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U.S. stock returns and oil prices: The tale from daily data and the 2008–2009 financial crisis

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ABSTRACT

Using daily data from January 1999 to December 2011, we examine U.S. stock returns (S&P 500, Dow Jones, NASDAQ, and Russell 2000) based on a wide range of information, including equity VIX volatility, inflation expectations, interest rates, gold prices, and the USD/Euro exchange rate. The focus is on oil price returns, which have been previously found to exert mostly negative effects on U.S. stock returns. Identifying the crisis of 2008–2009 as a significant period of economic contraction and subsequent "recovery", we check the stability of the stock-oil relationship by GARCH and MGARCH-DCC models. Prior to the financial crisis, stock returns are slightly (negatively) affected by oil prices and by the USD/Euro. For the subsample of mid-2009 onwards, however, stock returns are positively affected by oil prices and a weaker USD/Euro. As with inflation expectations, we interpret these findings as U.S. stocks responding positively to expectations of recovery worldwide. Our proposed explanation is due to the changing correlation between stock markets and oil, either by standard GARCH models or by MGARCH-DCC models allowing the implied correlation to vary over time.

1. Introduction

We examine in this paper a vast information set at the daily frequency in all major financial markets to explain U.S. stock returns. Theoretically, stock returns depend on expected cash flows discounted by interest rates, as proposed in the seminal paper by Chen et al. (1986). Under this framework, a combination of forces impacts the expected earnings of firms. For instance, the shape of the yield curve (whether positively sloped, flat, or inverted), the market views on inflation expectations, as well as uncertainty in equity markets (captured by the "fear gauge index" of VIX in option contracts) are important domestic forces. At the same time, (domestic) interest rate increases should make stocks fall by discounting more heavily expected cash flows. In international markets, gold prices and fluctuations in exchange rates (through a higher trade and GDP channel) may also affect discounted cash flows. More difficult to ascertain is perhaps the impact of oil prices, which have confounding effects on stock markets. As surveyed by Killian (2008), the responses of real U.S. stock returns to oil price shocks differ substantially depending on the underlying causes of the oil price increase.

In addition to the multivariate nature of stock returns, the specific time period may be important since financial markets behave differently in bear and bull markets and the relationship among the variables may be subject to drastic changes. To illustrate, Engle (2004) examines daily levels of the S & P 500 index from 1963 through late 2003. The implied return series is centered around zero throughout the sample period with prices sometimes increasing and sometimes decreasing. He identifies the crash of October 1987 as "the most dramatic event" and concludes that volatility tends to be higher in bear markets. Engle (2004) looks next at the subperiod after the 1987 crash with record low volatility in the middle 1990s, accompanied by a slow and steady growth of equity prices. The volatility began to rise as stock prices go higher, reaching very high levels from 1998 onwards. When looking at the period since 1998, Engle (2004) sees high volatility to continue as the market turned down. The fact that financial price volatility is a manifestation of the arrival of new information makes volatility clustering an important topic.

We put forward a reexamination of this proposition using very flexible GARCH (1, 1) and MGARCH-DCC models that accommodate a wide range of domestic and international forces expected to influence U.S. stock returns. We also consider three important subsample estimations of these models. The first runs from Jan 1999 to Dec 2007, in what we refer to as the "pre-crisis period." The second starts at the beginning of 2008, right after the NBER identified December of 2007 as the start of the major recent financial crisis in the U.S. About six months later, in mid-2008, oil prices spiked in international markets and major U.S. stock returns underwent severe volatility periods to bottom out in March of 2009. The U.S. recession officially ended in June 2009, although economic growth has since been sluggish. The third subsample from July 2009 onwards refers to the U.S. economy

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entering a “recovery” phase. This four-year period since the onset of the major recession of 2008–2009 provides an excellent window to reexamine macroeconomic forces (domestic and international) on U.S. stock markets at the daily frequency.

Controlling for all financial markets, oil prices have no (or slightly negative) effects on stock returns in the years preceding the financial crisis of 2008–2009, together with negative exchange rate effects (lower USD against Euro led to lower stock returns). For the subsample of 2008 to mid-2009, however, there are positive exchange rate effects (weaker dollar versus Euro leads to higher stock returns). And, for the subsample of mid-2009 to 2011 (the “recovery” period) oil price returns have positive effects on stock returns, together with positive and stronger exchange rate effects. We use the rationalization in Chen et al. (1986) to interpret these two novel findings from our research.[1] As with a positive effect of inflation expectations, U.S. stocks respond positively to expectations of recovery during the aftermath of the crisis of 2008–2009, which include higher demand for oil together with more exports to the rest of the world. These findings are obtained for standard GARCH (1, 1) as well as for MGARCH-DCC models on the joint estimation of stock returns and changes in VIX (or oil returns).

2. Literature review

A strong correlation between crude oil price changes and U.S. GNP growth was documented by Hamilton (1983) for a period of upward oil price movements. Revisiting this issue for declines in oil prices in the mid-1980s, Mork (1989) confirmed the negative relationship for the U.S., while Jiménez-Rodríguez and Sánchez (2005) reconsidered this research topic for quarterly data from 1972 to 2001 and found contrasting effects across countries. Jones and Kaul (1996) use quarterly postwar data (until 1991) and find that U.S. and Canadian stock markets are rational: the reaction of stock prices to oil shocks can be accounted for by their impact on current and expected future real cash returns alone, with puzzling evidence for the U.K. and Japan.

Starting perhaps with Amano and Van Norden (1998) for major real effective exchange rates from Jan 1973 to Jun 1993, oil prices have been exerting a clear influence on real exchange rates as well. Chen and Chen (2007) use a monthly panel of G7 countries from Jan 1972 to Oct 2005 to find that real oil prices have been the dominant source of real exchange rate movements with significant forecasting power and greater predictability over longer horizons. Bénassy-Quéré et al. (2007) study cointegration and causality between the real price of crude petroleum and the dollar real exchange rate over the monthly 1974–2004 period and find that oil prices are more volatile than exchange rates (against the Euro and the real effective exchange rate) and that oil prices seem to “lead” exchange rates in a Granger causality sense. Lizardo and Mollick (2010) incorporate oil WTI prices to the monetary model of exchange rates and find under monthly data that oil price increases lead to a significant depreciation of the U.S. dollar against net exporter currencies (such as Canada, Mexico, and Russia) and to a depreciation of oil importer currencies (such as Japan). These studies show that oil prices have effects on the overall economy in what can be interpreted as a shift in the production function or in the real exchange rate by changing the terms of trade.

In principle, however, there is no reason why oil prices should impact aggregate indexes uniformly since a stock index is a combination of firms that may profit or lose in response to oil fluctuations. Nandha and Faff (2008), for example, study 35 global industry indices from Apr 1983 to Sep 2005 and conclude that WTI oil price rises have a negative impact on equity returns for all sectors, except mining, and oil and gas industries. Cong et al. (2008) find that oil price shocks do not show statistically significant impact on the real stock returns of most Chinese stock market indices from Jan 1996 to Dec 2007, except for manufacturing and some oil companies. In contrast to these mixed results, Chen (2010) employs time-varying transition probability Markov-switching models for monthly Standard & Poor's 500 index returns to show that increases in oil prices lead to a higher probability of a bear market. Examining monthly data from Jan 1996 to Dec 2007 for OPEC spot prices and Gulf Cooperation Council (GCC) stock markets, Arouri and Rault (2012) show that oil price increases have a positive impact on stock prices, except in Saudi Arabia.

Under a VAR approach, Killian (2008) suggests the responses of real U.S. stock returns to oil price shocks differ substantially depending on the underlying causes of the oil price increases. Apergis and Miller (2009) decompose oil-price changes into three components or shocks (oil supply, global aggregate demand, and global oil demand) for 8 major countries with monthly data from 1981 to 2007. In their VAR models of global oil production, global real economic activity, and real oil prices, they find that international stock market returns do not respond in a large way to oil market shocks.

El-Sharif et al. (2005) report for daily data from Jan 1989 to Jun 2001 a positive relationship between the price of crude oil and equity values in the oil and gas sectors in the UK, the largest oil producer in the European Union. Driesprong et al. (2008) perform econometric analysis on monthly data from Oct 1973 to Apr 2003 for several countries. They estimate stock returns on lagged oil prices and find usually negative coefficients in both industrial and emerging markets, which are further strengthened by introducing lags of several trading days. Park and Ratti (2008) use a first-differenced VAR (with short-term interest rates, real oil price, industrial production, and stock returns) and conclude that oil price shocks have a negative impact on real stock returns in the U.S. and several European countries over Jan 1986 to Dec 2005.

Studies that evaluate financial variables have admittedly taken a stand on the degree of volatility or risk involved in the series. Glosten et al. (1993) propose a GARCH in mean model to document a negative relation between conditional expected monthly return and conditional variance in the U.S. from Apr 1954 to Dec 1989. Using a class of GARCH models, Cifarelli and Paladino (2010) find strong evidence that WTI oil price shifts are negatively related to U.S. Dow Jones Industrial stock price index and exchange rate changes under weekly data from 1992 to 2008. During that period the average return on oil was higher than on equities, with significantly greater standard deviations as well. The GARCH models in Arouri (2011) contain oil prices and stock returns in Europe under weekly data from Jan 1998 to Jun 2010 and conclude that not all sectors are equally dependent on oil, with positive effects for oil & gas, basic materials, and consumer services sectors in Europe.

Very high-frequency studies on stock returns are desired since stocks change daily in response to many financial forces and news. Examples of this approach include Hammoudeh and Aleisa (2004), who examined daily GCC stock markets with mixed results; and Bachmeier (2008) who used daily data from Jan 1986 to Oct 2003 to show that oil price shocks have negative effects on U.S. stock returns, albeit with a very low explanatory power. Other studies have examined other financial markets with daily data. From Jan 1999 to Oct 2007, Sari et al. (2010) put forward a VAR approach to detect co-movements in gold, silver, platinum, palladium, WTI oil spot and the Euro/USD exchange rate.

Precisely because the oil-stock relationship may occur under an indirect channel it is important to consider aggregate market volatility and fixed income markets (short-term interest rates, the yield curve, and inflation expectations). Ang et al. (2006) build a dynamic model for GDP growth and yield spreads and predict that the short rate has more predictive power than any term spread, with a confirmation of this finding by forecasting GDP out-of-sample techniques. Theoretical and empirical work has documented the responses of stock

[1] Pesaran and Timmermann (2000) reconsidered this approach to *monthly* stock returns in the U.K. FTSE index from Jan 1965 to Dec 1993 responding to dividend-yield, the 3-month Treasury bill rate, and inflation, while allowing for changes in industrial production, money supply, and oil prices. They found statistically significant negative impacts on stock returns of oil price changes (−0.060), a negative coefficient on money supply (−0.343), a positive coefficient on industrial production (0.482), and a positive yet very small coefficient on dividend-yield (0.009).

Table 1A
Descriptive statistics (daily data from Jan. 1999 to Dec. 2007) — Sample I.

	SP500	DOW	NASDAQ	RUS2000	GOLD	OIL_WTI	EURO	JPY	IUS	YIELD	INF__EXP	VIX
In levels												
Mean	1225.8	10564.9	1857.0	562.2	406.3	41.023	1.120	0.872	3.822	1.464	2.728	20.123
Median	1231.2	10535.5	1619.7	522.8	360.3	32.480	1.146	0.860	4.280	1.223	2.407	19.770
Maximum	1565.2	14164.5	4704.7	855.8	841.1	98.830	1.487	0.984	6.869	3.871	4.461	45.080
Minimum	776.8	7286.3	804.7	327.0	252.8	11.380	0.829	0.742	1.000	−0.769	1.335	9.890
Std. Dev.	180.1	1281.6	753.8	135.2	146.8	19.185	0.168	0.053	1.893	1.267	0.870	6.725
Skewness	−0.287	0.448	1.591	0.520	1.004	0.771	−0.025	0.016	−0.116	0.206	0.443	0.584
Kurtosis	2.376	3.600	5.097	2.133	2.879	2.633	1.810	2.290	1.519	1.699	1.753	2.916
N	2347	2347	2347	2347	2347	2347	2346	2347	2347	2347	2347	2347
Return/differenced												
	RET_SP500	RET_DJ	RET_ND	RET_RUSS	RET_GOLD	RET_OILWTI	RET_EURO	RET_JPY	DIFF_I	DIFF_YIELD	DIFF_INF	VIX_CHG
Mean	0.0001	0.0002	0.0003	0.0003	0.0005	0.0012	0.0001	0.0000	−0.0002	0.0002	−0.0009	0.0016
Median	0.0000	0.0000	0.0005	0.0003	0.0000	0.0000	0.0001	0.0000	0.0000	−0.0001	0.0000	−0.0007
Maximum	0.0573	0.0635	0.1877	0.0584	0.0726	0.1114	0.0239	0.0289	0.5700	0.5385	0.2124	0.6422
Minimum	−0.0583	−0.0713	−0.0973	−0.0726	−0.0606	−0.1582	−0.0264	−0.0388	−0.4200	−0.4762	−0.1825	−0.2591
Std. Dev.	0.0110	0.0105	0.0217	0.0129	0.0098	0.0230	0.0061	0.0061	0.0267	0.0663	0.0444	0.0574
Skewness	0.1254	0.0037	0.4630	−0.0654	0.1307	−0.3188	0.0797	0.1182	−1.3338	0.2437	0.0900	1.1037
Kurtosis	5.4602	6.6456	8.0756	4.1854	8.6570	5.4554	3.8502	5.3904	162.5924	10.7963	5.0850	11.5366
Sharpe ratio	0.0124	0.0202	0.0133	0.0261	0.0512	0.0500	0.0176	0.0042	−0.0058	0.0030	−0.0204	0.0272
N	2346	2346	2346	2346	2346	2346	2345	2346	2346	2346	2346	2346

