U.S. Oil Impacts:

The Impacts of Horizontal Multi-stage Hydraulic Fracturing Technologies on Historical Oil Production, International Oil Costs, and Consumer Petroleum Product Costs

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Presented by:

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Fairfax, VA

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Introduction

- Horizontal multi-stage hydraulic fracturing (HMSHF) technologies, also known as “fracking,” have enabled North American oil and gas producers unprecedented access to a previously inaccessible resource base.
- This newfound oil and gas supply has fundamentally altered the North American flow of oil and gas.
- The American Petroleum Institute (API) engaged ICF to assess the impacts of HMSHF technologies on U.S. oil production, international oil costs, and U.S. petroleum product consumer costs.

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Key Findings

- U.S. oil production from HMSHF increased from an estimated 0.75 million barrels per day (MMbpd) in 2008 to nearly 4.78 MMbpd by 2013.
- ICF estimates that international oil prices were between $12 and $40 per barrel lower in 2013 than they would have otherwise been without US HMSHF crude oil production. ICF estimates that international Brent crude oil prices would have averaged $122 to $150 per barrel in 2013 without U.S. HMSHF crude oil and condensate production increases.
- Given the international nature of U.S. petroleum product movements, ICF also estimates that 2013 U.S. petroleum product prices were between $0.29 and $0.94 per gallon lower than they would have otherwise been without U.S. HMSHF.
- This reduction in petroleum product prices have saved U.S. consumers an estimated $63 to $248 billion in 2013 and estimated cumulative savings of between $165 and $624 billion from 2008 to 2013.

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Impacts of U.S. Oil Production on Prices

	2008	2009	2010	2011	2012	2013
U.S. HMSHF Production Change (MMbpd)	↑ 0.75	↑ 0.88	↑ 1.18	↑ 1.96	↑ 3.33	↑ 4.78
Brent Price Change (2014$/bbl)	↓ $1.82-$5.43	↓ $1.35-$4.06	↓ $2.25-$6.79	↓ $5.13-$15.74	↓ $8.74-$27.6	↓ $12.08-$39.36
U.S. Consumer Petroleum Product Cost Change (2014$/gallon)	↓ $0.04-$0.13	↓ $0.03- $0.10	↓ $0.05-$0.16	↓ $0.12-$0.37	↓ $0.21-$0.66	↓ $0.29-$0.94

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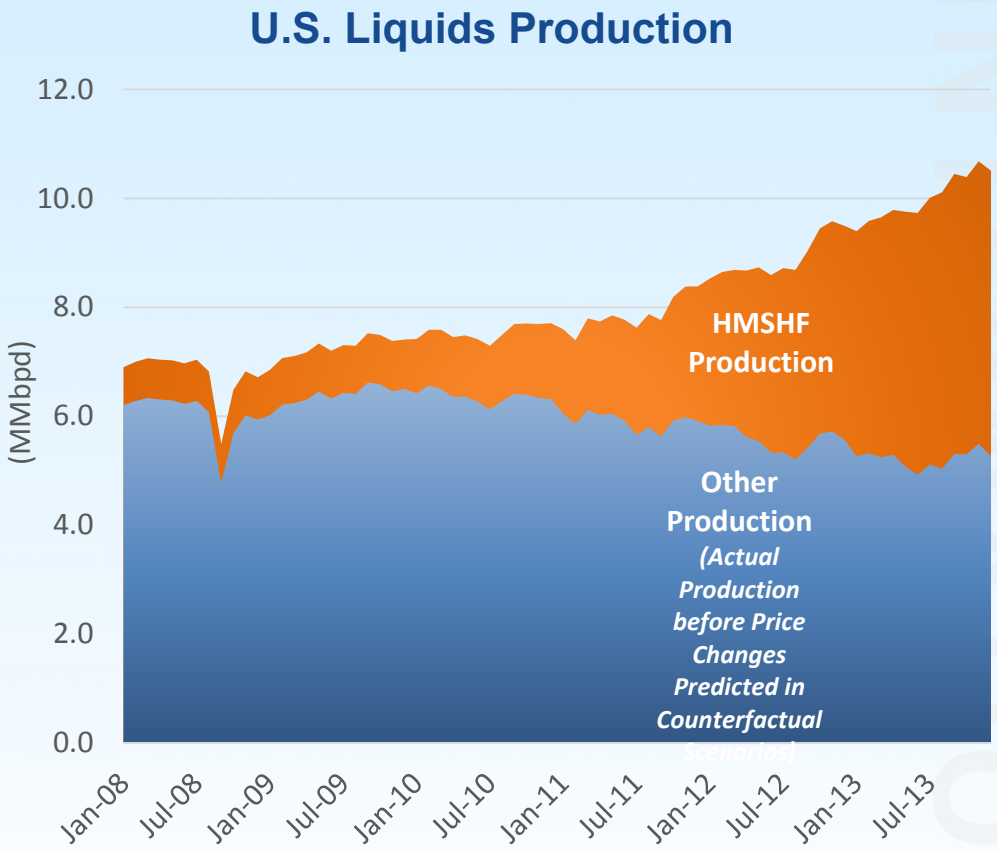
Methodology: U.S. Production Volume Changes



Sources: Total production – http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS2&f=M; HMSHF production – ICF assessment of play-level data from DrillingInfo's DI Desktop product, HDPI

U.S. production of horizontal multi-stage hydraulically fractured (HMSHF) wells comprised 11% of U.S. crude oil, condensate, and NGL production in 2008, rising to nearly 48% of total production by 2013.

Year	Annual HMSHF Crude, Condensate, and NGL Production (MMbpd)
2008	0.75
2009	0.88
2010	1.18
2011	1.96
2012	3.33
2013	4.78

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Methodology: Study Background

Study Objective: ICF assessed the impacts of HMSHF technologies on U.S. oil and NGL production and international oil costs through comparing actual historical energy market data to *counterfactual* data, which removed U.S. HMSHF subject wells, and assessed the impact on global oil supplies and oil supply costs.

Study Period: 2008 – 2013.

Production Volumes: U.S. crude oil, lease condensate, and natural gas liquids (NGLs).

International Prices: The Brent price was used as the benchmark for changes in international oil prices.

U.S. Consumer Petroleum Product Cost Changes: U.S. petroleum products are highly correlated with Brent prices. Thus, changes in Brent price and U.S. oil consumption were used to calculate consumer Petroleum Product cost changes.

Cases: ICF compared actual historical data (i.e., Actual Case) to a Counterfactual Case in which U.S. production of HMSHF-related liquids did not occur.

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Methodology: Identification of Horizontal Multi-Stage Hydraulically Fractured (HMSHF) Well Production

- HMSHF wells includes crude, condensate, and NGLs.
- ICF evaluated play-level oil and gas production through 2013 using the HPDI commercial well-level database.
- Plays are identified by area and formation names.
- Horizontal wells are coded as horizontal in the database.
- The total volume of annual oil and gas production from horizontal wells in a play is determined.
- For the current study, all production from identified horizontal oil and gas wells starting in 2000 was used for the impact analysis.

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Methodology: Plays and Years of Significant Activity

	Period of Activity		Period of Activity
Appalachia		Rockies	
Appalachian Marcellus	2008-13	Denver Niobrara	2010-13
Appalachian Utica	2011-13	Denver Wattenberg	2010-13
		Green River Niobrara	2012-13
Gulf Coast		Piceance Niobrara	2010-13
Haynesville	2008-13	Paradox Cane Creek	2012-13
Cotton Valley	2005-13	Paradox Gothic	2009-13
Fort Worth Barnett	2004-13	Powder River Niobrara	2011-13
Gulf Coast Eagle Ford	2008-13		
Gulf Coast Pearsall	2010-13	Permian	
		Permian Avalon-Bone Sp	2009-13
Midcontinent		Permian Basin Wolfberry	2010-13
Arkoma Fayetteville	2005-13	Permian Basin Cline	2010-13
Arkoma Moorefield	2006-13	West Texas Barnett	2008-13
Anadarko Cleveland	2007-13	West Texas Woodford	2010-13
Anadarko Granite Wash	2005-13		
Anadarko Woodford	2005-13	Williston	
Arkoma Caney	2008-13	Williston Bakken	2004-13
Arkoma Woodford			

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Methodology: Study Approach

Three approaches to assessing potential impacts of HMSHF technologies on U.S. oil and NGL production and international oil costs:

- Method 1: Long-run supply and demand equilibration model, based on long-run supply and demand elasticities.
- Method 2: Short-run static regression model where the average monthly Brent spot price is regressed on a number of independent variables.
- Method 3: Short-run simultaneous supply-demand regression model estimating the impact that price and other selected independent variables have on world oil supply and demand levels.

