Sources of Volatility during Four Oil Price Crashes

John Baffes
jbaffes@worldbank.org

Varun Kshirsagar
varun.kshirsagar@gmail.com

June 5, 2015

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. We provide evidence that oil prices declined in a relatively measured manner during 2014/15, with a dispersion of price changes that was considerably smaller than comparable oil price declines. This finding is robust to using both descriptive 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 equity market shocks was muted.*

KEY WORDS: Crude oil price, volatility, oil price crashes, commodity markets

JEL: Q43, Q47, E39

The views expressed here are our own and do not reflect those of the World Bank.

1. Introduction

The dollar price 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 oil price declines (figure 1). The largest took place during the financial crisis of 2008/09 (prices declined by 76.7 percent in 113 trading days), followed by the 1985/86 crash when OPEC abandoned price targeting (prices declined by 66.4 percent in 82 days), and the crash related to the first Gulf War when prices declined by 47.9 percent in 71 days. During each of these episodes, oil price volatility (the standard deviation of log returns) was about twice as large (above 4.6 percent in all cases) compared to the historical average of 2.4 percent. In contrast, volatility was considerably less elevated during the recent crash, at 2.6 percent (figures 2 and 3).

We use a number of non-parametric (descriptive) 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 recent 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 a narrative involving a measured fall in prices.

2. 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 shocks using observations 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:

[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 from ex-ante volatility implied by option prices – which measure market expectations of volatility before it is realized.

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

$R_{t-1}^{Equity[\bullet]}$ and $R_{t-1}^{XR[\bullet]}$, represent logarithmic changes of the equity and exchange rate indices; the [+] and [-] signs are associated with positive and negative changes allowing for asymmetric impacts of such shocks. Taking expectations on both sides of (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 for the oil price (because data is available from 1985) and the US S&P 500 for the equity index; the broad trade weighted US dollar index was used as an exchange rate proxy.[3]

3. Results

On average, the daily oil price decline was -0.86 percent during the recent crash with a considerably less dispersion compared to earlier 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 the absolute value of logarithmic returns did not exceed 2 percent) was much closer to the historical average than to the three previous oil price crashes.

To confirm these observations and also identify drivers of volatility, we estimate the GARCH specification discussed earlier. Tables 2 and 3 report results. The specification is applied to 7 samples: 1985-2015 (full sample), 1985-2003 (the pre-boom period), 2004-15 (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, the half-lives are larger (greater than 12 days) for the crashes

[3] We also 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 comparable period.

involving a loss in price support from OPEC (1985/86 and 2014/15) compared to the crashes engendered by the first Gulf War and financial crisis (2 days for each).

Second, positive equity market shocks during the three previous crashes were associated with greater volatility. 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 neither positive nor negative equity shocks.

Third, although the appreciation of the U.S. dollar was associated with greater volatility during the 1991/92 and 2014/15 crashes—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 only a 12.1 percent increase during the first Gulf War crash.

For robustness, we report volatility estimates for each crash period using three sample windows—the full sample, the relevant pre- and post-2004 period, and the 250-day window ending with each crash (Table 3).[4] The conditional variance for the latest crash ranges from 4.3 to 6.1 percent while estimates of the conditional variance of the earlier crashes are about four time as high (ranging from 15.2 to 24.9 percent).

4. 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 both the 2008/09 and 2014/15 crashes reflect structural changes in commodity markets that have engendered greater price volatility. However, oil price volatility during the 1985-2003 period was nearly identical to that of the 2004-15 period (Table 1). We show that the 2008/09 and 2014/15 price crashes differ on two dimensions. First, oil prices declined in a relatively measured manner in 2014, with the dispersion of price changes that was considerably smaller than earlier declines.[5] Second, the U.S. dollar appreciation exerted a strong influence on volatility during the recent crash, while the impact of shocks to equity markets were muted.

[4] Mean volatility (estimated using the GARCH specification) for each crash period is similar for sample windows of different sizes.

[5] 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
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
25^{th} percentile	-1.12	-1.07	-1.19	-3.84	-3.32	-4.54	-2.21
75^{th} 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 when coalition forces invaded Iraq. "Fraction of stable days" denotes the number of days with absolute daily oil price changes not exceeding 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*