Note: Daily data from Jan. 1999 to Dec. 2007. Euro is US dollar per Euro and JPY is US dollar per 100 Japanese Yen. Yield is ten-year T-bond minus 3 month T-bill. Inflation expectation (INF_EXP) is ten-year T-bond minus ten year TIPS. All variables are in return except interest rate, yield and inflation expectations which are in differences.

returns to changes in VIX as well. Dennis et al. (2006), for example, report (in a system of two equations: one for returns, another for the conditional variance of the return residual) negative and statistically significant VIX coefficients on returns in 48 of the 50 firms when estimating daily returns on daily changes in the individual firm's implied volatility, daily changes in VIX, and the return residual. Bollerslev et al. (2009) adopt a general equilibrium model to derive the implied equity premium as a sum of two terms: the first is the classic risk-return tradeoff and the second is a true premium for volatility risk, with the volatility risk premium depending on the assumptions of recursive utility. They provide evidence that stock market returns are predictable by the difference between "model-free" implied and realized variances or the variance risk premium, with the degree of predictability largest at intermediate quarterly horizons.[2]

3. The data

All data collected for this paper are daily from January 1 1999 to December 30 2011 from *Datastream*. This period, coinciding with the post-1997 Asian financial crisis, is subsequent to the collapse of oil prices in 1998 as a result of the oil surplus accumulated after the crisis. The data include: U.S. exchange rates against major currencies (Euro and JPY), short and long-term U.S. interest rates, U.S. major stock indexes and VIX. The stock price indices used to calculate daily returns are: S&P 500 COMPOSITE, Dow Jones Industrial Average, NASDAQ, and Russell 2000. VIX is the Chicago Board Options Exchange Market Volatility Index of the implied volatility of S&P 500 index options. Furthermore, oil price per barrel West Texas Intermediate (WTI) and gold price of Handy & Harman Base dollar per Troy Ounce are available in commodity markets. Exchange rate is U.S. dollar per Euro: *an increase means USD depreciation*, with the U.S. dollar per 100 Japanese Yen as an alternative series. Short-term interest rates are captured by the three month U.S. Libor rate. We also obtain U.S. 2-year Treasury notes and 10-year Treasury bonds. Yield (the shape of the yield curve) is calculated in two ways: the difference between 10-year U.S. Treasury bond and 3-month U.S. Treasury bill; and the difference between 10-year U.S. Treasury bond and 2-year U.S. Treasury note. We report below on the former but the latter was checked for robustness.[3] Inflation expectation is the difference between the 10-Year U.S. Treasury bond and 10-Year U.S. Treasury Inflation-Protected Securities (TIPS). Previous versions used the price of gold to proxy for inflation expectations but the anonymous referee pointed out that this more accurate measure of inflation expectations could indeed be obtained for our sample.

Table 1A presents the descriptive statistics of all series for the first subsample period of study: Jan 1999 to Dec 2007. This period precedes the onset of the major recession that started in Dec 2007, according to the U.S. NBER. In order to compare returns against standard deviation across markets, we follow Serban (2010), who collected major monthly exchange rates and equity returns and constructed Sharpe ratios (mean divided by standard deviation), showing higher figures for stock markets than FX markets in industrial economies over Dec 1978 to Feb 2008. Adopting this framework in return/differenced form, gold and oil price returns in Table 1A show the highest Sharpe ratio of about 5.1% and 5.0%, respectively, followed by Euro dollar with Sharpe ratio of 1.76%. Compared to gold and oil, stocks have less return adjusted for risk over time, varying from 1.24% in S&P 500 to 1.33% in Nasdaq and from 2.02% in Dow Jones and 2.61% in Russell 2000. While returning less than commodity markets, this suggests that over the first subperiod returns of Dow 30 large company and Russell 2000 small company stocks grew faster — adjusted for risk — than other benchmarks.

Table 1B focuses on the second subsample, right after the start of the December 2007 recession in the U.S. as documented by the NBER. In this

[2] A reverse causation channel is also present in the literature. Giot (2005) revisits the negative and statistically significant relationship between the returns of U.S. stock markets and implied volatility indices (VIX for the S&P 100 and VXN for the NASDAQ 100). He regresses from Aug 2003 to January 2003 daily changes in VIX (or VXN) on one-day returns on the S&P 100 index (or NASDAQ 100) and find asymmetries with negative returns for the S&P 100 index being associated with greater relative changes in implied volatility, while the NASDAQ market had less evidence of asymmetries. Adrian and Rosenberg (2008) decompose equity market volatility into short-run (to capture the tightness of financial constraints) and long-run components (linked to business cycle risk). Using daily data on U.S. value weighted CRSP portfolio return from 1963 to 2005, they find that negative returns increase short-run and long-run volatility more than positive returns.

[3] Defining the yield curve as the difference between the U.S. 10-year T-bond and the 2-year T-note, we observe a very similar pattern. The alternative series, however, has lower mean and standard deviations, and smaller extremes (maximum and minimum values). In the estimations below we will use the difference between 10-year U.S. Treasury bond and 3-month U.S. Treasury bill, which is closer to the definition in Chen et al. (1986) of long bond minus 1-month Treasury bill. Ang et al. (2006) contains recent evidence of term spreads on GDP growth.

Table 1B
Descriptive statistics (daily data from Jan. 2008 to Dec. 2011) — Sample II.

	SP500	DOW	NASDAQ	RUSS2000	GOLD	OIL_WTI	EURO	JPY	IUS	YIELD	INF__EXP	VIX
In levels												
Mean	1144.0	10689.5	1857.9	655.0	1159.7	84.0	1.396	1.109	1.074	2.783	1.266	27.690
Median	1165.9	10946.7	1862.3	676.9	1106.0	82.6	1.394	1.104	0.435	2.859	1.342	24.260
Maximum	1468.4	13264.8	2429.5	865.3	1895.0	145.7	1.600	1.319	4.819	3.809	3.132	80.860
Minimum	676.5	6547.1	1036.5	343.3	712.5	30.8	1.192	0.894	0.245	0.610	−0.163	14.620
Std. Dev.	171.0	1504.7	358.5	115.3	289.1	22.3	0.089	0.114	1.148	0.634	0.630	11.380
Skewness	−0.517	−0.550	−0.393	−0.456	0.634	0.122	0.231	0.028	1.315	−0.587	−0.053	1.750
Kurtosis	2.387	2.365	2.303	2.498	2.330	3.132	2.487	1.974	3.467	3.059	3.500	6.316
N	1044	1044	1044	1044	1044	1044	1044	1044	1044	1044	1044	1044
Return/Differenced												
	RET_SP500	RET_DJ	RET_ND	RET_RUSS	RET_GOLD	RET_OILWTI	RET_EURO	RET_JPY	DIFF_I	DIFF_YIELD	DIFF_INF	VIX_CHG
Mean	0.0000	0.0001	0.0003	0.0002	0.0007	0.0005	−0.0001	0.0004	−0.0039	0.0011	−0.0017	0.0027
Median	0.0005	0.0004	0.0006	0.0001	0.0004	0.0000	0.0002	0.0003	0.0000	0.0000	−0.0014	−0.0059
Maximum	0.1158	0.1108	0.1258	0.0927	0.0710	0.2371	0.0348	0.0389	0.2925	0.7167	0.3907	0.5000
Minimum	−0.0904	−0.0787	−0.1052	−0.1185	−0.0766	−0.1225	−0.0262	−0.0504	−0.3863	−0.4861	−0.5802	−0.2957
Std. Dev.	0.0178	0.0162	0.0182	0.0223	0.0147	0.0296	0.0079	0.0079	0.0372	0.0899	0.0685	0.0746
Skewness	−0.0053	0.2100	0.1197	−0.1173	−0.1182	0.6927	0.1455	0.0503	−2.3183	0.3323	−0.4417	1.2976
Kurtosis	9.2429	9.8341	8.9720	5.7251	6.5424	9.9039	4.2168	7.4486	41.9678	10.3996	10.6839	8.0850
Sharpe ratio	0.0005	0.0032	0.0137	0.0097	0.0486	0.0156	−0.0105	0.0490	−0.1063	0.0118	−0.0253	0.0360
N	1044	1044	1044	1044	1044	1044	1044	1044	1044	1044	1044	1044

Notes: Daily data from Jan. 2008 to Dec. 2011. Euro is US dollar per Euro and JPY is US dollar per 100 Japanese Yen. Yield is ten-year T-bond minus 3 month T-bill. Inflation expectation (INF_EXP) is ten-year T-bond minus ten-year TIPS. All variables are in return except interest rate, yield and inflation expectations which are in differences.

sub-sample the highest Sharpe ratios are registered for the Japanese yen (4.90%), followed very closely by gold (4.86%). Euro actually appreciated against the dollar with negative Sharpe ratio of −1.05%. At relatively high historical prices, West Texas intermediate oil returns have now a much lower adjusted mean of 1.56% for this subsample. In this period the technology heavy Nasdaq and the Russell 2000 indexes have higher adjusted for risk returns of 1.37% and 0.97%, respectively than the other equity markets. Overall, stock returns (adjusted for risk) are much lower in this 4-year period subsample than returns in commodity or exchange rate markets.

Tables 2A and 2B present the correlation coefficients among the major series for the first and second subsamples. The results indicate that the highest correlation coefficients are between the stock returns and VIX varying from −0.583 in Nasdaq to −0.741 in S&P 500 from 1999 to 2007, and varying from −0.745 in Russell to −0.783 in S&P 500 from 2008 onwards. The other interesting correlation is between exchange rates and stock returns. In the first subsample the U.S. dollar exchange rate to both currencies is negatively correlated with stock returns: with values close to −0.16 or −0.13 in both S&P and Dow markets. In the second subsample the U.S. dollar exchange rate to Japanese Yen is negatively correlated with stock returns (values varying from −0.395 to −0.452) while the correlation between the U.S. dollar exchange to Euro with stock returns is positive with values from 0.350 to 0.405. This suggests that in the first subsample depreciations of the USD co-move negatively with stock returns. In the second, however, there is a negative correlation between stock markets and JPY and a positive correlation with Euro.

The correlation coefficients between stock returns and oil price changes change dramatically too. In the first subsample, the correlation between oil price and stock returns is weak and not statistically

Table 2A
Correlation Returns/differences — Sample I (Jan. 1999–Dec. 2007).

Probability	RET_SP500	RET_DJ	RET_ND	RET_RUSS	RET_GOLD	RET_OILWTI	RET_EURO	RET_JPY	DIFF_I	DIFF_YIELD	DIFF_INF	VIX_CHG
RET_SP500	1.000											
RET_DJ	0.942	1.000										
	(0.000)											
RET_ND	0.830	0.685	1.000									
	(0.000)	(0.000)										
RET_RUSS	0.830	0.738	0.787	1.000								
	(0.000)	(0.000)	(0.000)									
RET_GOLD	−0.068	−0.093	−0.052	−0.030	1.000							
	(0.001)	(0.000)	(0.011)	(0.141)								
RET_OILWTI	−0.019	−0.050	−0.008	0.016	0.093	1.000						
	(0.347)	(0.015)	(0.711)	(0.446)	(0.000)							
RET_EURO	−0.163	−0.161	−0.170	−0.122	0.242	0.044	1.000					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.032)						
RET_JPY	−0.126	−0.131	−0.070	−0.081	0.134	0.062	0.336	1.000				
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.003)	(0.000)					
DIFF_I	0.021	0.025	0.007	0.040	−0.044	0.021	−0.044	−0.040	1.000			
	(0.298)	(0.235)	(0.733)	(0.050)	(0.033)	(0.308)	(0.033)	(0.052)				
DIFF_YIELD	0.120	0.126	0.136	0.133	−0.022	0.015	−0.125	−0.086	−0.058	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.290)	(0.470)	(0.000)	(0.000)	(0.005)			
DIFF_INF	0.117	0.125	0.086	0.129	−0.101	−0.098	−0.197	−0.182	0.084	0.456	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
VIX_CHG	−0.741	−0.698	−0.583	−0.675	0.081	−0.012	0.097	0.144	−0.022	−0.101	−0.104	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.576)	(0.000)	(0.000)	(0.280)	(0.000)	(0.000)	

Notes: Euro is US dollar per Euro and JPY is US dollar per 100 Japanese Yen. Yield is ten-year T-bond minus 3 month T-bill. Inflation expectation (INF_EXP) is ten-year T-bond minus ten-year TIPS. All variables are in return except interest rate, yield and inflation expectations which are in differences. T-values are shown in the parenthesis.