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Methodology: Method 1 Approach (Long-run Elasticities)

Method 1: Long-run supply and demand elasticities

- Long-run demand and supply elasticities were derived from the EIA's 2013 Annual Energy Outlook (AEO), which were used in previous API studies (including the Crude Oil Export Study).
- Model determined how world markets would equilibrate if the U.S. produced less crude oil, condensate, and NGLs between 2008 and 2013.
- Global markets equilibrated based on long-run demand and supply elasticities.
- The markets equilibrated by both producing more oil elsewhere (such as in Saudi Arabia) and consuming less oil (through oil price increases).
- The use of long-run elasticities may understate the price impacts, given the relatively rapid increase in U.S. production volumes.

Long-run Demand Elasticity	**-0.227**
Long-run Supply Elasticity	**0.281**

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Methodology: Method 2 Approach (Short-Run Price Model)

- Whereas Method 1 took a long-run view of oil supply and demand dynamics, Method 2 assessed changes in the context of short-run market changes.
- The price model is a static regression model where the average monthly oil spot price is regressed on a number of independent variables.
- The initial list of variables that were considered to be used in the price model were based on our review of previous academic and bank research papers.
- From that list, we selected a subset of variables that provide best fit for the price model. The selection process was based on the results of a stepwise regression which through statistical tests, identifies variables that provide best model fit.
- The stepwise regression process identified world exports, total inventory levels, real GDP, US/EUR exchange rate, U.S. production levels, and change in world inventory levels as independent variables that best explain price.

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Methodology: Method 3 Approach (Short-run Supply-Demand Model)

- The supply-demand regression model estimates the impact that price, and other selected independent variables, have on world oil demand and supply levels.
- ICF uses a variation of Three-Stage Least Squares (3SLS) model where the supply and demand equations are simultaneously estimated.
  - The 3SLS approach is necessary because a price variable, which appears on the right-hand side of the regression equations, is jointly determined with the left-hand side quantity variable.
  - The standard treatment to address this bias is to add instrumental variables that can hold supply and demand curves constant.
- Independent variables included in the model were identified with a combination of results from stepwise regression and review of existing literature.

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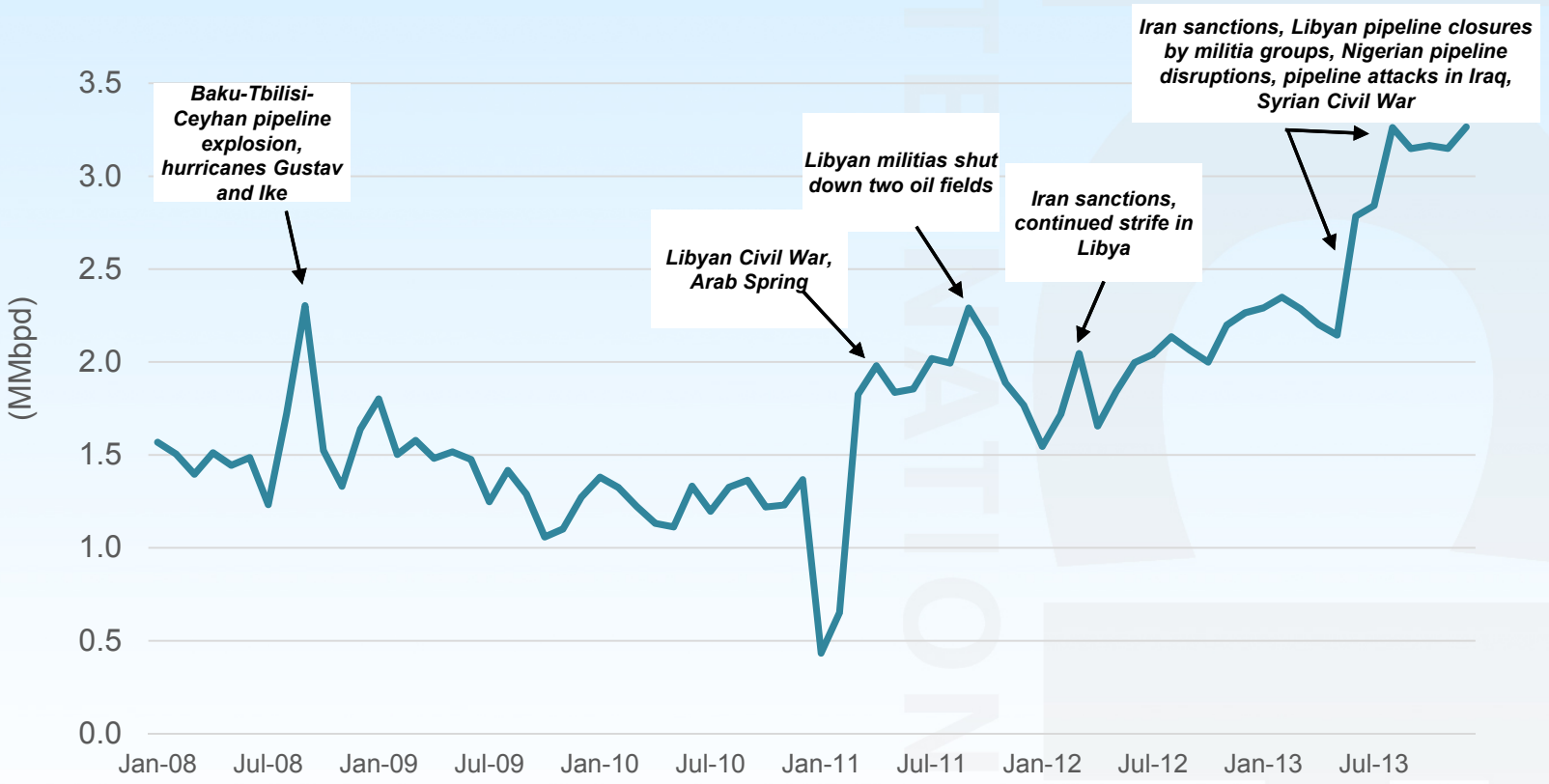
Methodology: Method 3 Approach (Short-run Supply Disruptions)

Estimated Global Oil Supply Disruptions



Source: 2011-2013 supply outages: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5&pid=53&aid=1&cid=regions&syid=2008&eyid=2013&unit=TBPD; estimated supply outages/unused capacity and estimated supply outages based on ICF analysis

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Method 1 Results

Method 1 Key Results

Economic Changes	2008	2009	2010	2011	2012	2013
Supply* Changes (MMbpd)						
Actual World Supply	85.72	84.95	87.52	87.83	89.69	90.03
Counterfactual World Supply	85.39	84.56	87.00	86.96	88.22	87.91
World Supply Delta	**(0.33)**	**(0.39)**	**(0.53)**	**(0.88)**	**(1.47)**	**(2.11)**
Actual U.S. Supply	8.56	9.13	9.68	10.14	11.11	12.30
Counterfactual U.S. Supply	7.86	8.31	8.58	8.30	8.01	7.89
U.S. Supply Delta	**(0.71)**	**(0.83)**	**(1.11)**	**(1.83)**	**(3.10)**	**(4.42)**
Consumption Changes (MMbpd)**						
Actual World Consumption	84.70	84.92	87.53	88.49	89.16	90.33
Counterfactual World Consumption	84.36	84.53	87.00	87.62	87.69	88.21
World Consumption Delta	**(0.33)**	**(0.39)**	**(0.53)**	**(0.88)**	**(1.47)**	**(2.11)**
Brent Price Changes (2014$/bbl)						
Actual Brent Price FOB	$104.17	$65.81	$83.86	$114.93	$115.31	$110.21
Counterfactual Brent Price FOB	$105.99	$67.17	$86.11	$120.06	$124.05	$122.30
Brent Price Delta	**$1.82**	**$1.35**	**$2.25**	**$5.13**	**$8.74**	**$12.08**
U.S. Consumer Petroleum Product Cost Changes ($2014b)						
Estimated U.S. Cost Changes	**$9.97**	**$7.15**	**$12.15**	**$27.20**	**$45.21**	**$63.58**
U.S. Consumer Petroleum Product Cost Changes ($2014/gallon)						
Estimated U.S. Cost Changes	**$0.04**	**$0.03**	**$0.05**	**$0.12**	**$0.21**	**$0.29**

* Includes crude oil, condensate, and natural gas liquids (NGLs).

