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Sources of Volatility during Four Oil Price Crashes

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Abstract

Previous sharp oil price declines have been accompanied by elevated ex post volatility. In contrast, volatility was much less elevated during the oil price crash in 2014/15. This paper provides evidence that oil prices declined in a relatively measured manner during 2014/15, with dispersion of price changes that was considerably smaller than comparable oil price declines. This finding is robust to nonparametric and GARCH measures of volatility. Further, the U.S. dollar appreciation exerted a strong influence on volatility during the recent crash; in contrast, the impact of shocks on equity markets was muted.

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Sources of Volatility during Four Oil Price Crashes

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I. Introduction

The dollar value of crude oil declined 51.2 percent in 83 trading days (October 1, 2014 to January 29, 2015).[1] Since 1984, when oil started trading on futures exchanges, there have been only three other episodes with comparably large declines (Figure 1). The largest took place during the financial crisis of 2008/09 (oil prices declined by 76.7 percent in 113 trading days), followed by the 1985/86 crash when OPEC abandoned price targeting (oil prices declined by 66.4 percent in 82 trading days), and the crash related to the first Gulf War when prices declined by 47.9 percent in 71 trading days. During each of these three episodes, oil price volatility was about twice as large (above 4.6 percent in all cases) as the historical average (2.4 percent). In contrast, volatility was considerably less elevated during the recent oil price crash at 2.6 percent (Figures 2 and 3).

We use a number of nonparametric measures of volatility and a GARCH (1,1) estimate to document the "missing" oil price volatility during the 2014/15 crash.[2] Candidate explanations for the 2014/15 crash (e.g., OPEC's abandonment of price support) are consistent with large declines on the days that the market absorbs relevant news. Yet, the maximum daily decline during the crash (5.5 percent) was less than half the maximum declines during the earlier crashes and there was also considerably less dispersion around the mean decline—consistent with the narrative involving a measured fall in prices.

II. Empirical Model

We employ a GARCH (1, 1) model (Bollerslev 1986; Engel and Patton 2001) to estimate daily oil price volatility and identify the influence of equity market and exchange rate

[1] The reasons behind the oil price plunge have been discussed elsewhere (e.g., Arezki and Blanchard 2014; Baffes et al 2015).

[2] The ex-post measures of volatility used here are different that the implied volatility based on option prices—which measure market expectations of volatility before it is realized.

shocks using data from January 1, 1985 to March 10, 2015. The model is parsimonious and also widely used in the literature (Hansen and Lund 2005; Tsay 2010).

We begin by conditioning the oil price returns on the riskless asset as follows:

$$R_t^{OIL} = \beta_0 + \beta_1 Tbill_t + \varepsilon_t. \quad (1)$$

R_t^{OIL} denotes the first difference of oil price, $R_t^{OIL} = log(P_t^{OIL}/P_{t-1}^{OIL})$ where P_t^{OIL} is the price of oil at time *t*; $Tbill_t$ denotes the U.S. Treasury Bill; ϵ_t is a heteroscedastic error term whose variance follows a Gaussian autoregressive moving average process defined as follows:

$$Var(\varepsilon_t) = \sigma_t^2 = \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2 +$$
$$exp\left(\alpha_0 + \alpha_3 R_{t-1}^{Equity[+]} + \alpha_4 R_{t-1}^{Equity[-]} + \alpha_5 R_{t-1}^{XR[+]} + \alpha_6 R_{t-1}^{XR[-]}\right). \quad (2)$$

$R_{t-1}^{Equity[\bullet]}$ and $R_{t-1}^{XR[\bullet]}$, represent logarithmic changes of the equity and exchange rate indices, respectively; the [+] and [-] signs are associated with positive and negative changes, respectively, allowing for asymmetric impacts of shocks from the equity and exchange rate indices. Taking expectations on both sides of Equation (2) gives:

$$E(\sigma^2) = \frac{exp\left(\alpha_0 + \alpha_3 R_{t-1}^{Equity[+]} + \alpha_4 R_{t-1}^{Equity[-]} + \alpha_5 R_{t-1}^{XR[+]} + \alpha_6 R_{t-1}^{XR[-]}\right)}{(1 - \alpha_1 - \alpha_2)}. \quad (3)$$

We used the West Texas Intermediate (WTI) settlement price of the front futures contract as a measure of the oil price (because data are available from 1985); the US S&P 500 was used as the equity index; and the broad trade weighted US dollar index (from the Federal Reserve) was used as an exchange rate proxy.