Table 2B
Correlation returns/differenced — Sample II (Jan. 2008–Dec. 2011).

Probability	RET_SP500	RET_DJ	RET_ND	RET_RUSS	RET_GOLD	RET_OILWTI	RET_EURO	RET_JPY	DIFF_I	DIFF_YIELD	DIFF_INF	VIX_CHG
RET_SP500	1.000											
RET_DJ	0.987	1.000										
	(0.000)											
RET_ND	0.943	0.921	1.000									
	(0.000)	(0.000)										
RET_RUSS	0.937	0.910	0.904	1.000								
	(0.000)	(0.000)	(0.000)									
RET_GOLD	−0.017	−0.028	−0.038	0.002	1.000							
	(0.578)	(0.374)	(0.223)	(0.943)								
RET_OILWTI	0.323	0.301	0.264	0.278	0.213	1.000						
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)							
RET_EURO	0.405	0.396	0.350	0.369	0.203	0.340	1.000					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						
RET_JPY	−0.446	−0.452	−0.432	−0.395	0.125	−0.143	0.076	1.000				
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.014)					
DIFF_I	−0.021	−0.031	0.019	−0.034	0.031	0.070	−0.013	−0.094	1.000			
	(0.500)	(0.312)	(0.530)	(0.273)	(0.317)	(0.023)	(0.680)	(0.002)				
DIFF_YIELD	0.225	0.217	0.219	0.231	0.019	0.197	0.096	−0.278	0.139	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.546)	(0.000)	(0.002)	(0.000)	(0.000)			
DIFF_INF	0.199	0.201	0.212	0.191	−0.082	0.082	−0.054	−0.333	0.176	0.570	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)	(0.008)	(0.082)	(0.000)	(0.000)	(0.000)		
VIX_CHG	−0.783	−0.765	−0.749	−0.745	0.002	−0.267	−0.346	0.364	0.047	−0.227	−0.192	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.938)	(0.000)	(0.000)	(0.000)	(0.126)	(0.000)	(0.000)	

Notes: Euro is US dollar per Euro and JPY is US dollar per 100 Japanese Yen. Yield is ten-year T-bond minus 3-month T-bill.
Inflation expectation (INF_EXP) is ten-year T-bond minus ten-year TIPS. All variables are in return except interest rate, yield and inflation expectations which are in differences.
T-values are shown in the parenthesis.

significant except for Dow Jones returns (−0.050). In the second subsample the correlation between oil price and stock returns become stronger and positive (varying from 0.26 in Nasdaq to 0.32 in S&P 500) and highly statistically significant in all U.S. stock markets. For the empirical results below, we will split the sample further as follows: sample I from Jan 1 1999 to Dec 31 2007; sample II from Jan 1 2008 to Jun 30 2009; and sample III from Jul 1 2009 to Dec 30 2011. Doing so will help distinguish between the 18-month recession in subsample II and the "recovery period" in subsample III.

We check the stationary of the series in our model using three classes of unit root tests. The standard ADF, DF-GLS, and KPSS tests all find that — except for interest rate and the yield curve — all series are stationary, which is not surprising since all these series are expressed in returns. Checking for unit roots in interest rate and yield curve in first differences we found that interest rate and yield are also stationary in first differences. We thus perform estimations of all financial series in returns and interest rate series in differences. Therefore, in all empirical models below interest rate and yield curve are used in our models in first-differences.

Fig. 1 provides the charts for stock markets in levels (left panels) and their corresponding returns (right panels). It is easy to identify for the series in levels the bottom in stock markets right after the 2001 mild recession and the most recent recession in 2008. For returns, the figures in general indicate that there were high fluctuations mostly in 2008–2009 during the recent financial crisis. Nasdaq stock returns also display considerable volatility clustering around 2000–2001, a period associated with the "dot.com" bubble bust. Fig. 2 presents the actual values of VIX and inflation expectations associated with U.S. markets. There is the spike in VIX in 2008 and the continuing fall in inflation expectations as measured by the spread between the U.S. 10-year Treasury bond and TIPS. Fig. 3 contains the short-term interest rate and the yield curve, which indicates the decrease of interest rates in recessions along with negative values for the yield curve in recessions.

Fig. 4 displays gold and oil prices, along with the major exchange rates against the USD. Gold prices follow an upward trend. Oil prices reach their peak around June 2008 and then sharply declined with the economic downturn and turmoil in the fall of 2008. The last two charts contain U.S. dollar exchange rates against Euro and Japanese Yen. They display a similar pattern of U.S. dollar appreciating until mid-2001 and then depreciating against both currencies until 2008. The pattern of exchange rates differs after 2008. The U.S. dollar starts to appreciate against the Euro after 2008, while the U.S. dollar kept depreciating against the Japanese Yen.[4]

4. Empirical methodology

The methodology used includes GARCH (1, 1) and MGARCH-DCC models with all series in returns, except interest rates and yield curve which are used in first differences. The family of GARCH models is appropriate since the relationship between returns and risk can be successfully captured as noted by, among others, Cifarelli and Paladino (2010), Engle (2004), and Glosten et al. (1993).[5] All series are expressed in returns (except for interest rates), which make the short-term interest rates and the steepness of the yield curve stationary. In all models robust standard errors (Bollerslev–Wooldrige) are reported. The GARCH model used in the analysis takes the following form:

$$R_t = \beta_0 + \beta_1 \Delta VIX_t + \beta_2 \Delta \Pi^e{}_t + \beta_3 \Delta i_t + \beta_4 \Delta gold_t + \beta_5 \Delta Yield_t$$
$$+\beta_6 \Delta oilwti_t + \beta_7 \Delta e_t + \beta_8 \Delta R_{t-1} + \varepsilon_t \varepsilon_t \rightarrow N(0, h_t);\ and \qquad (1)$$
$$h^2{}_t = c + \quad {}_k \quad \varepsilon^2{}_{t-k} + \quad {}_t \quad h^2{}_{t-1}$$

where: R_t is the U.S. stock index return (the growth rate of closing prices between day t and t-1) in any of the four stock markets; ΔVIX_t captures the change in VIX (S&P index volatility); $\Delta \Pi^{\mathbf{e}}_{\mathbf{t}}$ captures changes in inflation expectations as the difference between the 10-year U.S.

[4] Note that while Fig. 2 contains the series in levels, the correlation coefficients in Table 2 are among the series actually used in the estimations below: in returns (asset prices) or in first-differences (interest rates).

[5] Engle (2004) explains how the ARCH models were created in the 1970s based on Milton Friedman's conjecture that the level of inflation was not a problem but the unpredictability of inflation was. The uncertainty about future costs and prices would prevent entrepreneurs from investing, leading into recession. To Engle (2004), his goal was to model uncertainty as changing over time. The ARCH model he proposed took weighted averages of past squared forecasted errors (a weighted variance), with the weights giving more influence to recent information and less to distant past.

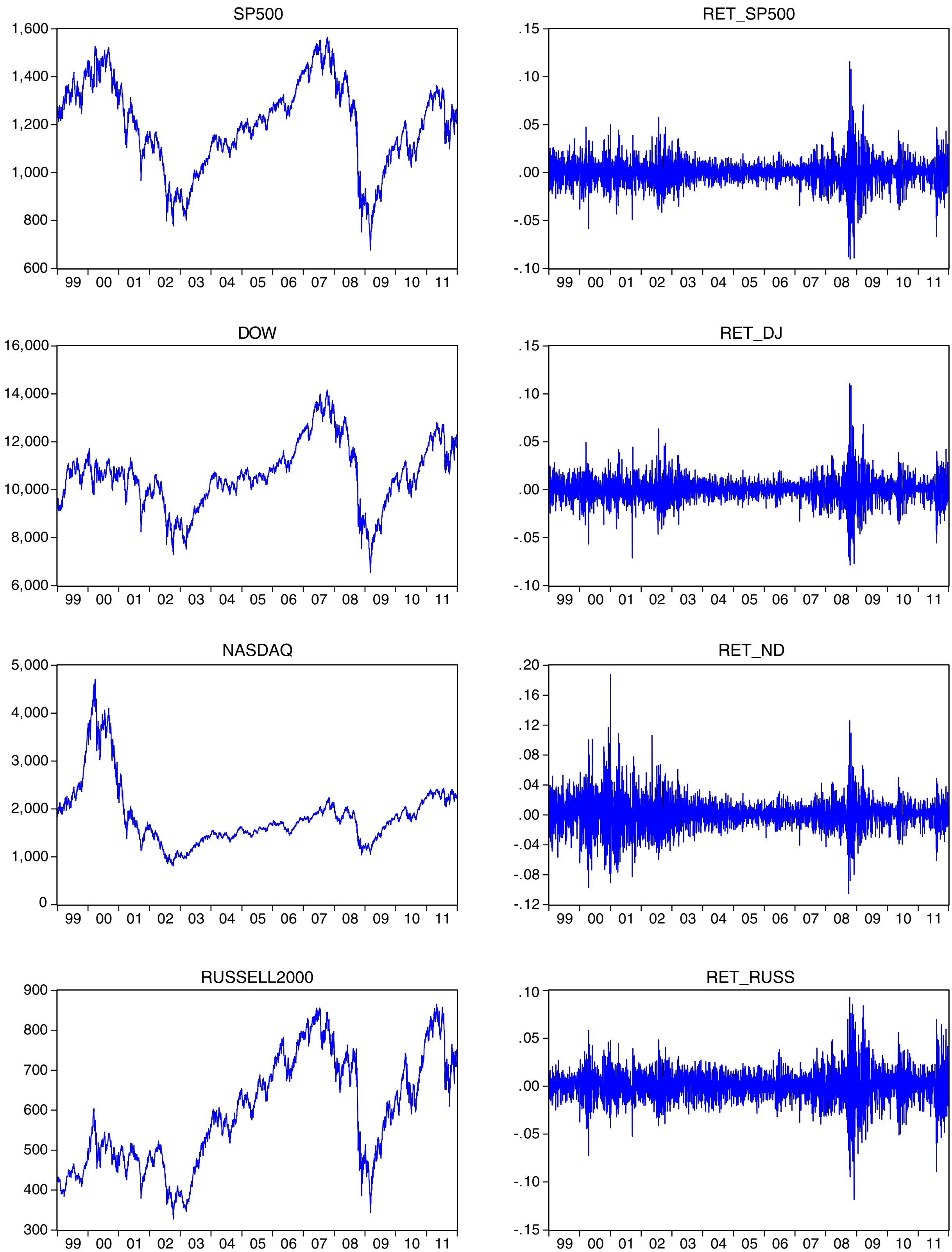

Fig. 1. U.S. Stock Indexes (in levels and daily returns). Notes: Daily data from Jan. 1999 to Dec. 2011. Actual (graphs at left) and calculated returns (graphs at right) of S&P 500, Dow Jones, NASDAQ, and Russell 2000 indices are shown.