** Includes internal consumption, refinery Petroleum Product and loss, and bunkering. Also included, where available, is direct combustion of crude oil.

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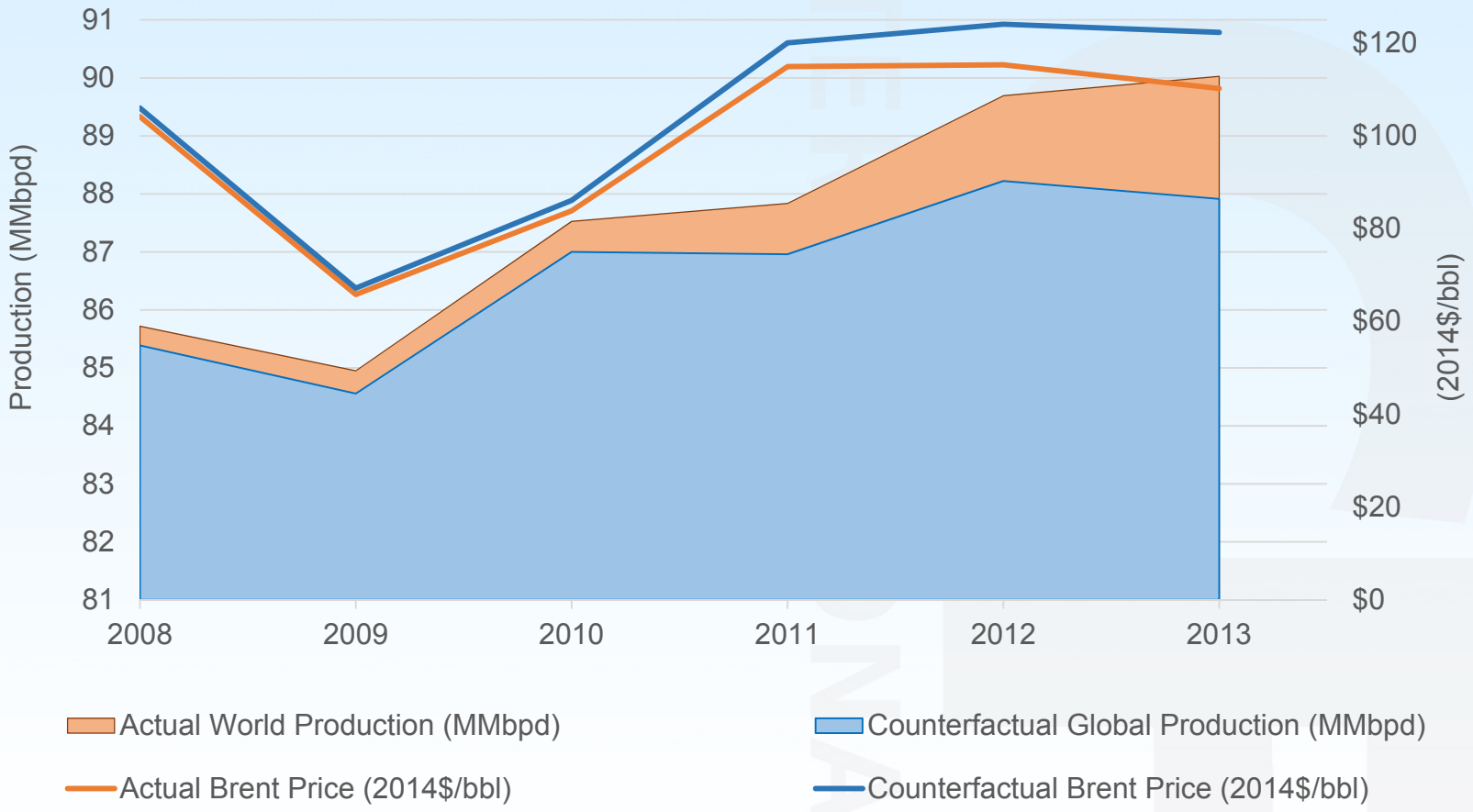
Method 1 Results

Actual versus Counterfactual Production and Price Impacts



Sources: 2008-2013 actual world production and Brent prices: EIA; 2008-2013 counterfactual assessments: ICF

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Method 2 Price Model Results

Actual versus Counterfactual Production and Price Impacts

Economic Changes	2008	2009	2010	2011	2012	2013
U.S. Crude and Condensate Production Changes (MMbpd)						
Actual Production	5.01	5.35	5.47	5.65	6.51	7.45
Counterfactual Production	4.54	4.80	4.73	4.33	4.03	3.75
Production Delta	**(0.48)**	**(0.55)**	**(0.74)**	**(1.32)**	**(2.48)**	**(3.70)**
Brent Price Changes (2014$/bbl)						
Actual Brent Price FOB	$105.63	$66.52	$84.97	$116.51	$114.88	$110.12
Counterfactual Brent Price FOB	$108.16	$69.43	$88.91	$123.50	$128.03	$129.72
Brent Price Delta	**$2.53**	**$2.91**	**$3.94**	**$6.98**	**$13.15**	**$19.60**
U.S. Consumer Petroleum Product Cost Changes						
Actual U.S. Crude Oil Consumption (MMbpd)	19.50	18.77	19.18	18.88	18.49	18.89
Estimated Cost Changes ($2014b)*	**$17.97**	**$19.91**	**$27.57**	**$48.13**	**$88.76**	**$135.10**
U.S. Consumer Petroleum Product Cost Changes ($2014/gallon)						
Estimated Cost Changes*	**$0.06**	**$0.07**	**$0.09**	**$0.17**	**$0.31**	**$0.47**

* Assumes static U.S. crude oil consumption

Note: Price impact differences based on crude oil and condensate production changes only, a statistically significant factor in the regression model. These volumes exclude NGLs.

Sources: 2008-2013 actual Brent prices, U.S. crude/condensate production, and U.S. crude oil consumption: EIA; 2008-2013 counterfactual assessments: ICF

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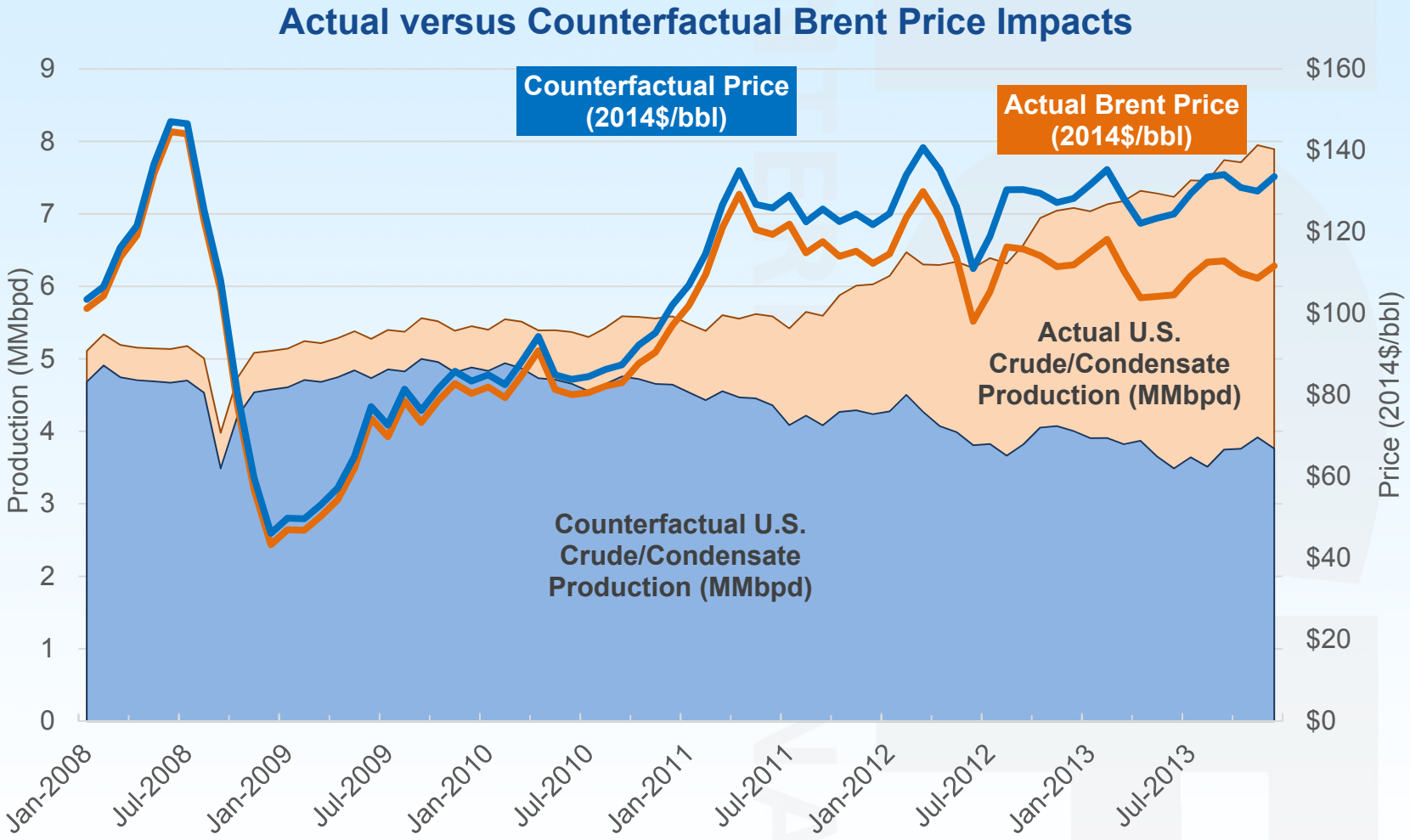
Method 2 Price Model Results