III. Results

On average, the daily oil price decline was -0.86 percent during the recent crash, with

considerably less dispersion around this mean during the earlier three crashes (Table 1). The standard deviation of returns during the recent crash was 2.6 percent, similar to the historical average of 2.4 percent, but about half the magnitude of the earlier crashes. In contrast to the other crashes, the inter-quartile range (2.9 percent) was also much closer to the historical average of 2.3 percent. The proportion of days when prices fell by more than 2 percent was less than the other crashes as well (though greater than the historical average); the number of days when prices rose by more than 2 percent was also less than all three previous crashes and the historical average. Last, a measure of the proportion of 'stable' days (i.e. days in which absolute log returns did not exceed 2 percent) was much closer to the historical average than to values associated with the three previous oil price crashes.

To confirm these observations and also identify drivers of volatility during each crash period, we estimate a GARCH specification as discussed earlier, the results of which are reported in Tables 2 and 3. The specification is applied to seven samples: 1985-2015 (full sample), 1985-2003 (pre-boom period), 2004-2015 (post-boom period), and four 250 day periods ending with the end of each crash.

We draw three conclusions. First, while shocks to volatility have a smaller half-life during oil price crashes, of the four crashes, the half-lives are larger (greater than 12 days) for the crashes involving a loss in price support from OPEC (1985/86 and 2014/15) compared to the crashes engendered by the first Gulf War (1985/86) and financial crisis of 2008/09 (which each exhibited a half-life of just 2 days).

Second, positive equity market shocks during the three previous crashes were associated with greater volatility while this was not the case during the recent crash. Further, negative equity shocks were associated with greater volatility during the crashes of the first Gulf War and financial crisis. For example, while unconditional variance (with no equity shocks) was just 3.5 percent during the 2008/09 crash, the conditional variance

was six times as high (22.3 percent). The recent crash was not associated with either positive or negative equity shocks.

Third, in contrast to the other crashes, the appreciation of the U.S. dollar was associated with greater volatility during the crashes of 1991/92 and 2014/15. A 0.5 percent appreciation in the exchange rate is associated with a 39.6 percent increase in variance during the 2014/15 crash and a 12.1 percent increase during the first Gulf War crash.

For robustness, we re-estimate the parameters for each crash period using three sample windows—the full sample, the relevant sub-sample (either the pre-boom period before 2004 or the boom period starting in 2004), and the 250-day window that ends with the end of each crash (Table 3). The results indicate that the mean volatility (estimated using the GARCH specifications) for each crash period is similar for sample windows of different sizes. Similar to the previous estimates, the conditional variance for the latest crash period is estimated to be between 4.3 percent and 6.1 percent while estimates of the conditional variance of the earlier crashes are about four times as high (ranging from 15.2 to 24.9 percent). Finally, we estimated the model for the post-2000 period using the Brent benchmark and the MSCI world equity index; the results were substantively similar for the relevant periods.

IV. Conclusion

It has often been argued that we are now in an era of higher "commodity price volatility" (Dobbs et al 2011; McNally and Levi 2011). In this context, it is tempting to assert that the 2008/09 and 2014/16 crashes reflect structural changes in commodity markets that have engendered greater oil price volatility. However, this note documented that oil price volatility during the 1985-2003 period was nearly identical to that of the 2004-2015 period (Table 1).

We show that there are two key differences between the 2008/09 and 2014/15 oil

price crashes. First, oil prices declined in a relatively measured manner in 2014, with the dispersion of price changes (around a downward drift) that was considerably smaller than comparably large oil price declines.[3] Second, the U.S. dollar appreciation exerted a strong influence on volatility during the recent crash, while in contrast, the impact of shocks to equity markets was muted.

[3] Volatility exhibited an upward trend after the 2014/15 crash ended (see Figure 2).