Treasury bond and "inflation protected" TIPS; $\Delta \mathbf{i_t}$ is the change in interest rate 3 month LIBOR rate; ΔYield_t is change in the difference between 10-year Treasury bond and 3-month Treasury bill; Δgold_t is the change in gold price; Δoilwti_t is the change in oil price West Texas Intermediate; Δe_t is the change in exchange rate (EUR or JPY); R_{t-1} is lagged stock index return; and ε_t is the error term. In addition to the subsample analysis reported in detail below, we estimated (1) for the whole sample introducing a dummy variable to capture the recent

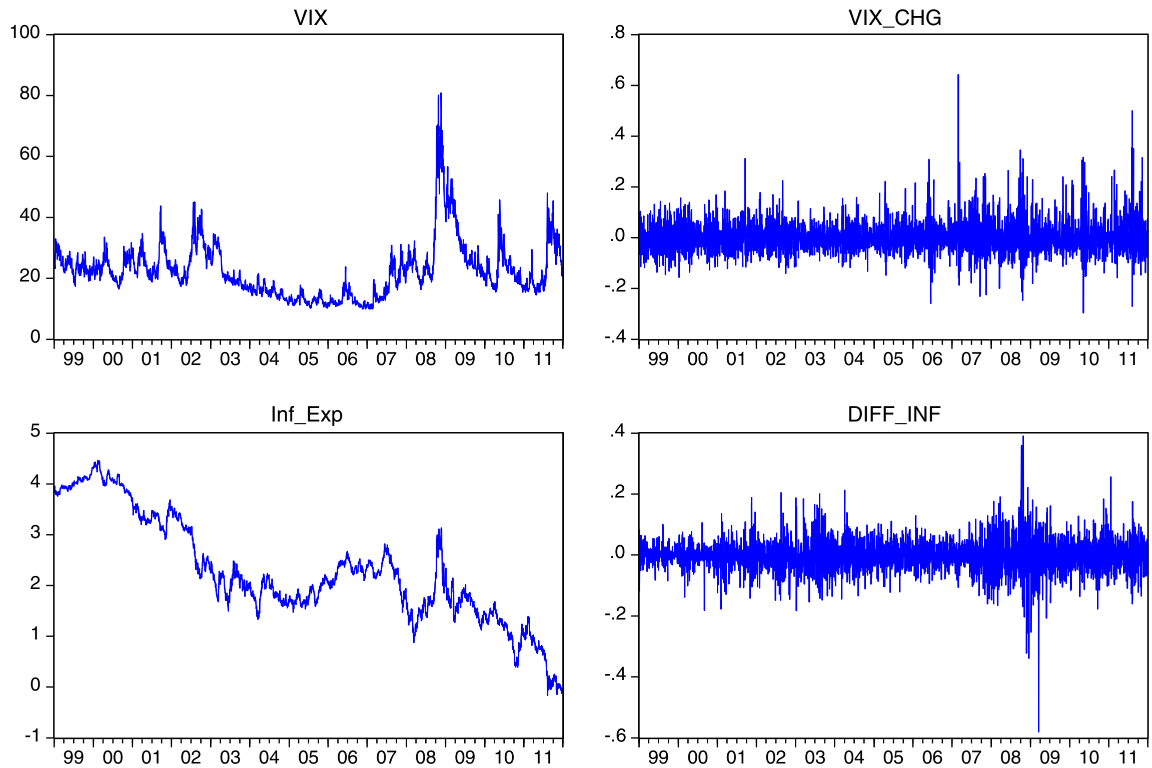

Fig. 2. U.S. "Fear Gauge" Index of VIX Option Contracts and U.S. Inflation Expectations. Notes: Daily data from Jan. 1999 to Dec. 2011. VIX is the Chicago Board Options Exchange Market Volatility Index of the implied volatility of S&P 500 index options. Inflation expectation is the difference between the 10-Year U.S. Treasury bond and 10-Year U.S. TIPS. Actual (graphs at left) and calculated changes or differences (graphs at right) are shown.

financial crisis and its aftermath (dum08, following the NBER original definition of the recession in December of 2007, defined as 1 from January 1, 2008 to December 30, 2011; all else 0).[6]

The unexplained returns (ε_t) are assumed to be normally distributed with zero mean and conditional variance governed by a standard GARCH (1, 1) process.[7] The maximum likelihood (ML) method is used to estimate the model above and its variants. The expected sign for VIX coefficient (β_1) is negative, as stock returns tend to be inversely related with S&P volatility. The expected sign for inflation expectations (β_2) is ambiguous. In theory, a rise in expected inflation reduces equity prices because of two factors: higher inflation is associated with lower expected real earnings growth as well as higher required real equity returns.[8] The expected sign for the interest rate coefficient (β_3) is negative since interest rates discount the expected flow of future earnings. It is possible, however, that this channel is neutralized when the U.S. economy is in a "liquidity trap". The expected sign on gold prices (β_4) is ambiguous. While gold prices are an indicator of uncertainty in international financial markets, commodities could also be signaling monetary policy forces dominant in the economy. Akram (2009), for example, uses structural VAR models on quarterly data from 1990 to 2007 to conclude that commodity prices increase significantly in response to reductions in real interest rates. The expected sign on the yield curve (β_5) is positive since a steeper yield curve is usually taken as the normal state of the economy; the inverted yield curve generally indicate an increase in the likelihood of recessions. The expected sign on oil prices (β_6) is negative if one adopts the position that the U.S. is oil importing country and stock returns at the aggregate respond to a shock that moves the production function downwards in the U.S. However, the oil-stocks relationship is more complex as Killian (2008) suggests that higher oil prices necessarily cause lower returns only in case of oil-market specific demand shocks; the response may be muted in case of other shocks. Furthermore, as a commodity price, oil prices may signal a different message in a particularly depressed economic environment. The coefficient on exchange rates (β_7) is ambiguous since expected earnings move depending on the degree of exposure of firms to international markets.[9]

Eq. (1) is fitted to various models by including one variable at a time and finally including all variables. We see (1) as flexible enough to accommodate changes in all major financial markets. Lagged stock returns are intended to capture potential omitted factors not captured by daily data, such as: dividend payments, earnings announcements, etc.[10] When estimating several versions of (1) we verify the possible high correlation among regressors. For instance, we report in Tables 2A and 2B that inflation expectations and the yield curve

[6] The NBER identified the month of December 2007 as when the crisis of 2008–2009 started in the U.S. Since we have daily data, it is difficult to determine when exactly in the month of December 2007 to break the sample. Breaking the whole sample at the very beginning of January 2008 assumes the new subsample as right after the whole information set became available in industrial production, employment, and other markets. We believe this is a better working assumption than breaking arbitrarily in mid-December or in late November 2007. The whole sample result is not reported, since the result is not as interesting as the sub-samples, but is available upon request.

[7] The frequency distributions of stock returns are certainly not fat-tailed (in both subsamples) and more closely satisfy the Normal. Of course, the use of daily data helps and in large samples the issue of a fat-tailed distribution could be ignored; Enders (2004). Yet there is no evidence of fat-tailed distributions of returns in our subsamples and the Normal distribution assumption is reasonable.

[8] When Sharpe (2002) runs regressions for price-earnings ratios in U.S. S & P 500 stocks for quarterly data from 1983 to 2001, he finds usually a negative coefficient on ten-year expected inflation. However, once he controls for expected earnings and bond yields, expected inflation no longer helps explain equity prices. Engsted and Tanggaard (2002) report for U.S stock data over 1926–1997 very weak relationships between (ex-post) stock returns and inflation.

[9] Boyer and Filion (2007) document that a weakening of Canadian dollar against USD not only have a negative impact on stocks of oil and gas companies but also that exchange rate effects change significantly over 1995–1998 and 2000–2002.

[10] Note, however, that to find the precise long-run elasticities for the model with lagged returns the estimated short-run coefficients should be divided by (1/ 1 − estimated coefficients for the lagged return).

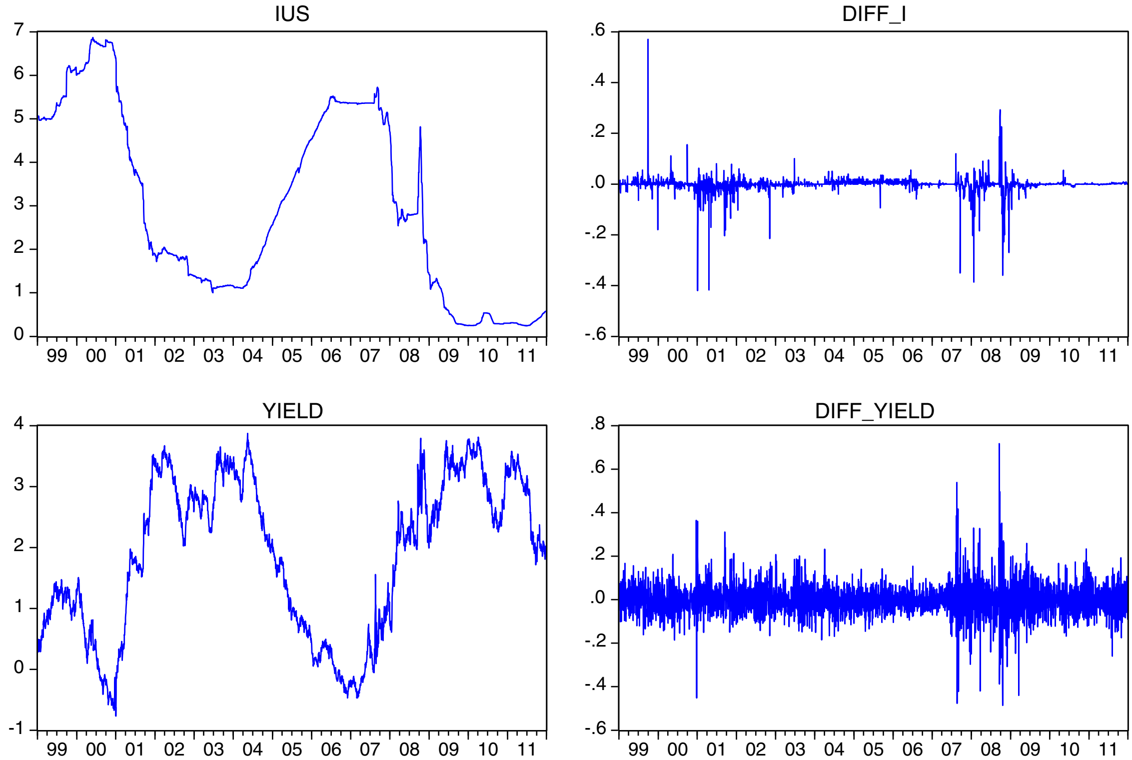

Fig. 3. U.S. interest rate and yield curve. Notes: Daily data from Jan. 1999 to Dec. 2011. U.S. interest rate is the U.S. 3-month BBA Libor rate and Yield is 10-year U.S. Treasury bond minus 3-month U.S. Treasury bill. Actual (graphs at left) and calculated differences (graphs at right) are shown.

are highly correlated (0.456 and 0.570, respectively) and so are not be jointly present in the estimations.

Eq. (1) above accommodates all new information that affect expected cash flows and discount rates: "…As time goes by, we get more information on these future events and revalue the asset. So at a basic level, financial price volatility is due to the arrival of new information. Volatility clustering is simply clustering of information arrival." Engle (2004, p. 408). Our analysis is for the aggregate of major stock indices and we are using overall market uncertainty (VIX), together of the regressors in (1), to assess returns at the daily frequency. There are, however, similarities with existing research for individual stocks. Estimating excess returns of individual stocks on the three Fama and French (1996) factors, Fu (2009) performs time-series regressions for each stock in each month, and the idiosyncratic volatility (reflecting firm-specific and volatile information) of a stock is computed as the standard deviation of the regression residuals.

On the volatility equation, the one period ahead forecast variance (h^2_t), the so-called conditional variance, is a function of three terms: a constant; the lag of the squared residual from the mean equation (ε^2_{t-k}, the ARCH term); and the last period's forecast variance (h^2_{t-l}, the GARCH term). Two other modifications of (1) are: i) to allow changes in the variance equation to respond to daily forces in the market, and these are found to be zero (or very close to zero) values in all cases; and ii) to provide joint estimations of stock returns and other processes through a multivariate GARCH framework. As a generalization of Eq. (1) for more than one equation, we first attempted the Engle and Kroner (1995) method for joint estimation of stock and oil price returns but convergence was never achieved. Bauwens et al. (2006) survey multivariate GARCH models and Wang and Wu (2012) compare their forecasting exercises.

It was possible to apply the Multivariate GARCH Dynamic Conditional Correlation (MGARCH-DCC) models, although not always in the very general form of (1). In these models the conditional variances are modeled as univariate GARCH models and the conditional covariances are modeled as nonlinear functions of the conditional variances. The conditional quasi-correlation parameters that weight the nonlinear combinations of the conditional variances follow the GARCH-like process specified in Engle (2002), in which the log-likelihood of the MGARCH-DCC model is written as the sum of a volatility part and a correlation part. Under a two-step approach to maximizing the likelihood function, a long expression (equation 33 of that article) can be derived for the covariance matrix of the correlation parameters.