Sources: 2008-2013 actual Brent prices: EIA; 2008-2013 counterfactual assessments: ICF

Note: Price impact differences based on crude oil and condensate production changes only, a statistically significant factor in the regression model.

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Method 2 Results

Considered Variables

- ICF assessed over 20 variables to assess impacts on global oil prices, which were used in both Method 2 and Method 3.

Variable No.	Considered Model Variables	N	Mean	Std Dev	Source
1	1st 12-month Price Moving Average ($/bbl)	157	71.4	30.2	ICF
2	2nd 12-month Price Moving Average ($/bbl)	145	68.1	29.0	ICF
3	Brent 1st Month Future Price ($/bbl)	168	71.8	32.6	Bloomberg
4	Brent 4th Month Future Price ($/bbl)	168	71.9	32.7	Bloomberg
5	Change in Inventory (MMbbl)	167	9.3	21.9	EIA
6	Days of Inventory (Days)	168	75.0	2.3	ICF
7	Difference b/w 4th and 1st Month Out Future Price ($/bbl)	168	0.0	2.0	ICF
8	Europe Real Brent Spot Price ($/bbl)	168	71.5	32.5	EIA
9	Real GDP Level (B$)	168	46544	4679	OECD
10	Saudi Spare Capacity (MMbpd)	132	1.9	0.9	ICF
11	Total Inventory (MMbbl)	168	6303	465	OPEC
12	Total World Production (MMbpd)	168	83.9	4.3	EIA
13	Unplanned Production Disruptions (MMbpd)	168	2	1	EIA
14	US HF Liquids (MMbpd)	72	2.1	1.5	EIA
15	US/EUR Exchange Rate (US$/EUR Ratio)	168	1.2	0.2	EIA
16	US Total Production (MMbpd)	168	5.7	0.7	U.S. FED
17	World Capacity (MMbpd)	168	84.1	4.2	EIA
18	World Demand (MMbpd)	156	80.3	4.1	OPEC
19	World Rig Count (Number of Rigs)	168	2748	602	BAKER HUGHES INCORPORATED
20	World Trade Exports Values in (B$)	108	1338	488	WTO
21	Yield on 3-Yr US Treasury (%)	168	2.7	1.8	U.S. FED

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Method 2 Price Model Results

- The price regression model estimates that a one-million barrel per day increase in U.S. crude and condensate production levels would drop the world's crude oil price by $5.30 per barrel in real 2014 dollars.
- In 2013, the average monthly incremental U.S. crude and condensate HMSHF production reached 3.7 million barrels per day. This incremental production level translates to a $19.60 per barrel (real 2014 dollars) decline in the world crude price.

Price Model:Base

The REG Procedure
Model: MODEL1
Dependent Variable: Real_P Europe Real Brent Spot Price ($/bbl)

Number of Observations Read	168
Number of Observations Used	108
Number of Observations with Missing Values	60

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	50168	8361.32420	79.03	<.0001
Error	101	10685	105.79501		
Corrected Total	107	60853			

Root MSE	10.28567	R-Square	0.8244
Dependent Mean	90.82678	Adj R-Sq	0.8140
Coeff Var	11.32449		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	-242.65509	44.60413	-5.44	<.0001
exports2	World Trade Exports Values in (B$)	1	0.00953	0.00251	3.79	0.0003
Total_I	Total Inventory (MMbbl)	1	-0.05866	0.00968	-6.06	<.0001
GDP	Real GDP Level (B$)	1	0.01279	0.00094236	13.58	<.0001
xchng	US/EUR Exchange Rate Ratio	1	77.06233	13.04820	5.91	<.0001
usprod	U.S. Production Levels (MMbpd)	1	-5.29657	2.27908	-2.32	0.0221
chng_inv	Change in Inventory (MMbbl)	1	0.11773	0.05241	2.25	0.0269

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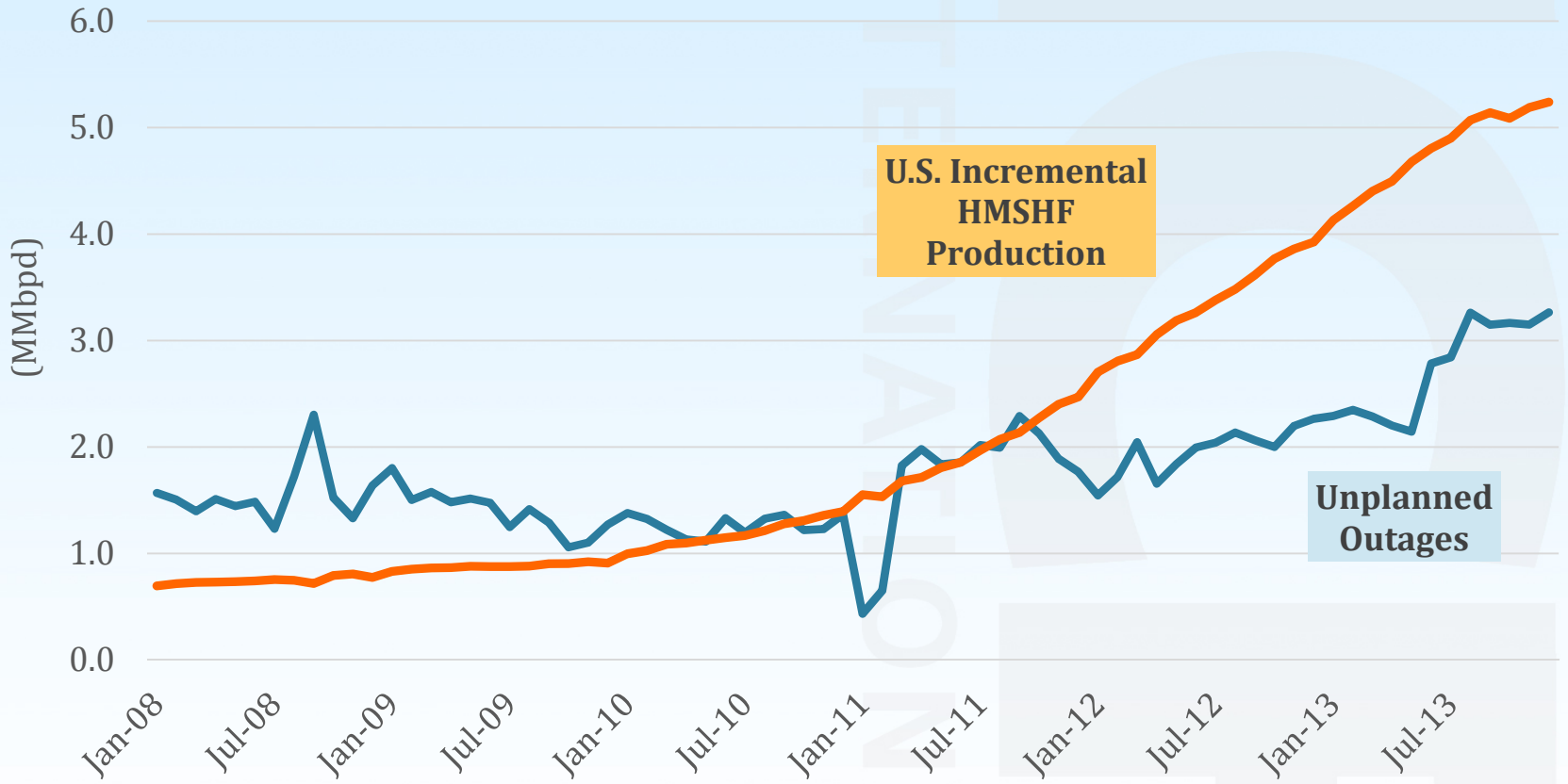
Method 3 Data