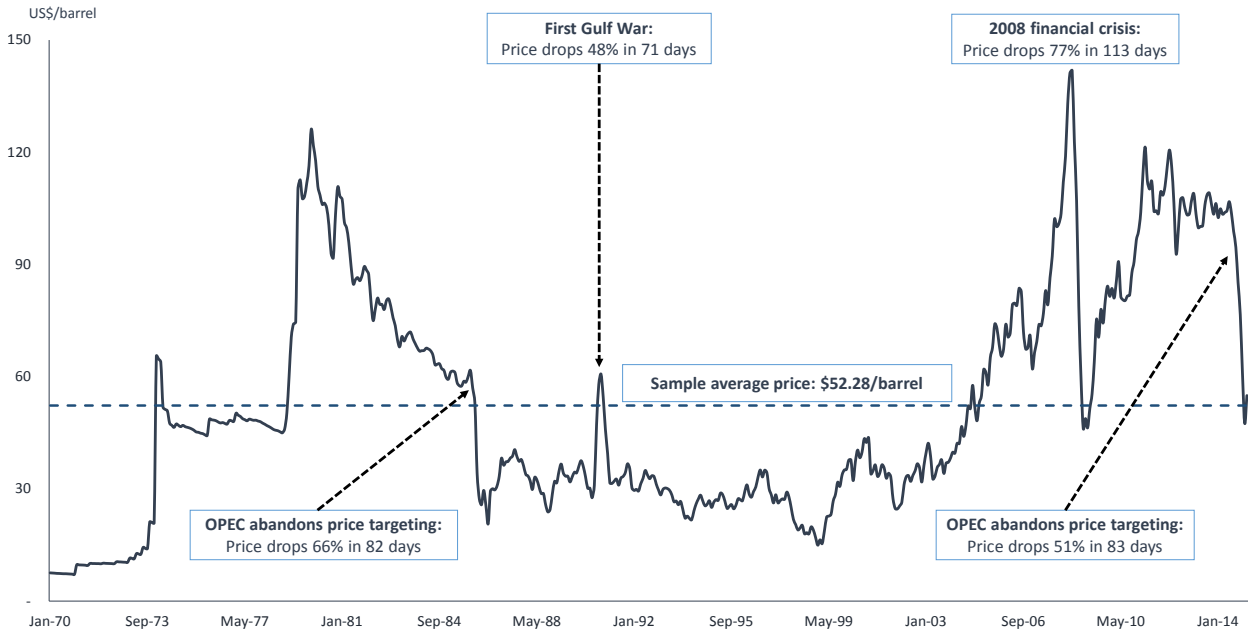
Notes: One (*), two (**), and three (***) asterisks denote parameter estimate significant at the 10, 5, and 1, percent levels.

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	—	—	—	—

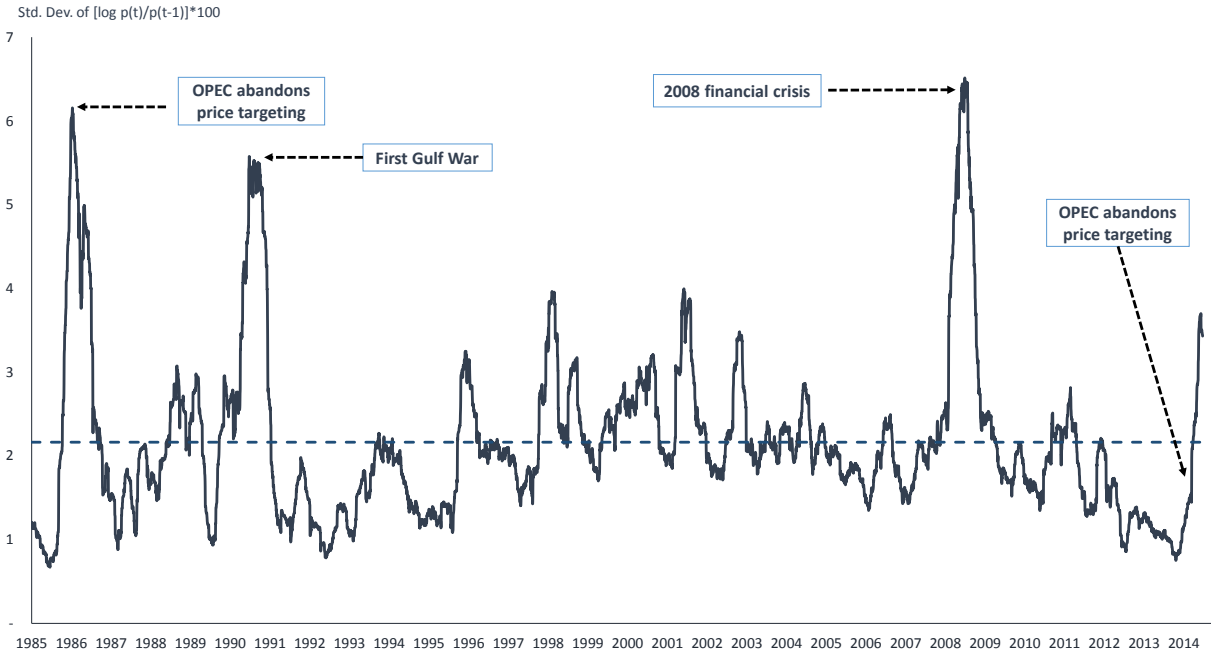
Notes: Row 1 reports the square of the standard deviation, shown in the second panel of table 1. A cell is assigned "—"when the driver is not statistically significant at a 5% level.