Eqs. (2a) and (2b) below are estimated as MGARCH DCC for stock returns and the change in VIX as dependent variables. This specification achieved convergence reasonably well for one of the markets (NASDAQ) with lagged returns appearing in (RHS) of the changes in VIX equation. The assumption here is that stock returns and changes in VIX depend on all financial factors:

$$R_t = \gamma_0 + \gamma_1 \Delta i_t + \gamma_2 \Delta yield_t + \gamma_3 \Delta inf_t + \gamma_4 \Delta gold_t + \gamma_5 \Delta oilwti_t + \gamma_6 \Delta e_t + \gamma_7 R_{t-1} + \varepsilon_{it} \quad (2a)$$

$$\Delta VIX_t = \gamma_0 + \gamma_1 \Delta i_t + \gamma_2 \Delta yield_t + \gamma_3 \Delta inf_t + \gamma_4 \Delta gold_t + \gamma_5 \Delta oilwti_t + \gamma_6 \Delta e_t + \gamma_7 R_{t-1} + \varepsilon_{it} \quad (2b)$$

Furthermore, MGARCH-DCC based correlations are estimated for stock returns and oil returns as dependent variables based on Eqs. (3a) and (3b) below for each sample period. In contrast to the system in Eqs. (2a)–(2b), this specification not always achieved convergence and we will report the results only for the sake of checking the correlation associated with this system of equations:

$$R_t = \gamma_0 + \gamma_1 \Delta VIX_t + \gamma_2 \Delta i_t + \gamma_3 \Delta yield_t + \gamma_4 \Delta inf_t + \gamma_5 \Delta gold_t + \gamma_6 \Delta e_t + \gamma_7 R_{t-1} + \varepsilon_{it} \quad (3a)$$

$$\Delta oilwti_t = \gamma_0 + \gamma_1 \Delta VIX_t + \gamma_2 \Delta i_t + \gamma_3 \Delta yield_t + \gamma_4 \Delta inf_t + \gamma_5 \Delta gold_t + \gamma_6 \Delta e_t + \gamma_7 oilwti_{t-1} + \varepsilon_{it} \quad (3b)$$

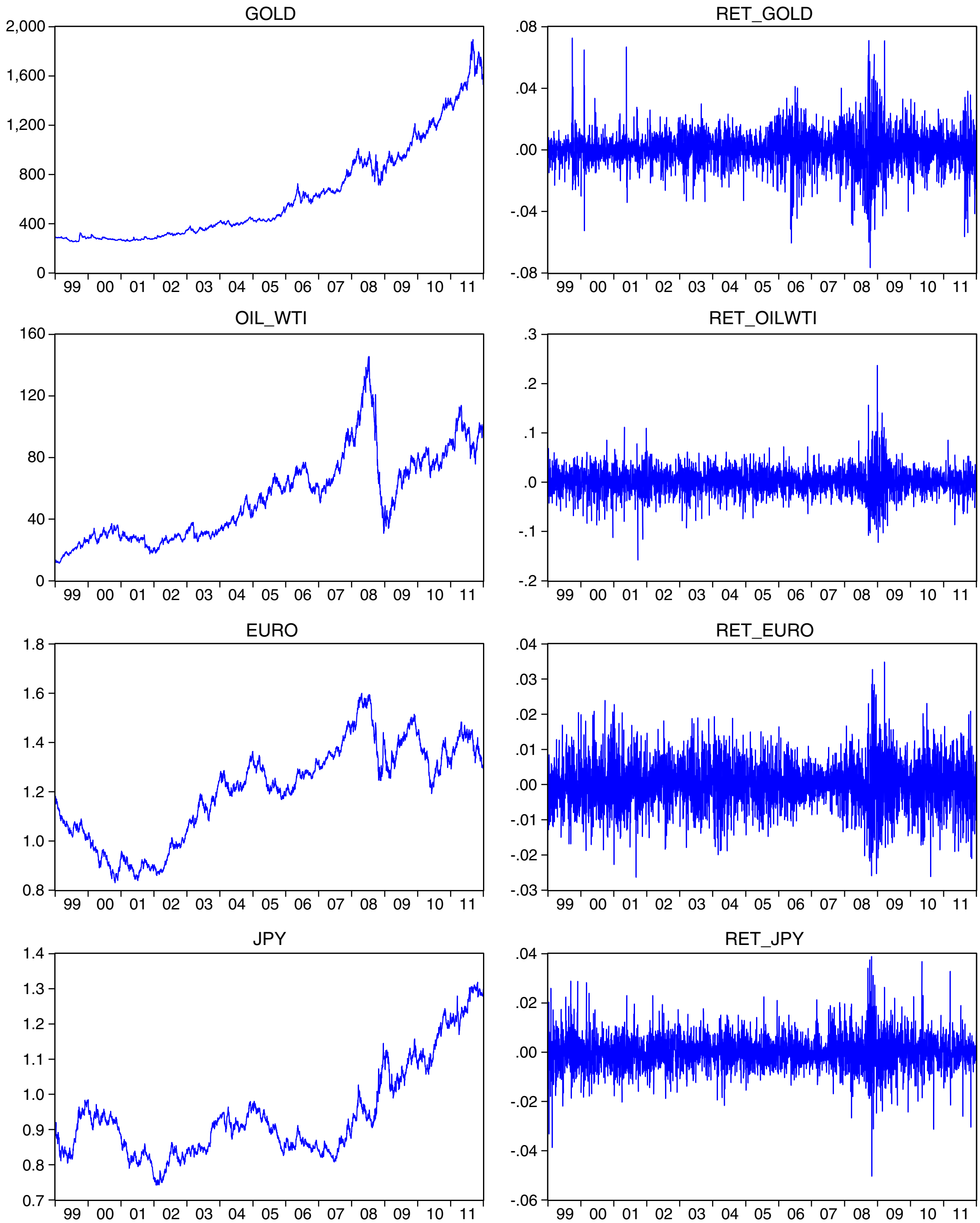

Fig. 4. Gold, oil, and exchange rates in international markets. Notes: Daily data from Jan. 1999 to Dec. 2011. Oil price per barrel West Texas Intermediate (WTI) and gold price of Handy & Harman Base dollar per Troy Ounce. Exchange rates are U.S. dollar per Euro and U.S. dollar per 100 Japanese Yen. Actual (graphs at left) and calculated returns (graphs at right) are shown.

5. Results

The GARCH (1,1) results are reported in Table 3 as Tables 3A, 3B, and 3C. We split the sample as follows: sample I from Jan 1 1999 to Dec 31 2007; sample II from Jan 1 2008 to Jun 30 2009; and sample III from Jul 1 2009 to Dec 30 2011. We use the following order of discussion in the table: S&P 500 stock index; DJIA; NASDAQ; and Russell 2000 stock indexes. Table 3 is numbered as Tables 3A, 3B, and 3C, to more easily identify the sample period.

Table 3A with the results for the pre-2008 period indicates that the (β_1)-coefficient (associated with VIX changes) is negatively correlated with all stock indices, with values varying from about −0.12 in Dow Jones to −0.17 in NASDAQ. This coefficient is fairly robust throughout: the higher the changes in the “fear gauge” index the

Table 3A
GARCH Sample I stock returns.

$R_t = \beta_0 + \beta_1 \Delta VIX_t + \beta_2 \Delta i_t + \beta_3 (\Delta yield) + \beta_4 \Delta inf_t + \beta_5 \Delta gold_t + \beta_6 \Delta oilwti_t + \beta_7 \Delta e_t + \beta_8 (R_{t-1}) + \varepsilon_{it}$.

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
			Sample I	**S&P500**			
$\beta_1(\Delta vix_t)$	−0.129***	−0.129***	−0.129***	−0.129***	−0.129***	−0.129***	−0.129***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
β_2 (Δi $_t$)	−0.010*	−0.011**	−0.011**	−0.011**	−0.011**	−0.011*	−0.011**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
β_3 (Δyield$_t$)	0.004						
	(0.003)						
β_4 (Δinf.$_t$)		0.010***	0.010***	0.009**	0.007*	0.006*	0.006*
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
β_5 (Δgold$_t$)			0.008			0.027*	0.027*
			(0.015)			(0.015)	(0.015)
β_6 (Δoil_wti_t)				−0.010		−0.010	−0.010
				(0.007)		(0.007)	(0.007)
$\beta_7(\Delta e_t)$					−0.110***	−0.120***	−0.120***
					(0.027)	(0.028)	(0.028)
$\beta_8(R_{t-1})$							−0.001
							(0.019)
Arch	0.248***	0.259***	0.260***	0.259***	0.250***	0.251***	0.251***
	(0.052)	(0.055)	(0.055)	(0.055)	(0.054)	(0.055)	(0.055)
Garch	0.772***	0.756***	0.756***	0.756***	0.755***	0.759***	0.759***
	(0.096)	(0.096)	(0.096)	(0.096)	(0.096)	(0.096)	(0.096)
N	2346	2346	2346	2346	2345	2345	2345
AIC	−16587.3	−16593.4	−16591.7	−16594.3	−16606.8	**−16609.1**	−16607.1
BIC	−16546.9	−16553.1	−16545.6	−16548.3	**−16560.7**	−16551.5	−16543.7
LM(3)	1.881	1.795	1.807	5.751	1.950	2.345	1.770
	(0.598)	(0.616)	(0.614)	(0.124)	(0.583)	(0.504)	(0.622)
			Sample I	**Dow**	**Jones**		
$\beta_1(\Delta vix_t)$	−0.117***	−0.117***	−0.116***	−0.117***	−0.117***	−0.117***	−0.117***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
β_2 (Δi $_t$)	−0.007	−0.009	−0.010*	−0.009	−0.009	−0.008	−0.008
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
β_3 (Δyield$_t$)	0.006**						
	(0.003)						
β_4 (Δinf.$_t$)		0.012***	0.012***	0.011***	0.009**	0.008**	0.008**
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
β_5 (Δgold$_t$)			−0.020			−0.000	−0.001
			(0.015)			(0.015)	(0.015)
β_6(Δoil_wti$_t$)				−0.024***		−0.024***	−0.024***
				(0.007)		(0.007)	(0.007)
$\beta_7(\Delta e_t)$					−0.113***	−0.112***	−0.113***
					(0.030)	(0.030)	(0.031)
$\beta_8(R_{t-1})$							0.003
							(0.023)
Arch	0.211***	0.210***	0.209***	0.218***	0.207***	0.214***	0.213***
	(0.044)	(0.043)	(0.043)	(0.044)	(0.045)	(0.045)	(0.045)
Garch	0.886***	0.896***	0.896***	0.867***	0.894***	0.867***	0.868***
	(0.104)	(0.108)	(0.108)	(0.104)	(0.112)	(0.107)	(0.107)
N	2346	2346	2346	2346	2345	2345	2345
AIC	−16493.0	−16500.1	−16500.2	−16513.9	−16513.7	**−16525.4**	−16523.5
BIC	−16452.7	−16459.8	−16454.2	−16467.8	−16467.6	**−16467.8**	−16460.1
LM(3)	0.847	0.862	0.866	1.019	1.103	1.516	1.192
	(0.838)	(0.835)	(0.834)	(0.797)	(0.776)	(0.679)	(0.755)

Notes: Robust standard errors in parentheses *p<.10, **p<.05, ***p<.01. Sample I is from Jan. 1 1999 to Dec. 31 2007.

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
			Sample I	**NASDAQ**			
β_1 (Δvix_t)	−0.173***	−0.169***	−0.169***	−0.169***	−0.169***	−0.168***	−0.168***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
β_2 (Δi_t)	−0.010	−0.013	−0.013	−0.012	−0.011	−0.010	−0.010
	(0.012)	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)	(0.010)
β_3 (Δyield$_t$)	0.017***						
	(0.006)						
β_4 (Δinf.$_t$)		0.024***	0.024***	0.022***	0.014**	0.012*	0.012**
		(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
β_5 (Δgold$_t$)			−0.004			0.043	0.043
			(0.026)			(0.027)	(0.027)
β_6 (Δoil_wti$_t$)				−0.031**		−0.030**	−0.030**
				(0.015)		(0.015)	(0.015)
β_7 (Δe_t)					−0.302***	−0.316***	−0.311***
					(0.060)	(0.061)	(0.061)

Table 3A (*continued*)

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
β_8 ($R_{t\text{-}1}$)							−0.023
							(0.028)
Arch	0.293***	0.311***	0.310***	0.315***	0.309***	0.315***	0.316***
	(0.050)	(0.052)	(0.052)	(0.052)	(0.051)	(0.052)	(0.052)
Garch	0.839***	0.824***	0.824***	0.823***	0.821***	0.823***	0.821***
	(0.097)	(0.096)	(0.096)	(0.095)	(0.095)	(0.094)	(0.093)
N	2346	2346	2346	2346	2345	2345	2345
AIC	−12706.9	−12709.1	−12707.1	−12713.0	−12738.6	**−12742.1**	−12741.5
BIC	−12666.6	−12668.8	−12661.0	−12666.9	**−12692.5**	−12684.5	−12678.1
LM(3)	61.20***	43.058***	44.335***	43.985***	44.304***	43.853***	49.814***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			Sample I	**Russell**	**2000**		
β_1 (Δvix_t)	−0.144***	−0.144***	−0.144***	−0.144***	−0.144***	−0.144***	−0.145***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
β_2 (Δi_t)	0.003	−0.000	0.000	−0.000	−0.000	0.000	0.000
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
β_3 ($\Delta yield_t$)	0.014***						
	(0.004)						
β_4 ($\Delta inf._t$)		0.018***	0.019***	0.018***	0.016***	0.016***	0.016***
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
β_5 ($\Delta gold_t$)			0.036*			0.049**	0.048**
			(0.021)			(0.022)	(0.022)
β_6 (Δoil_wti_t)				0.003		0.002	0.002
				(0.009)		(0.009)	(0.009)
β_7 (Δe_t)					−0.073**	−0.092**	−0.096***
					(0.037)	(0.037)	(0.037)
β_8 ($R_{t\text{-}1}$)							0.023
							(0.018)
Arch	0.105***	0.105***	0.105***	0.105***	0.103***	0.102***	0.099***
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.023)
Garch	1.046***	1.054***	1.058***	1.052***	1.064***	1.073***	1.090***
	(0.143)	(0.143)	(0.144)	(0.143)	(0.145)	(0.147)	(0.150)
N	2346	2346	2346	2346	2345	2345	2345
AIC	**−15308.8**	−15304.3	−15305.9	−15302.5	−15300.7	−15303.1	−15303.2
BIC	**−15268.5**	−15264.0	−15259.8	−15256.4	−15254.6	−15245.5	−15239.8
LM(3)	7.858**	4.816	3.929	5.689	5.058	4.828	4.304
	(0.049)	(0.186)	(0.269)	(0.128)	(0.168)	(0.185)	(0.230)

Notes: Robust standard errors in parentheses $^{*}p<.10$, $^{**}p<.05$, $^{***}p<.01$. Sample I is for the period Jan. 1 1999–Dec. 31 2007.

lower daily stock returns, all else constant. Based on information criteria (AIC and SIC) it is possible to conclude that models in columns V and VI are preferred for S&P 500, DJ, and NASDAQ, while the model in column I is preferred for Russell 2000. The preferred models have the values of AIC/SIC highlighted in bold in the tables.