Global Unplanned Outages *(ICF estimates 2008-2010, EIA estimates 2011-2013)* and U.S. HMSHF Production



Source: 2011-2013 unplanned outages: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5&pid=53&aid=1&cid=regions&syid=2008&eyid=2013&unit=TBPD; 2008-2010 unplanned outages: estimated supply outages/unused capacity and estimated supply outages based on ICF analysis; U.S. incremental HMSHF production: ICF assessment of play-level data from DrillingInfo's DI Desktop product, HDPI

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Method 3 Supply-Demand Model Elasticity Estimates

- Since the supply-demand regression model is estimated in log format, the model estimates are interpreted as supply and demand elasticities.
- The cumulative short-run supply price elasticity is estimated at 0.1 (= 0.05 + 0.05). This means that a 1% increase in current and historical price would increase world production by 0.1%.
- The cumulative short-run demand price elasticity is estimated at -0.078 (= -0.015 + -0.063). This means that a 1% increase in historical price would decrease world production by 0.078%.

Model	SUPPLY
Dependent Variable	lprod
Label	Log of Production in (MMbpd)

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variable Label
Intercept	1	3.896622	0.020966	185.85	<.0001	Intercept
lprice	1	0.052992	0.007319	7.24	<.0001	Log of Brent Real Price($/bbl)
lprice12	1	0.050544	0.007458	6.78	<.0001	Log of Price MovAvg 1-12 Month Lag
lusprod	1	0.070324	0.012197	5.77	<.0001	Log of US production
ldisrupt	1	-0.02986	0.004757	-6.28	<.0001	Log of ICF Est. Unplanned Prod Disruptions
yr05	1	0.019342	0.004209	4.60	<.0001	Calendar Dummy Variable for Year 2005
yr08	1	-0.02097	0.004773	-4.39	<.0001	Calendar Dummy Variable for Year 2008
yr09	1	-0.00873	0.004254	-2.05	0.0421	Calendar Dummy Variable for Year 2009
yr11	1	-0.01249	0.004375	-2.85	0.0050	Calendar Dummy Variable for Year 2011

Model	DEMAND
Dependent Variable	lprod
Label	Log of Production in (MMbpd)

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variable Label
Intercept	1	-4.82481	0.504396	-9.57	<.0001	Intercept
lprice12	1	-0.01547	0.007158	-2.16	0.0324	Log of Price MovAvg 1-12 Month Lag
lprice24	1	-0.06364	0.006876	-9.26	<.0001	Log of Price MovAvg 13-24 Month Lag
lgdp	1	0.890985	0.050617	17.60	<.0001	Log of Real GDP (B$)
yr07	1	-0.01634	0.003354	-4.87	<.0001	Calendar Dummy Variable for Year 2007
yr09	1	0.021486	0.004624	4.65	<.0001	Calendar Dummy Variable for Year 2009
yr11	1	-0.01811	0.003551	-5.10	<.0001	Calendar Dummy Variable for Year 2011

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Method 3 Results

Method 3 Key Results

Economic Changes	2008	2009	2010	2011	2012	2013
Supply* Changes (MMbpd)						
Actual World Supply	85.72	84.95	87.52	87.83	89.69	90.03
Counterfactual World Supply	85.40	84.57	87.02	86.99	88.27	87.98
World Supply Delta	**(0.32)**	**(0.38)**	**(0.51)**	**(0.85)**	**(1.42)**	**(2.05)**
Actual U.S. Supply	8.56	9.13	9.68	10.14	11.11	12.30
Counterfactual U.S. Supply	7.86	8.31	8.58	8.30	8.02	7.90
U.S. Supply Delta	**(0.71)**	**(0.83)**	**(1.11)**	**(1.83)**	**(3.09)**	**(4.41)**
Consumption Changes (MMbpd)**						
Actual World Consumption	84.70	84.92	87.53	88.49	89.16	90.33
Counterfactual World Consumption	84.37	84.54	87.02	87.64	87.74	88.28
World Consumption Delta	**(0.32)**	**(0.38)**	**(0.51)**	**(0.85)**	**(1.42)**	**(2.05)**
Brent Price Changes (2014$/bbl)						
Actual Brent Price FOB	$104.17	$65.81	$83.86	$114.93	$115.31	$110.21
Counterfactual Brent Price FOB	$109.60	$69.87	$90.65	$130.67	$142.91	$149.57
Brent Price Delta	**$5.43**	**$4.06**	**$6.79**	**$15.74**	**$27.60**	**$39.36**
U.S. Consumer Petroleum Product Cost Changes ($2014b)						
Estimated Cost Changes	**$35.67**	**$25.67**	**$43.84**	**$99.87**	**$170.89**	**$247.99**
U.S. Consumer Petroleum Product Cost Changes ($2014/gallon)						
Estimated Cost Changes*	**$0.13**	**$0.10**	**$0.16**	**$0.37**	**$0.66**	**$0.94**

* Includes crude oil, condensate, and natural gas liquids (NGLs).

** Includes internal consumption, refinery Petroleum Product and loss, and bunkering. Also included, where available, is direct combustion of crude oil.

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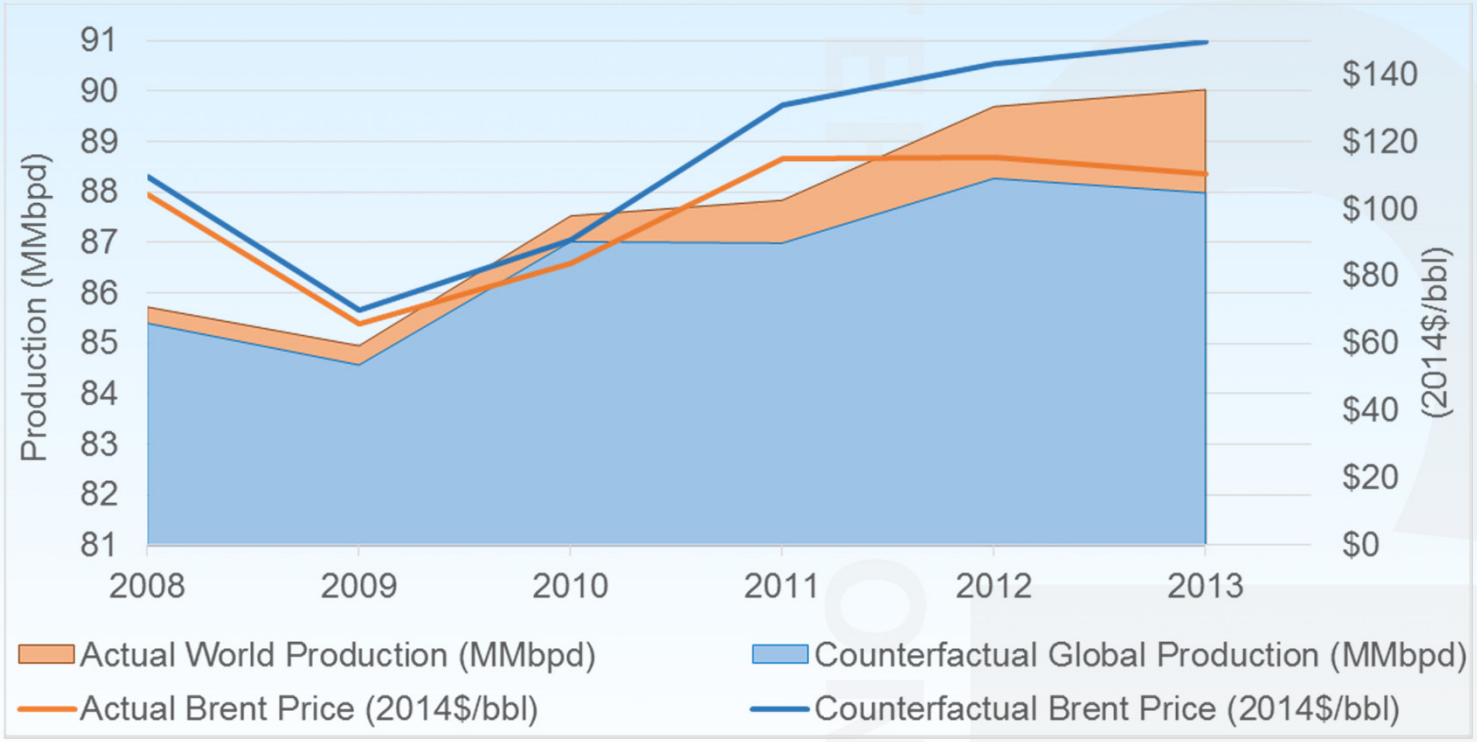
Method 3 Results