Table 1
Oil Price Summary Statistics

	Full Sample *1985-2015*	**Pre-Boom** *1983-2003*	**Post-Boom** *2004-2015*	**Crash 1** *11/25/85-03/31/86*	**Crash 2** *11/08/90-02/21/91*	**Crash 3** *07/14/08-02/19/09*	**Crash 4** *10/01/14-01/29/15*
Nominal price level statistics							
Maximum	145.29	40.42	145.29	31.70	35.53	145.18	91.01
Minimum	10.42	10.42	32.48	10.42	18.50	33.87	44.45
Max to Min change (%)	—	—	—	-66.4	-47.9	-76.7	-51.2
Returns statistics							
Mean	0.01	0.01	0.01	-1.33	-0.35	-1.29	-0.86
Standard Deviation	2.38	2.42	2.32	4.69	5.18	4.62	2.58
Interquartile Range	2.31	2.26	2.41	4.82	6.00	5.54	2.90
Skewness	-0.22	-0.36	0.06	0.01	0.00	0.41	-0.39
Kurtosis	8.69	9.02	7.97	3.36	3.46	3.80	4.84
Distribution of quartiles							
Minimum	-17.45	-17.45	-13.07	-13.91	-13.17	-12.60	-10.79
Median	0.03	0.00	0.06	-1.37	-0.27	-1.27	-0.89
Maximum	16.41	14.03	16.41	11.04	12.68	14.55	5.49
25th percentile	-1.12	-1.07	-1.19	-3.84	-3.32	-4.54	-2.21
75th percentile	1.20	1.19	1.22	0.98	2.68	1.00	0.70
Fraction of days with shocks							
Greater than +1%	0.28	0.28	0.29	0.24	0.39	0.26	0.18
Greater than +2%	0.15	0.15	0.14	0.20	0.32	0.19	0.10
Less than -1%	0.27	0.26	0.28	0.52	0.45	0.54	0.45
Less than -2%	0.14	0.14	0.15	0.44	0.30	0.43	0.29
Fraction of stable days	0.71	0.72	0.71	0.37	0.38	0.37	0.61
Observations	*7,575*	*4,759*	*2,816*	*82*	*71*	*113*	*83*

Notes: "—" indicates not applicable. The observation for January 17, 1991 has been excluded—it dropped 33 percent, from $32.00/bbl on January 16 to $21.22/bbl on January 17 (it was the day coalition forces invaded Iraq, consequently reducing the likelihood of oil supply disruptions). The 'fraction of stable days' denotes the number of days with absolute daily oil price changes that do not exceed 2 percent.

Table 2
GARCH (1, 1) Estimates

	Full Sample: *1985-2015*	**Pre-Boom:** *1985-2003*	**Post-Boom:** *2004-15*	**Crash 1:** *11/19/85-04/31/86*	**Crash 2:** *11/09/90-02/22/91*	**Crash 3:** *07/02/08-02/13/09*	**Crash 4:** *10/01/14-01/28/15*
Mean equation							
β_0	0.02	0.01	0.02	-0.46	-0.63	-0.85	-0.57**
	(0.82)	(0.13)	(0.48)	(0.28)	(0.20)	(1.59)	(2.44)
$TBill_t$	0.00	0.01	0.03	0.07	0.10	0.47*	13.27**
	(0.03)	(0.08)	(1.57)	(0.30)	(0.24)	(1.79)	(2.21)
Variance equation							
α_0	-2.58***	-1.62*	-3.13***	-2.13	-0.46	-0.08	-2.58***
	(5.87)	(1.64)	(7.09)	(0.96)	(1.32)	(0.16)	(3.72)
ε_{t-1}^2	0.06***	0.10***	0.06***	0.28	0.02	0.07	0.00
	(7.58)	(5.91)	(4.32)	(0.87)	(0.28)	(1.03)	(0.02)
σ_{t-1}^2	0.93***	0.01***	0.92***	0.67**	0.69***	0.67***	0.95***
	(111.9)	(85.2)	(53.1)	(1.99)	(8.20)	(4.91)	(56.5)
$R_{t-1}^{Equity[+]}$	0.18	0.57	-0.98	2.75**	1.21***	0.52**	-4.53
	(1.00)	(0.08)	(1.52)	(2.20)	(3.81)	(6.27)	(0.99)
$R_{t-1}^{Equity[-]}$	-0.53**	0.32	-0.62***	-1.08	-1.20***	-0.42***	13.9
	(2.42)	(1.60)	(4.07)	(0.50)	(4.53)	(3.38)	(1.30)
$R_t^{XR[+]}$	-2.27	10.68	-0.38	-210.6	3.41***	-0.74	6.66***
	(1.16)	(0.68)	(0.19)	(0.60)	(4.39)	(1.02)	(9.12)
$R_t^{XR[-]}$	16.72**	18.43	-0.86***	1.48	-0.30	-0.42	-0.14
	(2.16)	(1.20)	(2.99)	(0.46)	(0.25)	(1.07)	(0.02)
Key test statistics							
Log-Likelihood	-15700	-9929	-5760	-460	-684	-619	-439
Box-Ljung test (1 lag)	38***	40***	36***	29***	22***	248***	7268***
Persistence (GARCH)	0.996***	0.994***	0.988***	0.957***	0.713***	0.737***	0.947***
Half Life (days)	161.4	116.7	54.4	15.7	2.0	2.3	12.7
Observations	*7,325*	*4,603*	*2,722*	*250*	*250*	*250*	*250*