The change in yield, present in column I, is found to be positively correlated to all stock returns, except for S&P 500. Based on column I (no inflation expectations due to the correlation with yield curve) without international factors, stocks of companies in the NASDAQ or Russell market respond positively to a steeper yield curve (0.017 and 0.014, respectively); the coefficient is lower for DJ. As we move across columns, Gold is statistically significant only in two markets of Table 3A with positive coefficients of about 0.027 and 0.048-0.049 for S& P 500 for Russell 2000, respectively. Oil return is negatively correlated with stock returns only in two markets, when the dependent variables are returns of Dow Jones (β_6-coefficient of −0.024) and NASDAQ stock returns (β_6-coefficient of −0.030). This negative result is much weaker in the other two equity markets. The U.S. dollar/euro exchange rate has a negative impact on stock returns: as the USD depreciates stock returns fall in this subperiod, with a larger impact in NASDAQ.

In general, the model specifications for Table 3A in sample I have problems. The sums of ARCH and GARCH coefficients (the α and β coefficients in the variance equation) are always higher than one, violating the stationary condition. However, except for NASDAQ, the Lagrange Multiplier (LM) tests for lag length of three are not significant, always suggesting that serial correlation is not a problem and the specifications look reasonable.

Table 3B also reports the results for the second subsample (Jan 2008 to Jun 2009) right after the onset of the major economic downturn in the four panels. Similar to the pre-crisis results, VIX is strongly and negatively correlated with the stock returns with a coefficient of between −0.21 to −0.25 in all markets. The change in yield is again positive and statistically significant in two markets, varying from 0.017 in DJ to 0.018 in S&P 500, indicating that equities improve with a more upwardly sloped yield curve in times of economic hardship. However, based on information criteria (AIC and SIC) the models in columns V and VI are preferred for NASDAQ and Russell 2000, while S&P 500 coincides with model VI and models VI and VII are preferred for DJ. In general, stocks now have a positive relationship with inflation expectations in columns V to VII. One way of interpreting this is that in a depressed scenario an increase in inflation expectations is positive for stock returns. Higher inflation can be also associated with higher required real equity returns; see Sharpe (2002). On gold prices, markets react negatively to higher gold prices in the second subsample in columns VI and VII.[11]

In contrast to the first subsample, in sample II the crisis period indicates that oil returns do not have any impact on all stock returns, except for model IV in S&P 500, which is not chosen by information criteria. This indicates that during the crisis oil price increases are not priced in

[11] Existing works cast doubt on one-sided views of the stock-gold relationship. Baur and McDermott (2010) analyze the safe haven property of gold across daily, weekly, and monthly frequencies, regressing gold returns on stock returns and conclude that gold is not a hedge for most indices, with North America as the exception. We report positive and negative results depending on the subperiods, but these are not uniform across markets. In a previous version we offered an interpretation to gold of carrying inflation expectations. In this version, and following a suggestion from the Referee, we explicitly incorporate market inflation expectations, which make gold prices in (1) contain relatively more of uncertainty than macro factors. We leave this topic for further research.

Table 3B
GARCH Sample II Stock Returns.

$R_t = \beta_0 + \beta_1 \Delta VIX_t + \beta_2 \Delta i_t + \beta_3 (\Delta yield.) + \beta_4 \Delta inf._t + \beta_5 \Delta gold_t + \beta_6 \Delta oil\_wti_t + \beta_7 \Delta e_t + \beta_8 (R_{t-1}) + \varepsilon_{it}.$

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
			Sample II	**S&P500**			
$\beta_1(\Delta vix_t)$	−0.244***	−0.246***	−0.250***	−0.242***	−0.245***	−0.236***	−0.234***
	(0.014)	(0.018)	(0.019)	(0.019)	(0.017)	(0.015)	(0.015)
$\beta_2(\Delta i_t)$	0.014	0.010	0.008	0.010	0.010	0.014	0.014
	(0.018)	(0.017)	(0.016)	(0.016)	(0.014)	(0.020)	(0.020)
$\beta_3(\Delta yield_t)$	0.018**						
	(0.008)						
$\beta_4(\Delta inf._t)$		0.009	0.008	0.006	0.018**	0.019**	0.018**
		(0.010)	(0.010)	(0.010)	(0.009)	(0.008)	(0.008)
$\beta_5(\Delta gold_t)$			−0.076			−0.138***	−0.141***
			(0.068)			(0.045)	(0.047)
$\beta_6(\Delta oil\_wti_t)$				0.050**		0.023	0.025
				(0.025)		(0.023)	(0.022)
$\beta_7(\Delta e_t)$					0.406***	0.439***	0.443***
					(0.095)	(0.089)	(0.089)
$\beta_8(R_{t-1})$							−0.030
							(0.038)
Arch	0.400**	0.341**	0.401*	0.330**	0.314**	0.428**	0.445*
	(0.156)	(0.142)	(0.219)	(0.153)	(0.147)	(0.210)	(0.244)
Garch	0.513***	0.572***	0.493**	0.652***	0.576***	0.438***	0.421**
	(0.149)	(0.188)	(0.240)	(0.220)	(0.184)	(0.166)	(0.182)
N	391	391	391	391	391	391	391
AIC	−2295.3	−2287.7	−2289.8	−2294.5	−2318.7	**−2334.8**	−2333.8
BIC	−2267.5	−2259.9	−2258.1	−2262.7	−2286.9	**−2295.1**	−2290.1
LM(3)	14.074***	24.069***	25.448***	50.757***	20.188***	37.456***	28.826***
	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			Sample II	**Dow**	**Jones**		
$\beta_1(\Delta vix_t)$	−0.216***	−0.218***	−0.221***	−0.218***	−0.218***	−0.216***	−0.214***
	(0.013)	(0.014)	(0.015)	(0.014)	(0.013)	(0.012)	(0.012)
$\beta_2(\Delta i_t)$	0.007	0.002	−0.002	0.003	0.003	0.000	−0.001
	(0.019)	(0.026)	(0.017)	(0.022)	(0.014)	(0.014)	(0.013)
$\beta_3(\Delta yield_t)$	0.017**						
	(0.008)						
$\beta_4(\Delta inf._t)$		0.011	0.011	0.010	0.020***	0.022***	0.022***
		(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)
$\beta_5(\Delta gold_t)$			−0.073			−0.120***	−0.125***
			(0.056)			(0.046)	(0.045)
$\beta_6(\Delta oil\_wti_t)$				0.021		0.006	0.009
				(0.024)		(0.022)	(0.021)
$\beta_7(\Delta e_t)$					0.337***	0.402***	0.412***
					(0.089)	(0.088)	(0.088)
$\beta_8(R_{t-1})$							−0.047
							(0.041)
Arch	0.441**	0.373**	0.417*	0.351**	0.300*	0.361**	0.369*
	(0.181)	(0.168)	(0.216)	(0.176)	(0.161)	(0.177)	(0.193)
Garch	0.421***	0.481**	0.435**	0.518**	0.556**	0.482**	0.471**
	(0.150)	(0.188)	(0.200)	(0.230)	(0.218)	(0.188)	(0.198)
N	391	391	391	391	391	391	391
AIC	−2331.8	−2326.6	−2329.0	−2326.2	−2346.3	−2357.7	**−2358.1**
BIC	−2304.0	−2298.8	−2297.3	−2294.4	−2314.6	**−2318.1**	−2314.4
LM(3)	16.112***	41.217***	22.133***	46.879***	28.806***	14.240***	18.429***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)

Notes: Robust standard errors in parentheses * p<.10, ** p<.05, *** p<.01. Sample II is for the period Jan. 1, 2008–June 30, 2009.

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
			Sample II	**NASDAQ**			
$\beta_1(\Delta vix_t)$	−0.261***	−0.256***	−0.256***	−0.256***	−0.252***	−0.249***	−0.248***
	(0.015)	(0.016)	(0.016)	(0.016)	(0.016)	(0.015)	(0.015)
$\beta_2(\Delta i_t)$	0.023*	0.022*	0.022*	0.022*	0.023*	0.025**	0.026**
	(0.013)	(0.013)	(0.012)	(0.013)	(0.014)	(0.012)	(0.012)
$\beta_3(\Delta yield_t)$	0.013						
	(0.008)						
$\beta_4(\Delta inf._t)$		0.013	0.013	0.012	0.020**	0.021**	0.020**
		(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
$\beta_5(\Delta gold_t)$			−0.082			−0.137**	−0.138**
			(0.061)			(0.060)	(0.062)
$\beta_6(\Delta oil\_wti_t)$				0.013		0.003	0.007
				(0.026)		(0.024)	(0.024)
$\beta_7(\Delta e_t)$					0.287***	0.374***	0.382***
					(0.109)	(0.108)	(0.110)

Table 3B (*continued*)

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
$\beta_8(R_{t-1})$							−0.038
							(0.039)
Arch	0.245**	0.243**	0.265**	0.237*	0.199*	0.248**	0.227
	(0.113)	(0.120)	(0.124)	(0.122)	(0.111)	(0.123)	(0.142)
Garch	0.434**	0.404*	0.403**	0.422*	0.445*	0.416**	0.440*
	(0.204)	(0.215)	(0.174)	(0.235)	(0.252)	(0.190)	(0.236)
N	391	391	391	391	391	391	391
AIC	−2186.2	−2183.9	−2186.0	−2182.4	−2193.3	**−2200.6**	−2199.8
BIC	−2158.4	−2156.2	−2154.2	−2150.6	**−2161.5**	−2160.8	−2156.2
LM(3)	2.620	0.837	0.684	1.324	0.131	0.256	0.106
	(0.454)	(0.841)	(0.877)	(0.724)	(0.988)	(0.968)	(0.991)
			Sample II	**Russell**	**2000**		
$\beta_1(\Delta vix_t)$	−0.266***	−0.262***	−0.261***	−0.261***	−0.260***	−0.256***	−0.256***
	(0.024)	(0.021)	(0.020)	(0.021)	(0.018)	(0.018)	(0.018)
$\beta_2(\Delta i_t)$	0.009	0.003	0.002	0.003	0.002	0.001	0.002
	(0.021)	(0.019)	(0.019)	(0.019)	(0.019)	(0.017)	(0.018)
$\beta_3(\Delta yield_t)$	0.014						
	(0.012)						
$\beta_4(\Delta inf._t)$		0.021	0.021	0.021	0.029**	0.029**	0.029**
		(0.014)	(0.014)	(0.014)	(0.013)	(0.012)	(0.012)
$\beta_5(\Delta gold_t)$			−0.060			−0.135**	−0.136**
			(0.068)			(0.066)	(0.068)
$\beta_6(\Delta oil\_wti_t)$				0.022		0.006	0.008
				(0.029)		(0.028)	(0.027)
$\beta_7(\Delta e_t)$					0.422***	0.479***	0.483***
					(0.125)	(0.118)	(0.118)
$\beta_8(R_{t-1})$							−0.021
							(0.043)
Arch	0.258**	0.251**	0.283*	0.247**	0.216***	0.296**	0.281*
	(0.132)	(0.120)	(0.149)	(0.121)	(0.083)	(0.138)	(0.146)
Garch	0.743**	0.830**	0.770*	0.836**	0.914***	0.759**	0.790**
	(0.354)	(0.370)	(0.393)	(0.363)	(0.280)	(0.302)	(0.334)
N	391	391	391	391	391	391	391
AIC	−2037.7	−2039.0	−2038.3	−2037.9	−2057.3	**−2060.5**	−2058.8
BIC	−2009.9	−2011.2	−2006.5	−2006.2	**−2025.6**	−2020.8	−2015.3
LM(3)	49.793***	54.744***	52.831***	55.072***	75.501***	75.222***	75.723***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: Robust standard errors in parentheses * p<.10, ** p<.05, *** p<.01. Sample II is from Jan. 1, 2008 to June 30, 2009.

at all in any of the stock returns. Depreciations in the U.S. dollar/euro are now, however, invariably associated with higher stock returns. As the U.S. dollar depreciates against the euro, the stock market moves upward. The sums of ARCH and GARCH coefficients are for this sub-period mostly below one in all cases for the selected specifications by information criteria. On the volatility equation, we have lower ARCH terms (effects of the mean equation error on the conditional variance) than GARCH terms (persistence on the conditional variance). The Lagrange Multiplier (LM) tests are not significant, however, indicating the model specifications are good only for NASDAQ market, a reversal from the first period analysis.