Actual versus Counterfactual Production and Price Impacts



Sources: 2008-2013 actual world production and Brent prices: EIA; 2008-2013 counterfactual assessments: ICF

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Conclusion

- U.S. HMSHF production grew from 0.75 MMbpd in 2008 to 4.78 MMbpd in 2013, comprising nearly 48% of total U.S. crude oil, condensate, and NGL production by 2013.
- U.S. HMSHF production has led to positive economic impacts to the U.S. economy, as well as lower international oil prices than otherwise would have been without U.S. HMSHF crude oil, condensate, and NGL production increases.
- U.S. HMSHF production volumes increased global supplies, allowing global markets to equilibrate at lower prices and with more cushion in addressing supply disruptions.

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Conclusion

Key Results

Economic Changes	2008	2009	2010	2011	2012	2013
Supply* Changes (MMbpd)						
U.S. HMSHF Production	0.75	0.88	1.18	1.96	3.33	4.78
Method 1 World Supply Delta	(0.33)	(0.39)	(0.53)	(0.88)	(1.47)	(2.11)
Method 2 World Supply Delta	N/A	N/A	N/A	N/A	N/A	N/A
Method 3 World Supply Delta	(0.32)	(0.38)	(0.51)	(0.85)	(1.42)	(2.05)
Consumption Changes (MMbpd)**						
Method 1 World Consumption Delta	(0.33)	(0.39)	(0.53)	(0.88)	(1.47)	(2.11)
Method 2 World Consumption Delta	N/A	N/A	N/A	N/A	N/A	N/A
Method 3 World Consumption Delta	(0.32)	(0.38)	(0.51)	(0.85)	(1.42)	(2.05)

* Includes crude oil, condensate, and natural gas liquids (NGLs).

** Includes internal consumption, refinery Petroleum Product and loss, and bunkering. Also included, where available, is direct combustion of crude oil.

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Conclusion

Key Results (Cont.)

Economic Changes	2008	2009	2010	2011	2012	2013
Brent Price Changes (2014$/bbl)						
Method 1 World Price Delta	$1.82	$1.35	$2.25	$5.13	$8.74	$12.08
Method 2 World Price Delta†	$2.53	$2.91	$3.94	$6.98	$13.15	$19.60
Method 3 World Price Delta	$5.43	$4.06	$6.79	$15.74	$27.60	$39.36
U.S. Consumer Petroleum Product Cost Changes ($2014b)						
Method 1 U.S. Cost Delta	$9.97	$7.15	$12.15	$27.20	$45.21	$63.58
Method 2 U.S. Cost Delta††	$17.97	$19.91	$27.57	$48.13	$88.76	$135.10
Method 3 U.S. Cost Delta	$35.67	$25.67	$43.84	$99.87	$170.89	$247.99
U.S. Consumer Petroleum Product Cost Changes ($2014/gallon)						
Method 1 U.S. Cost Delta	$0.04	$0.03	$0.05	$0.12	$0.21	$0.29
Method 2 U.S. Cost Delta††	$0.06	$0.07	$0.09	$0.17	$0.31	$0.47
Method 3 U.S. Cost Delta	$0.13	$0.10	$0.16	$0.37	$0.66	$0.94

† Prices changes associated with changes in U.S. crude oil and condensate production.

†† Assumes static U.S. crude oil consumption

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Bibliography

Brent futures price historical data, Distributed by Bloomberg Information Services. (Downloaded 2014)

Crude oil historical inventory data. Produced and Distributed by Energy Information Agency (EIA) (Downloaded 2014)

Brent market historical spot price data. Distributed by Energy Information Agency (EIA) (Downloaded 2014)

Historical Gross Domestic Product (GDP) of OECD and non-OECD counties data. Produced and Distributed by The Organization for Economic Co-operation and Development (OECD). (Downloaded 2014)

Historical world crude oil production levels data. Produced and Distributed by Energy Information Agency (EIA) (Downloaded 2014)

Historical unplanned crude oil production disruptions data. Produced and Distributed by Energy Information Agency (EIA) (Downloaded 2014)

Historical U.S. HF Liquids production data. Produced and Distributed by Energy Information Agency (EIA) (Downloaded 2014)

Historical U.S. to Euro exchange rate data. Federal Reserve Economic Data. Produced and Distributed by Federal Reserve Bank of St. Louis (Downloaded 2014)

Historical world rig count data. Produced and Distributed by Baker Hughes Incorporated (Downloaded 2014)

Historical world trade exports data. Produced and Distributed by World Trade Organization (WTO) (Downloaded 2014)

Historical yield on 3-yr U.S. treasuries data. Produced and Distributed by U.S. Department of Treasury (Downloaded 2014)

Historical Saudi spare capacity data. Produced and Distributed by Energy Information Agency (EIA) (Downloaded 2014)

Lin, Cynthia. "Estimating Annual and Monthly Supply and Demand for World Oil: A Dry Hole?" Department of Economics, Harvard University. March 29, 2004.

Dees Stephane, Gasteuil Audrey, Kaufmann Robert, and Mann Michael. "Assessing The Factors Behind Oil Price Changes" Working Paper Series No 855 / January 2008. European Central Bank.

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Appendices

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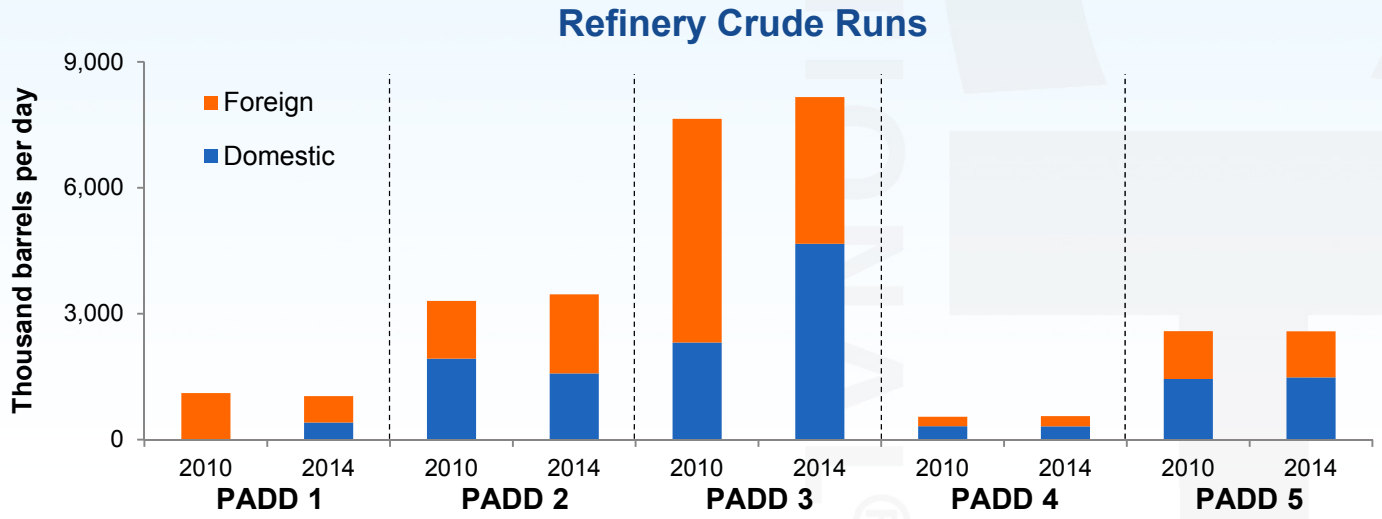
Appendices: Appendix 1 Refinery Crude Run Impact