Notes: One (*), two (**), and three (***) asterisks denote parameter estimate significant at the 10, 5, and 1, percent levels.

Table 3
Robustness Checks

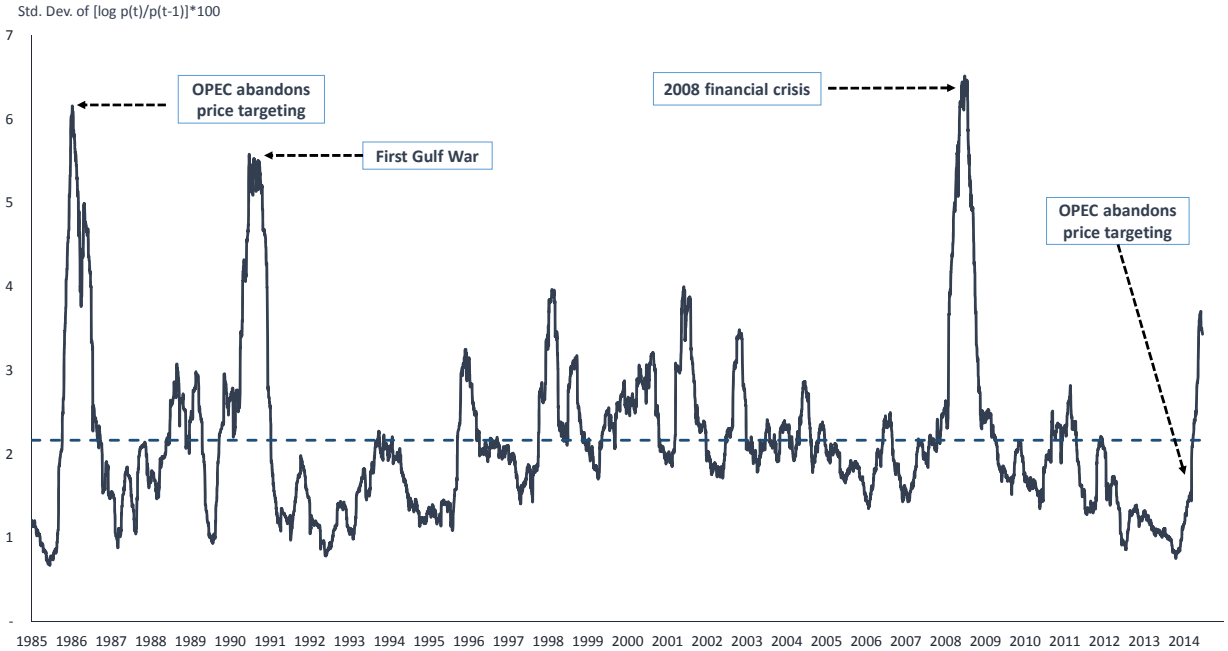
	Crash 1: *11/19/85-04/31/86*	**Crash 2:** *11/09/90-02/22/91*	**Crash 3:** *07/02/08-02/13/09*	**Crash 4:** *10/01/14-01/28/15*
Sample variance (from table 1)	22.0	26.9	21.4	6.6
Conditional variances, based on the different estimation windows				
Full sample	15.4	23.7	18.9	6.1
Pre-boom/post-boom	15.2	23.2	21.3	5.7
250-day window	20.8	24.9	22.3	4.3
Other statistics, based on 250-day window				
Unconditional variance	2.7	2.2	3.5	1.4
Mean, +1% equity	43.0	7.5	5.9	—
Mean, -1% equity	—	7.3	5.3	—
Mean, +0.5% exchange rate	—	12.1	—	39.6
Mean, -0.5% exchange rate	—	—	—	—