For the subsample after the crisis (from Jul 2009 to Dec 2011), we do find interesting results for the recovery period in Table 3C. First, the shapes of the yield curve and inflation expectations have positive effects on returns of all equity markets. Based on information criteria (AIC and SIC), however, model VI is preferred for three of the markets and models IV and VII are preferred for Russell 2000. The post-crisis period indicates that oil returns have strong positive effects on all stock returns, varying from 0.092 (in NASDAQ) and 0.094 (in DJ) to 0.116 in S&P 500 and to 0.173 or 0.185 in Russell 2000. Since oil coefficients in all panels are highly significant and positive, we interpret that increases in oil prices carry the idea of recovery in world markets to take the U.S. economy out of the slump.

This combination of higher oil prices and a weaker exchange rate conveys the idea of recovery in world markets and of a substantial trade channel through U.S. exports. As oil prices increase the stock index returns increase irrespective of the stock index type, which is a different relationship than that observed in the 1999–2007 years as well as in the 18-month crisis period. Since early 2009 marked the crash of the U.S. stock market the increase in oil prices could have been interpreted by markets as an indicator of increase in aggregate demand. The exchange rates coefficients are also larger and highly significant in all panels indicating that as the U.S. dollar depreciates against the euro the stock market return increase. This could happen through the trade channel by U.S. firms exporting more goods and services to European countries.[12]

Table 4 reports the DCC model for joint estimation of returns and changes in VIX for the NASDAQ market, which was the only one with convergence. Based on information criteria (AIC and SIC) models in columns V and VI are preferred for pre-crisis, columns V and VII are preferred for the crisis period, and column VI is preferred for the recovery phase. As seen earlier, stocks move up in response to an increase in inflation expectations. Further, the positive relationship with inflation expectations is amplified in the downturn: β_4-coefficients almost double

[12] We have done similar analysis using the Japanese Yen. In subsample I the U.S. dollar exchange rate against the Japanese yen is not significantly associated with stock returns. In subsample II the exchange rate is negatively associated with stock index returns. While this is the opposite of what happened with the Euro, this could be explained by the total volume of trade between the U.S. and Japan being lower than the total volume of trade between the U.S. and European Union (EU). If so, U.S. stock markets do not react as much as expected to changes in JPY during the crisis. We check this by inspecting the U.S. Trade in Goods by Country, available from the U.S. Dept. of Commerce, Bureau of the Census, Foreign Trade. Based on the downloadable EXCEL data file at http://www.census.gov/foreign-trade/balance/ in 2010 the total U.S. imports from EU (in USD million) were 319,194.8 and the total U.S. exports to EU were 239,583.3 million. Corresponding figures for U.S. Japan trade in 2010 were: 120,545.2 million and 60,485.61 million. These figures account for a total U.S. volume of trade (imports + exports) of about 3.09 times more with the EU than Japan in 2010, against about 1.88 times in 1999.

Table 3C
GARCH sample III stock returns.

$R_t = \beta_0 + \beta_1 \Delta VIX_t + \beta_2 \Delta i_t + \beta_3(\Delta yield) + \beta_4 \Delta inf_t + \beta_5 \Delta gold_t + \beta_6 \Delta oil\_wti_t + \beta_7 \Delta e_t + \beta_8(R_{t-1}) + \varepsilon_{it}$.

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
			Sample III	**S&P500**			
$\beta_1(\Delta vix_t)$	−0.120***	−0.129***	−0.127***	−0.118***	−0.114***	−0.109***	−0.109***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)
$\beta_2(\Delta i_t)$	0.117	0.128	0.134	0.105	0.087	0.075	0.072
	(0.083)	(0.092)	(0.085)	(0.090)	(0.072)	(0.076)	(0.075)
$\beta_3(\Delta yield_t)$	0.035***						
	(0.005)						
$\beta_4(\Delta inf_t)$		0.021***	0.023***	0.021***	0.019***	0.020***	0.020***
		(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
$\beta_5(\Delta gold_t)$			0.055*			−0.014	−0.013
			(0.031)			(0.025)	(0.025)
$\beta_6(\Delta oil\_wti_t)$				0.140***		0.116***	0.117***
				(0.015)		(0.016)	(0.016)
$\beta_7(\Delta e_t)$					0.350***	0.252***	0.247***
					(0.048)	(0.045)	(0.045)
$\beta_8(R_{t-1})$							−0.020
							(0.027)
Arch	0.117**	0.124*	0.125*	0.175***	0.138*	0.147***	0.151***
	(0.058)	(0.068)	(0.071)	(0.063)	(0.078)	(0.053)	(0.055)
Garch	0.976***	0.998***	0.997***	0.695***	0.909***	0.706***	0.701***
	(0.235)	(0.216)	(0.217)	(0.211)	(0.243)	(0.241)	(0.232)
N	653	653	653	653	653	653	653
AIC	−4737.7	−4686.3	−4690.1	−4800.2	−4761.4	**−4834.5**	−4833.4
BIC	−4706.3	−4654.9	−4654.2	−4764.3	−4725.6	**−4789.7**	−4784.1
LM(3)	0.333	1.581	0.935	0.237	0.138	0.257	0.087
	(0.954)	(.664)	(0.817)	(0.972)	(0.987)	(0.968)	(0.993)
			Sample III	**Dow**	**Jones**		
$\beta_1(\Delta vix_t)$	−0.107***	−0.115***	−0.113***	−0.104***	−0.099***	−0.095***	−0.095***
	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)
$\beta_2(\Delta i_t)$	0.094	0.101	0.105	0.090	0.060	0.056	0.055
	(0.077)	(0.087)	(0.079)	(0.086)	(0.065)	(0.070)	(0.069)
$\beta_3(\Delta yield_t)$	0.034***						
	(0.005)						
$\beta_4(\Delta inf_t)$		0.021***	0.023***	0.021***	0.020***	0.020***	0.020***
		(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)
$\beta_5(\Delta gold_t)$			0.060**			−0.000	−0.000
			(0.030)			(0.025)	(0.025)
$\beta_6(\Delta oil\_wti_t)$				0.121***		0.094***	0.095***
				(0.015)		(0.015)	(0.015)
$\beta_7(\Delta e_t)$					0.338***	0.254***	0.253***
					(0.043)	(0.042)	(0.042)
$\beta_8(R_{t-1})$							−0.005
							(0.026)
Arch	0.170**	0.157*	0.155*	0.221***	0.174**	0.184***	0.184***
	(0.080)	(0.082)	(0.081)	(0.085)	(0.080)	(0.068)	(0.068)
Garch	0.692***	0.836***	0.861***	0.565***	0.774**	0.562*	0.563*
	(0.250)	(0.210)	(0.204)	(0.215)	(0.307)	(0.325)	(0.322)
N	653	653	653	653	653	653	653
AIC	−4813.8	−4762.2	−4768.4	−4852.7	−4839.8	**−4891.3**	−4889.3
BIC	−4782.4	−4730.8	−4732.5	−4816.8	−4803.9	**−4846.4**	−4840.0
LM(3)	0.330	0.774	0.419	0.163	0.578	0.298	0.373
	(0.954)	(0.856)	(0.936)	(0.983)	(0.902)	(0.960)	(0.946)
	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
			Sample III	**NASDAQ**			
$\beta_1(\Delta vix_t)$	−0.123***	−0.132***	−0.131***	−0.121***	−0.121***	−0.115***	−0.115***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)
$\beta_2(\Delta i_t)$	0.035	0.036	0.043	0.027	0.014	0.015	0.019
	(0.071)	(0.078)	(0.074)	(0.076)	(0.070)	(0.070)	(0.070)
$\beta_3(\Delta yield_t)$	0.032***						
	(0.006)						
$\beta_4(\Delta inf_t)$		0.021***	0.023***	0.023***	0.021***	0.022***	0.023***
		(0.007)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
$\beta_5(\Delta gold_t)$			0.070**			0.021	0.020
			(0.031)			(0.027)	(0.027)
$\beta_6(\Delta oil\_wti_t)$				0.110***		0.092***	0.091***
				(0.018)		(0.018)	(0.018)
$\beta_7(\Delta e_t)$					0.261***	0.170***	0.175***
					(0.051)	(0.051)	(0.052)
$\beta_8(R_{t-1})$							0.017
							(0.029)

Table 3C (*continued*)

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
Arch	0.111**	0.088*	0.104*	0.114**	0.083*	0.106**	0.108**
	(0.050)	(0.045)	(0.054)	(0.047)	(0.045)	(0.046)	(0.048)
Garch	0.872***	0.953***	0.871**	0.750*	0.824***	0.693*	0.647
	(0.247)	(0.290)	(0.349)	(0.389)	(0.298)	(0.383)	(0.415)
N	653	653	653	653	653	653	653
AIC	−4533.1	−4504.5	−4509.5	−4553.6	−4532.2	**−4563.2**	−4561.6
BIC	−4501.7	−4473.1	−4473.6	−4517.7	−4496.3	**−4518.3**	−4512.3
LM(3)	0.785	0.352	0.417	0.110	0.317	0.176	0.252
	(0.853)	(0.950)	(0.937)	(0.991)	(0.957)	(0.981)	(0.969)
			Sample III	**Russell**	**2000**		
$\beta_1(\Delta vix_t)$	−0.157***	−0.170***	−0.169***	−0.154***	−0.155***	−0.147***	−0.147***
	(0.010)	(0.009)	(0.008)	(0.010)	(0.008)	(0.010)	(0.010)
$\beta_2(\Delta i_t)$	0.126	0.147	0.154	0.126	0.116	0.107	0.101
	(0.110)	(0.119)	(0.115)	(0.113)	(0.112)	(0.113)	(0.113)
$\beta_3(\Delta yield_t)$	0.042***						
	(0.009)						
$\beta_4(\Delta inf._t)$		0.020**	0.021**	0.022**	0.020**	0.020**	0.020**
		(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)
β_5 $(\Delta gold_t)$			0.056			−0.023	−0.021
			(0.047)			(0.041)	(0.041)
$\beta_6(\Delta oil\_wti_t)$				0.185***		0.171***	0.173***
				(0.025)		(0.026)	(0.025)
$\beta_7(\Delta e_t)$					0.339***	0.183**	0.173**
					(0.081)	(0.079)	(0.079)
$\beta_8(R_{t-1})$							−0.034
							(0.034)
Arch	0.118*	0.146**	0.154**	0.183***	0.144**	0.171***	0.172***
	(0.061)	(0.073)	(0.076)	(0.065)	(0.071)	(0.065)	(0.063)
Garch	0.970***	0.879***	0.834***	0.713***	0.858***	0.751***	0.768***
	(0.250)	(0.239)	(0.234)	(0.192)	(0.222)	(0.194)	(0.184)
N	653	653	653	653	653	653	653
AIC	−4121.6	−4090.8	−4091.2	−4173.8	−4116.3	−4177.5	**−4177.6**
BIC	−4090.3	−4059.4	−4055.3	**−4138.0**	−4080.4	−4132.7	−4128.3
LM(3)	81.973***	53.057***	58.394***	48.826***	35.203***	32.908***	35.682***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: Robust standard errors in parentheses *p<.10, **p<.05, ***p<.01. Sample III is from July 1, 2009 to Dec. 30, 2011.

between the pre-crisis and each of the later subsamples. One possibility is the higher liquidity provided by Quantitative Easing (QE) procedures by the Federal Reserve in the crisis and subsequent recovery period. In contrast to the pre-crisis and crisis subsamples, oil returns are now positively associated with stock returns: 0.175-coefficient in model VI. Also, depreciations in the U.S. dollar/euro are also strongly associated with higher stock returns in the recovery period: the coefficient is 0.558 and statistically significant in column VI. As the U.S. dollar depreciates against the euro, the stock market moves upward in line with a strong trade-GDP channel. On the volatility equation for the DCC models, the coefficients tend to keep the same properties as in the GARCH (1, 1) models with sum > 1 the pre-crisis period and < 1 in the subsequent periods. Moreover, lambda 1 and lambda 2 are adjustment parameters that govern the dynamic correlation process. We have tested them for being jointly equal to zero (not reported in Table 4) and almost all of them are significantly different from zero. If they were zero the DCC model could be reduced to Constant Conditional Correlation (CCC).