(thousand bbl/d)	PADD 1		PADD 2		PADD 3		PADD 4		PADD 5		U.S.	
	2010	2014	2010	2014	2010	2014	2010	2014	2010	2014	2010	2014
Foreign imports	1,093	632	1,377	1,880	5,329	3,497	225	243	1,139	1,100	9,163	7,352
Canadian	203	271	1,199	1,839	144	166	225	243	192	217	1,963	2,735
Other	891	362	178	42	5,184	3,331	0	0	947	883	7,200	4,617
Foreign exports	6	26	33	79	3	152	0	0	0	0	42	258
Total crude runs	1,106	1,037	3,305	3,459	7,642	8,161	542	559	2,582	2,580	15,177	15,796
Domestic crude runs	13	405	1,928	1,578	2,313	4,665	317	316	1,443	1,480	6,015	8,445
Foreign crude runs	1,093	632	1,377	1,880	5,329	3,497	225	243	1,139	1,100	9,163	7,352
Percent domestic runs	1.2%	39.0%	58.3%	45.6%	30.3%	57.2%	58.5%	56.6%	55.9%	57.4%	39.6%	53.5%
Percent foreign runs	98.8%	61.0%	41.7%	54.4%	69.7%	42.8%	41.5%	43.4%	44.1%	42.6%	60.4%	46.5%
Canadian	18.3%	26.1%	36.3%	53.2%	1.9%	2.0%	41.5%	43.4%	7.4%	8.4%	12.9%	17.3%
Other	80.5%	34.9%	5.4%	1.2%	67.8%	40.8%	0.0%	0.0%	36.7%	34.2%	47.4%	29.2%

Source: EIA.
Note: 2014 data shown through May.
Domestic crude runs are total runs less foreign imports.



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Appendices: Appendix 1 Refinery Crude Run Impact (cont.)

Crude Runs

- U.S. refinery runs increased 4.1%, a combination of increased utilization (from increased domestic production) and increased refining capacity
- Domestic crude runs (total runs less foreign imports) increased over 40% and Canadian crude runs increased 34% while non-Canadian foreign crude runs fell by over 38%
- PADD 1 domestic crude runs increased dramatically with the addition of rail terminals at several of the region's major refineries (and regional distribution assets) to take advantage of discounted mid-continent crude, which displaced expensive foreign sourced crude, primarily from West Africa
- PADD 2 crude runs increased about 5%. Much higher Canadian imports (over 50% growth and 0.65 million bbl/d) displaced domestic crude as a number of refineries completed projects to increase runs of Canadian heavy grades (BP Whiting, Marathon Detroit and others). Canadian imports increased from about 35% of PADD 2 crude runs to over 50%.
- Domestic refinery runs doubled in PADD 3, with crude runs increasing by 2.35 million bbl/d, the most dramatic change in U.S. refinery crude supply
  - The continuing reversal and expansion of PADD 3 infrastructure to move crude to the Gulf Coast refining hub, and the continuing development of the Eagle Ford and Permian basins spurred this dramatic transformation
  - The increased supply into the Gulf Coast supplemented declining conventional domestic production and imports from traditional sources like Mexico, Venezuela, and Colombia which accounted for 0.62 million bbl/d of the 1.8 million bbl/d decrease in crude runs (34%)
- PADD 5 domestic refinery runs remained steady during the period as declines in California and North Slope crude production were offset by increased rail volumes of Bakken crude moving into the region

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Appendices: Appendix 1 Refinery Crude Run Impact (cont.)

Imports

- Non-Canadian U.S. crude imports fell nearly 36% (total imports fell nearly 20%)
- Canadian imports increased, primarily entering PADD 2 (83% of increased Canadian imports) as Western Canadian oil resources were further developed

Fracking Impact

- Production of shale oil from HF has enabled domestic crude runs to increase by about 2.4 million bbbl/d from 2010 to the first five months of 2014. An additional 0.22 million bbl/d of domestic crude has been exported.
- Foreign import reliance (non-Canadian) has decreased dramatically by 2.6 million barrels per day despite an increase in U.S. crude runs of about 0.6 million barrels per day. This is a huge swing in balance of payments for the U.S. economy – nominally $66 billion / year dollars reduced payments for imported crude (or $74 billion / year shift in total U.S. trade balance, including exports).
- In addition, the reduced dependence on foreign imports provides a reduced exposure to the threat of supply loss in the event of global disruptions. Moreover, there is potential to lower the volume of crude oil in the Strategic Petroleum Reserve (SPR) to achieve similar days of supply protection with reduced volumes in storage.

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Appendices: Appendix 2 Price Elasticity Description

Price Elasticity Definition: measures the relationship between a change in quantity of a good (i.e., oil) and the change in price (i.e., Brent price as the international benchmark, U.S. petroleum product price).

Price Elasticity of Demand (Ed):

$$\frac{\%\ \text{Change in Demand}}{\%\ \text{Change in Price}}$$

Demand Elasticity Example:

Ed = -1.5

"A 10% decrease in price leads to a 15% increase in demand."

Inelastic Demand:
Demand for products changes little with price changes (e.g., water)

Elastic Demand:
Demand for products changes significantly with price changes (e.g., consumer purchases)

Price Elasticity of Supply (Es):

$$\frac{\%\ \text{Change in Supply}}{\%\ \text{Change in Price}}$$

Supply Elasticity Example:

Es = 0.5

"A 10% increase in price leads to a 5% increase in supply."

Inelastic Supply:
Supply for products changes little with price changes (e.g., public roads)

Elastic Supply:
Supply for products changes significantly with price changes (e.g., commodities)

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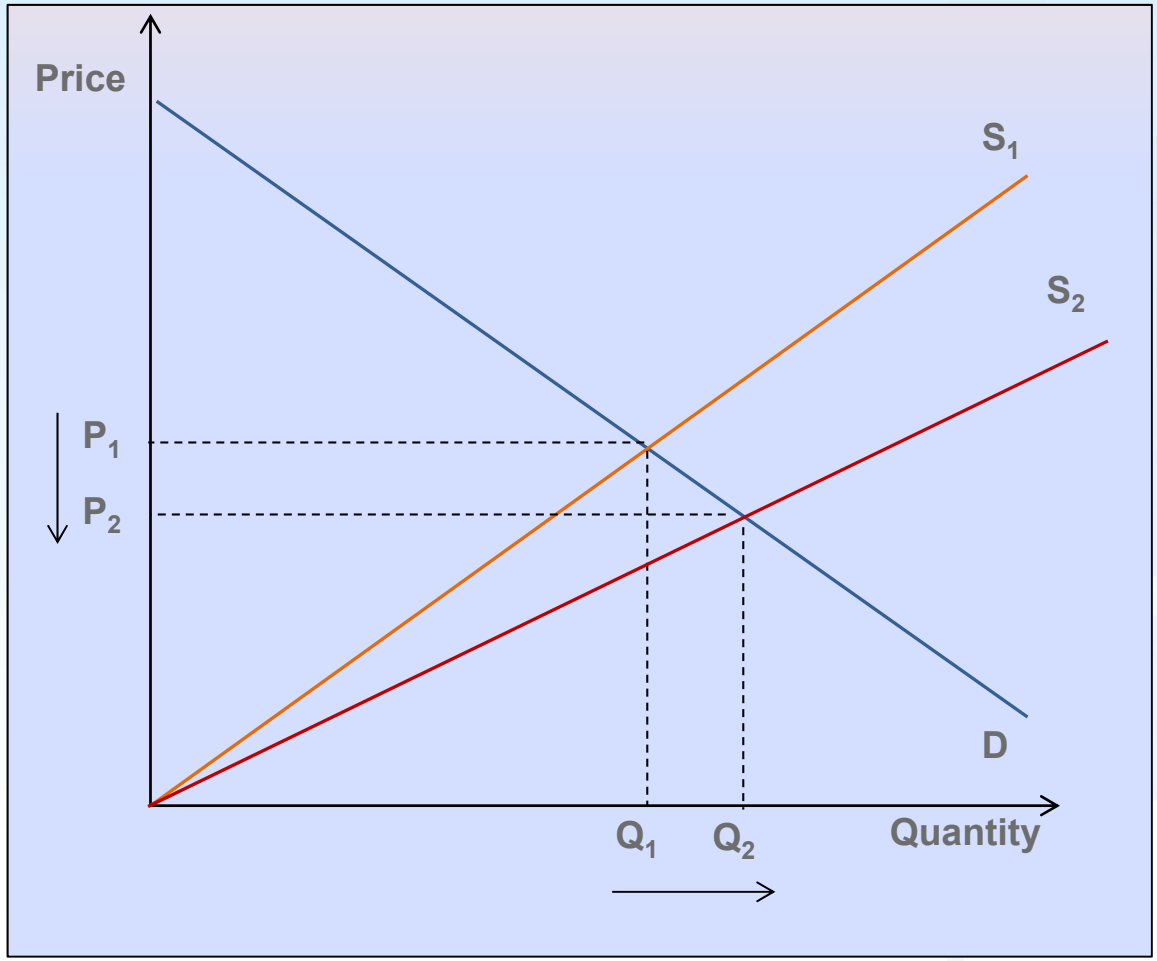
Appendices: Appendix 3 Market Equilibrium Description

