: This Table shows the estimated coefficients for the forecasting regression:

$$\sigma(BCG_{i,t+j}) = \alpha_H + \beta_H \sigma^{INT}_{IV,t} + Controls + \epsilon_{t+H}$$

Here, $\sigma^{INT}_{IV,t}$ is the YIV measured at time t and $BCG_{i,t+j}$ is the year-on-year growth rate in total loans issued by all commercial banks in the U.S. at time $t+j$. Controls include the term spread (TRM), the changes in the short-rate (ΔSY), the return on an index of treasury bonds (ITB), the returns on an index of corporate bonds (ICB), the value-weighted return on an index of all stocks in CRSP (VWR), the CBOE Volatility Index (VIX), and the equity-market related economic uncertainty index from Baker, Bloom, and Davis (2015) (UNC). The numbers in parenthesis are the t-statistics. Statistical significance is indicated by *, **, and *** at the 10%, 5% and 1% levels respectively. The standard errors are adjusted for heteroscedasticity, auto-correlation, and overlapping data using the Newey-West correction with up to 36 lags. Monthly data, 1990 - 2016.

$H =$	12	18	24	30	36	12	18	24	30	36
	Panel A: YIV					Panel B: YIV and lags				
$\sigma^{INT}_{IV,5}$						0.37***	0.58***	0.46***	0.36***	0.32***
						(5.17)	(3.57)	(3.23)	(2.73)	(2.40)
Lag σBCG	0.12		-0.15	-0.24	-0.32*	0.11	-0.02	-0.16	-0.24	-0.32*
	(1.39)	(0.01)	(-0.85)	(-1.33)	(-1.79)	(1.30)	(-0.20)	(-1.01)	(-1.39)	(-1.69)
TRM	0.23**	0.32*	0.35*	0.27	0.17	0.10	0.11	0.17	0.13	0.04
	(2.04)	(1.84)	(1.68)	(1.27)	(0.67)	(0.94)	(0.70)	(0.87)	(0.60)	(0.13)
ΔSY	-0.04	-0.16***	-0.34***	-0.45**	-0.47***	-0.01	-0.11*	-0.30**	-0.42**	-0.44**
	(-0.73)	(-2.49)	(-2.38)	(-2.26)	(-2.48)	(-0.19)	(-1.71)	(-1.99)	(-2.03)	(-2.27)
ITB	-0.08	-0.03	-0.03	-0.05	-0.11*	-0.07*	-0.02	-0.02	-0.04	-0.11**
	(-1.48)	(-0.35)	(-0.29)	(-0.68)	(-1.86)	(-1.63)	(-0.26)	(-0.25)	(-0.70)	(-2.16)
ICB	0.06	-0.09	-0.13	-0.13*	-0.10*	0.08**	-0.07	-0.11*	-0.12*	-0.09**
	(1.10)	(-0.94)	(-1.57)	(-1.69)	(-1.77)	(2.09)	(-1.21)	(-1.87)	(-1.83)	(-1.98)
VWR	-0.08**	-0.11***	-0.11**	-0.11**	-0.09*	-0.05	-0.06	-0.07	-0.08*	-0.06
	(-2.12)	(-2.64)	(-2.27)	(-2.14)	(-1.91)	(-1.31)	(-1.29)	(-1.53)	(-1.73)	(-1.50)
σ^{VIX}_{IV}	0.54***	0.51***	0.42***	0.33**	0.25*	0.33***	0.17	0.16	0.13	0.07
	(3.45)	(2.85)	(2.55)	(2.25)	(1.89)	(2.59)	(1.30)	(0.98)	(0.75)	(0.42)
UNC	-0.17*	-0.22	-0.26	-0.32	-0.33	-0.05	-0.01	-0.10	-0.19	-0.21
	(-1.86)	(-1.55)	(-1.34)	(-1.46)	(-1.57)	(-0.61)	(-0.17)	(-0.65)	(-1.01)	(-1.28)
$R^2 - ord$	48.20	32.87	25.70	19.95	16.44	57.61	48.39	33.57	24.05	19.45