Table 5 reports the correlation associated with the MGARCH-DCC estimation. The estimates refer to the system (3a)-(3b) for joint estimation of stock returns and oil. The changing correlation varies for sample I from either not statistically significant or negative for DJIA stock markets to not statistically significant or positive for S&P 500 and DJIA stock markets for sample II, whenever convergence was achieved. Remarkably, for sample III the correlation implied by the MGARCH-DCC algorithm is found to be positive and always statistically significant. This confirms what already seen by GARCH (1, 1) models: the oil-stock correlation is changing over time. In the recovery period, in particular, it is positive and much higher (around the 0.30 level) than the two preceding periods. When we verify the same MGARCH-based statistic for the system (2a)-(2b) we have very high and negative coefficients between stock returns and changes in VIX throughout: usually around −0.700 for all three samples, which underscores that the negative correlation between stocks and VIX is fairly constant over time.[13]

6. Concluding remarks

We put forward a reexamination of the proposition in Chen et al. (1986) using very flexible GARCH (1, 1) and MGARCH-DCC models to accommodate a wide range of domestic and international forces in explaining daily U.S. stock returns. Engle (2004) motivates how the ARCH models were created in the 1970s based on Milton Friedman's conjecture that the level of inflation was not a problem but the unpredictability of inflation was. For U.S. stock returns, fluctuations in exchange rates (higher trade and GDP channel), uncertainty in equity markets (captured by the "fear gauge" index of VIX in option contracts), and inflation expectations are found to have an impact on expected earnings of firms. More difficult to ascertain is the reaction to oil prices, which have confounding effects on stock markets as surveyed by Killian (2008) and documented by Apergis and Miller (2009).

In general, the pre-crisis sample differs from the two subsample results and the latter two differ between themselves as well. Our proposed explanation is due to the changing correlation between stock markets and oil, and between stock market and exchange rates. In subsamples I (Jan 1999–Dec 2007) and II (Jan 2008–Jun 2009) U.S. stock returns are not much associated with oil prices but in

[13] A table with these results is available upon request. Although sample I had convergence in all markets and models, sample II had convergence only in all models of NASDAQ and two models of S&P 500, and sample III had convergence in all models of NASDAQ and S&P 500, and only in one model each in DJ and Russell 2000.

Table 4
DCC estimations for NASDAQ Returns and VIX for Samples I, II and III.

$R_t = \beta_0 + \beta_2 \Delta i_t + \beta_3(\Delta yield) + \beta_4 \Delta inf_t + \beta_5 \Delta gold_t + \beta_6 \Delta oilwti_t + \beta_7 \Delta e_t + \beta_8(R_{t-1}) + \varepsilon_{it}$.

Sample I	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
$\beta_2(\Delta i_t)$	−0.005	−0.013	−0.012	−0.012	−0.011	−0.010	−0.010
	(0.011)	(0.009)	(0.008)	(0.009)	(0.007)	(0.007)	(0.007)
$\beta_3(\Delta yield_t)$	0.024***						
	(0.006)						
$\beta_4(\Delta inf._t)$		0.036***	0.034***	0.033***	0.027***	0.025***	0.025***
		(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
β_5 $(\Delta gold_t)$			−0.050*			−0.008	−0.007
			(0.026)			(0.027)	(0.027)
$\beta_6(\Delta oil\_wti_t)$				−0.025*		−0.022	−0.021
				(0.014)		(0.014)	(0.014)
$\beta_7(\Delta e_t)$					−0.313***	−0.313***	−0.307***
					(0.061)	(0.063)	(0.064)
$\beta_8(R_{t-1})$							−0.025
							(0.021)
Arch	0.381***	0.390***	0.400***	0.394***	0.386***	0.388***	0.386***
	(0.043)	(0.044)	(0.045)	(0.044)	(0.043)	(0.042)	(0.042)
Garch	0.871***	0.849***	0.841***	0.840***	0.862***	0.852***	0.852***
	(0.083)	(0.080)	(0.077)	(0.079)	(0.078)	(0.077)	(0.076)
Adjustment							
lambda1	0.002	0.002	0.011	0.002	0.002	0.002*	0.002
	(0.002)	(0.002)	(0.008)	(0.001)	(0.001)	(0.001)	(0.001)
lambda2	0.994***	0.994***	0.954***	0.994***	0.994***	0.994***	0.994***
	(0.001)	(0.001)	(0.016)	(0.001)	(0.001)	(0.001)	(0.001)
N	2346	2346	2346	2346	2345	2345	2345
AIC	−20382.2	−20383.3	−20369.2	−20388.6	−20408.2	**−20422.4**	−20420.1
BIC	−20290.0	−20291.1	−20265.5	−20284.9	**−20304.5**	−20295.7	−20281.9

Sample II	**Model I**	**Model II**	**Model III**	**Model IV**	**Model V**	**Model VI**	**Model VII**
$\beta_2(\Delta i_t)$	0.005	−0.003	−0.004	−0.003	−0.002	−0.009	−0.000
	(0.026)	(0.026)	(0.030)	(0.026)	(0.025)	(0.028)	(0.030)
$\beta_3(\Delta yield_t)$	0.020						
	(0.013)						
$\beta_4(\Delta inf._t)$		0.051**	0.049**	0.047**	0.060***	0.053***	0.049***
		(0.020)	(0.020)	(0.022)	(0.019)	(0.017)	(0.018)
β_5 $(\Delta gold_t)$			−0.095			−0.204**	−0.207**
			(0.082)			(0.081)	(0.082)
$\beta_6(\Delta oil\_wti_t)$				0.062		0.046	0.057
				(0.045)		(0.034)	(0.039)
$\beta_7(\Delta e_t)$					0.536***	0.605***	0.605***
					(0.164)	(0.159)	(0.162)
$\beta_8(R_{t-1})$							−0.136**
							(0.057)
Arch	0.177***	0.200***	0.209***	0.181**	0.167**	0.165**	0.108
	(0.060)	(0.074)	(0.072)	(0.081)	(0.071)	(0.068)	(0.080)
Garch	0.932***	0.748***	0.737***	0.792*	0.776**	0.841**	1.182
	(0.276)	(0.284)	(0.245)	(0.411)	(0.377)	(0.381)	(0.782)
lambda1	0.066	0.047	0.049	0.040	0.065	0.075	0.038
	(0.063)	(0.065)	(0.069)	(0.061)	(0.073)	(0.081)	(0.078)
lambda2	0.409	0.415	0.427*	0.383	0.341	0.347*	0.409**
	(0.333)	(0.274)	(0.256)	(0.291)	(0.271)	(0.207)	(0.194)
N	391	391	391	391	391	391	391
AIC	−3226.07	−3237.47	−3236.06	−3240.90	−3251.85	−3258.95	**−3263.14**
BIC	−3162.57	−3173.97	−3164.62	−3169.46	**−3180.41**	−3171.64	−3167.89

Notes: Robust standard errors are in parentheses *$p<.10$, **$p<.05$, ***$p<.01$. Sample I is for the period Jan. 1 1999–Dec. 31 2007 and Sample II is for the period Jan. 1, 2008–June 30, 2009. The DCC models are estimated with one equation for stock returns (reported above) and another for changes in VIX, omitted for space constraints.

Sample III	**Model I**	**Model II**	**Model III**	**Model IV**	**Model V**	**Model VI**	**Model VII**
β2(Δi t)	−0.003	0.073	0.079	0.007	0.101	0.069	0.072
	(0.132)	(0.142)	(0.139)	(0.120)	(0.128)	(0.115)	(0.111)
β3(Δyieldt)	0.073***						
	(0.010)						
β4(Δinf.t)		0.049***	0.052***	0.051***	0.050***	0.048***	0.048***
		(0.010)	(0.010)	(0.009)	(0.008)	(0.008)	(0.008)
β5 (Δgoldt)			0.130***			−0.022	−0.024
			(0.046)			(0.036)	(0.036)
β6(Δoil_wtit)				0.240***		0.175***	0.173***
				(0.029)		(0.027)	(0.027)
β7(Δet)					0.731***	0.558***	0.571***
					(0.074)	(0.066)	(0.066)
β8(Rt-1)							0.049
							(0.034)

Table 4 (*continued*)

Sample I	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
Arch	0.169*	0.139	0.154	0.200***	0.217***	0.254***	0.238***
	(0.099)	(0.087)	(0.111)	(0.074)	(0.066)	(0.073)	(0.074)
Garch	0.735*	1.103***	1.062**	0.463	0.527*	0.254	0.272
	(0.411)	(0.395)	(0.445)	(0.332)	(0.320)	(0.221)	(0.224)
lambda1	0.019	0.010	0.022	0.028	0.034	0.044	0.052
	(0.031)	(0.026)	(0.039)	(0.030)	(0.031)	(0.027)	(0.036)
lambda2	0.641***	0.568***	0.559*	0.666***	0.503	0.609***	0.389
	(0.134)	(0.200)	(0.336)	(0.129)	(0.597)	(0.203)	(0.424)
N	653	653	653	653	653	653	653
AIC	−6348.98	−6259.45	−6270.01	−6383.65	−6422.10	**−6480.33**	−6478.78
BIC	−6277.28	−6187.75	−6189.34	−6302.98	−6341.43	**−6381.73**	−6371.22

Notes: Robust standard errors in parentheses *p<.10, **p<.05, ***p<.01. Sample III is for the period Jul. 1, 2009 to Dec. 30, 2011. The DCC models are estimated with one equation for stock returns (reported above) and another for changes in VIX, omitted for space constraints.

Table 5
MGARCH–DCC based Correlation between Oil WTI and Stock Returns.

	Model I	Model II	Model III	Model IV	Model V	Model VI
Sample I (Jan 1 1999–Dec 31 2007)						
S&P500	−0.041*	−0.035	−0.036	−0.031	−0.034	−0.030
	(0.023)	(0.023)	(0.022)	(0.023)	(0.023)	(0.024)
Dow Jones	−0.088***	−0.078***	−0.074***	−0.073***	−0.070***	−0.069***
	(0.029)	(0.023)	(0.023)	(0.027)	(0.023)	(0.028)
NASDAQ	−0.154	−0.061	−0.111	−0.090	−0.091	−0.048
	(0.121)	(0.058)	(0.104)	(0.098)	(0.097)	(0.096)
Russell2000	0.005	0.015	0.011	–	0.012	0.12
	(0.026)	(0.025)	(0.025)		(0.025)	(0.025)
Sample II (Jan 1 2008–Jun 30 2009)						
S&P500	0.206***	–	0.220***	–	–	–
	(0.073)		(0.063)			
Dow Jones	–	–	0.150**	–	–	–
			(0.064)			
NASDAQ	0.058	0.060	0.078	−0.010	−0.007	0.001
	(0.076)	(0.076)	(0.074)	(0.067)	(0.069)	(0.067)
Russell2000	0.073	0.086	0.084	–	–	–
	(0.107)	(0.098)	(0.096)			
Sample III (Jul 1 2009–Dec 30 2011)						
S&P500	0.337***	–	–	–	0.332***	0.329***
	(0.044)				(0.044)	(0.044)
Dow Jones	0.288***	–	–	–	0.278***	0.276***
	(0.045)				(0.045)	(0.045)
NASDAQ	0.230***	0.269***	–	0.227***	0.221***	0.217***
	(0.050)	(0.049)		(0.048)	(0.048)	(0.048)
Russell2000	0.305***	–	–	0.307***	–	0.309***
	(0.042)			(0.043)		(0.044)

Notes: Robust standard error in parenthesis. *p<.10, **p<.05, ***p<.01. "–" indicate the MGARCH -DCC model does not converge. In MGARCH models the conditional variances are modeled as univariate GARCH models and the conditional covariances are modeled as nonlinear functions of the conditional variances. The conditional quasi-correlation parameters that weight the nonlinear combinations of the conditional variances follow GARCH-like processes. In Engle (2002), the log-likelihood of the MGARCH-DCC model is written as the sum of a volatility part and a correlation part. Under a two-step approach to maximizing the likelihood function, a long expression (equation 33 of that article) can be derived for the covariance matrix of the correlation parameters.

subsample III (Jul 2009–Dec 2011) this relationship becomes positive and statistically significant. We also find the response of U.S. equities to the Euro to be entirely plausible from the viewpoint of investors reacting to higher earnings due to a lower USD and increasing trade with the European Union.

The findings in this paper put in perspective the lower returns of U.S. stocks relative to gold, oil, and exchange rates over the years 1999–2011.[14] Examining a time span with substantial changes in return and risk, the results reported herein are very robust within the class of GARCH models employed. Our interpretation is that in the aftermath of the very severe economic slowdown indicators that signal future aggregate demand (inflation expectations, oil prices, and weaker USD) cause expected earnings to go up. An extension of this paper will go from aggregate uncertainty (VIX) to measures of idiosyncratic volatilities as in Fu (2009).

[14] On comparison of certain funds of commodities to equities, results vary but certainly performance of the aggregate contrasts with individual returns: "As with equities, bets on some individual commodities have offered incredible returns compared with indexes. In particular, soybeans, gold, copper, and oil have been star performers across various time-horizons in the past 15 years." WSJ (2012, p. C12.)

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