Market Equilibrium



- An increase in oil supply (i.e., U.S. HMSHF oil production) shifts the supply curve outward, forcing demand and supply to find a new equilibrium point (larger quantity at a lower price)
- ICF assessed these impacts on a short-run and long-run view
- The short-run view means that prices are more sensitive to supply disruptions and other changes, while the long-run view assumes a more steady change, factoring in technology changes

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Regression Analysis

Regression Equation Definition: assesses the relationship between a dependent variable (i.e., oil prices) and one or more independent variables (e.g., oil production, oil storage, oil consumption).

This relationship is then used to predict changes to the dependent variable (i.e., oil prices) based on changes to an independent variable (e.g., U.S. oil production).

Simple Regression Equation Setup: $Y = a + b * X$

Where,

Y	=	Dependent Variable (i.e., oil price)
a	=	Constant Variable
b	=	Slope of X
X	=	Independent Variable

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Appendices: Appendix 5 Regression Model Data

Data

- Both the price and supply-demand models use the same monthly data set. The data covers a period between January of 2000 to December of 2013 or 168 monthly observations.
- The list of variables selected to be considered as a part of these two models were based on ICF review of previous academic papers and studies. In particular, we used European Central Bank's (ECB) "Assessing the Factors Behind Oil Price Changes" published in 2008, and an academic paper by Cynthia Lin from Department of Economics at Harvard University (DEHU) "Estimating Annual and Monthly Supply and Demand for World Oil: A Dry Hole?" published in 2004.

Considered Model Variables

- In the table below we provide an alphabetical list of variables we considered when specifying our price and supply-demand regression models. In total, we considered 17 unique variables as well a number of transformations of those unique variables when specifying our models.
- The key sources of data were EIA, OECD, U.S. Federal Bank, OPEC, WTO, and Baker Hughes Incorporated.

Variable No.	Considered Model Variables	N	Mean	Std Dev	Source
1	1st 12-month Price Moving Average ($/bbl)	157	71.4	30.2	ICF
2	2nd 12-month Price Moving Average ($/bbl)	145	68.1	29.0	ICF
3	Brent 1st Month Future Price ($/bbl)	168	71.8	32.6	Bloomberg
4	Brent 4th Month Future Price ($/bbl)	168	71.9	32.7	Bloomberg
5	Change in Inventory (MMbbl)	167	9.3	21.9	EIA
6	Days of Inventory (Days)	168	75.0	2.3	ICF
7	Difference b/w 4th and 1st Month Out Future Price ($/bbl)	168	0.0	2.0	ICF
8	Europe Real Brent Spot Price ($/bbl)	168	71.5	32.5	EIA
9	Real GDP Level (B$)	168	46544	4679	OECD
10	Saudi Spare Capacity (MMbpd)	132	1.9	0.9	ICF
11	Total Inventory (MMbbl)	168	6303	465	OPEC
12	Total World Production (MMbpd)	168	83.9	4.3	EIA
13	Unplanned Production Disruptions (MMbpd)	168	2	1	EIA
14	US HF Liquids (MMbpd)	72	2.1	1.5	EIA
15	US/EUR Exchange Rate (US$/EUR Ratio)	168	1.2	0.2	EIA
16	US Total Production (MMbpd)	168	5.7	0.7	U.S. FED
17	World Capacity (MMbpd)	168	84.1	4.2	EIA
18	World Demand (MMbpd)	156	80.3	4.1	OPEC
19	World Rig Count (Number of Rigs)	168	2748	602	BAKER HUGHES INCORPORATED
20	World Trade Exports Values in (B$)	108	1338	488	WTO
21	Yield on 3-Yr US Treasury (%)	168	2.7	1.8	U.S. FED

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Appendices: Appendix 6 Stepwise Regression

Variable Selection Process

- The initial set of variables considered for the model was based on ICF review of previous academic papers and studies.
- The follow on filter was based on results of stepwise regression, which identified the most statistically significant subset of the initial set of variables based on Wald Chi-Square statistic.
- ICF further refined the list of the stepwise regression results based on statistical significance of those variables in the specified price and supply-demand models.

Stepwise Selection Results

- For price model the stepwise regression identified exports, inventory levels, GDP, U.S. to Euro exchange rate, U.S. production levels, change in inventory levels, difference b/w 4th and 1st month out future price, yield on 3-year U.S. Treasuries.
- For supply-demand model the stepwise regression identified GDP, U.S. to Euro exchange rate, price, U.S. production levels, unplanned production disruptions, exports, and series of calendar variables.

Price Model	Score Chi-Square
World Trade Exports Values in (B$)	73.4
Total Inventory (MMbbl)	27.3
Real GDP Level (B$)	14.7
US/EUR Exchange Rate (US$/EUR Ratio)	22.9
US Total Production (MMbpd)	6.7
Change in Inventory (MMbbl)	6.5

Supply-Demand Model	Score Chi-Square
Real GDP Level (B$)	87.9
US/EUR Exchange Rate (US$/EUR Ratio)	7.6
US Total Production (MMbpd)	9.2
Unplanned Production Disruptions (MMbpd)	4.9
World Trade Exports Values in (B$)	10.4

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Appendices: Appendix 7 Price Models

Price Model Coefficient Stability

- In the below tables we show seven separate models that estimate the impact of U.S. production levels on world's spot crude prices.
- The models show statistically significant and consistently negative impact of U.S. production on world's spot crude prices varying between -3.02 to -5.29.

Price Model Specification

- The price series showed very strong signs of autocorrelation
- The price model needs to be differenced to address non stationary price series process.
- Addressing both of these issues does not alter the stability of US production coefficient estimates

The Impact of U.S. Total Production (MMbpd) on World Crude Spot Price ($/bbl)					
Model Sepcification	**Model No.**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Base: Price = Intercept + Exports + Inventory + GDP + Exchange Rate + US Production + Change in Inventory	1	-5.29	2.279	-2.32	0.0221
Base without Chng in Inventory: Price = Intercept + Exports + Inventory + GDP + Exchange Rate + US Production	2	-5.21	2.323	-2.24	0.0271
Base without Chng in Inventory and Exports: Price = Intercept + Inventory + GDP + Exchange Rate + US Production	3	-3.02	1.826	-1.66	0.0997
Base without Chng in Inventory and Exports and Exchange Rate: Price = Intercept + Inventory + GDP + US Production	4	-4.25	1.416	-3.00	0.0031
The Impact of Change in U.S. Total Production (MMbpd) on change in World Crude Spot Price ($/bbl)					
Model Sepcification	**Model No.**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Base: ΔPrice = Intercept + AR1 + Δ Saudi Spare Capacity + Δ Inventory + ΔUS Production + Calendar Year 2008	1	-5.02	2.563	-1.96	0.0524
Base - Spare Capacity: ΔPrice = Intercept + AR1 + Δ Inventory + ΔUS Production + Calendar Year 2008	2	-4.49	2.331	-1.93	0.0558
Base - Spare Capacity - Year 2008: ΔPrice = Intercept + AR1 + Δ Inventory + ΔUS Production	3	-4.42	2.333	-1.9	0.0597

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