Figure 1
Oil Prices (WTI), Deflated by the U.S. CPI, 1970-2015



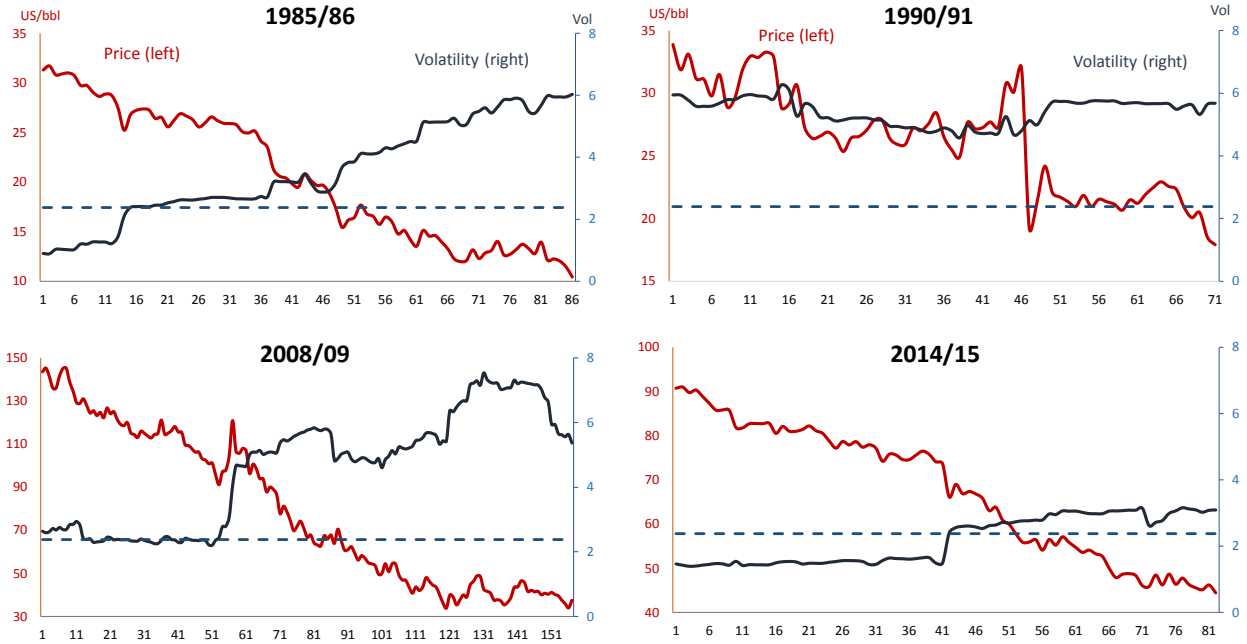
Source: World Bank
Note: Last observation is February 2015. Oil prices, which refer to WTI have been deflated by the U.S. CPI (2014 terms)

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
Volatility during the Largest Oil Price Crashes



Notes: Volatility is the standard deviation of WTI changes, presented as a 30-day trailing window. The numbers on the horizontal axis denote days after the crash began.

References

Arezki, R. and O. Blanchard (2014). "Seven questions about the recent oil price slump." *IMF Blog*, December 22. International Monetary Fund, Washington, D.C.

Baffes, J., M.A. Kose, F. Ohnsorge, and M. Stocker (2015). *The great plunge in oil prices: Causes, consequences, and policy responses*, Policy Research Note 15/01. The World Bank. Washington, D.C.

Baumeister, C. and L. Kilian (2015). "Understanding the decline in the oil price since June 2014." Center for Financial Studies, Working Paper No. 501, Frankfurt.

Bollerslev, T. (1986). "Generalized autoregressive conditional heteroskedasticity." *Journal of Econometrics*, 31, 307-327.

Dobbs, R., J. Oppenheim, and F. Thompson (2011). "A New Era for Commodities". *McKinsey Quarterly*, November 2011.

Engle, R.F. and A.J. Patton (2001). "What good is a volatility model?" *Quantitative Finance*, 1, 237-245.

Hansen, P.R. and A. Lunde (2005). "A forecast comparison of volatility models: Does anything beat a GARCH (1, 1)?" *Journal of Applied Econometrics*, 20, 873-889.

McNally, R. and M. Levi (2011). "A Crude Predicament." *Foreign Affairs*, July/August 2011.

Tsay, R. (2010). *Analysis of financial time series*. Vol. 543. John Wiley & Sons.