Notes: Row 1 reports the square of the standard deviation, shown in the second panel of table 1. A cell is assigned "—"when the driver is not statistically significant at a 5% level.

Figure 1
Oil Prices (WTI), U.S. CPI-deflated

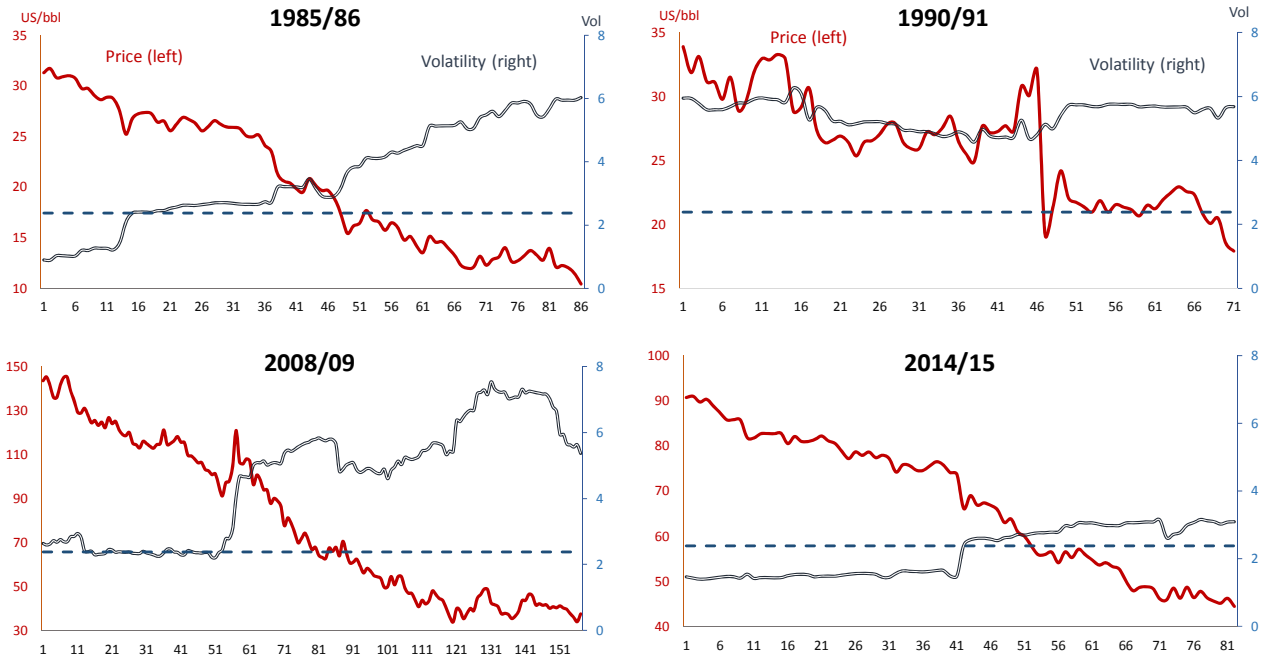
Source: World Bank
Note: Last observation is February 2015. Oil prices, which refer to WTI have been deflated by the U.S. CPI (2014 terms)

Figure 2
Oil Price Volatility, 1985-2015



Source: World Bank
Notes: Volatility is the standard deviation of the oil price (WTI) changes, presented as a 60-day trailing window.

Figure 3
Heightened Price Volatility during Three Previous Oil Price Crashes



Notes: Volatility is the standard deviation of the oil price (WTI) changes and is presented as a 30-day trailing window.

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