Oil sector investments and market shocks

Candace L. Barr

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Abstract

Investment in the U.S. oil sector increased greatly in the last two decades. This paper explores the role of market shocks in determining this trend. I construct a structural vector autoregression model to estimate the effects of oil market and macroeconomic shocks on investment projects and expenditures. Regressing the residuals of the identified shocks on measures of oil sector investments, I find that projects vary considerably in their response to shocks, highlighting the importance of idiosyncratic costs and planning horizons. Oil demand shocks effect all investments whereas supply shocks affect drilling the most. I find evidence of irreversibility weakening the response to demand shocks and of the consequence of both market and macroeconomic uncertainty for investment expenditures and projects.

1 Introduction

What market conditions promote oil sector investment? Drivers of growth and productivity, oil sector investments are the bedrock of industry performance. The timing and triggers of investment projects, however, remain less certain. Coupled with longer construction horizons and profitability forecasts, market uncertainty magnifies the bet on the future intrinsic to such irreversible investments.

The objective of this research is to disentangle the contributions of market shocks that influence irreversible investments in the U.S. oil industry. Since the tumultuous 1970s, the U.S. oil industry has

undergone seasons with varying market conditions—from decreasing domestic supply and increasing domestic demand, to rapidly increasing domestic supply and strong global demand—with crude oil fetching every price point in between. The nature of the investment projects, however, remains consistent across the decades: large, capital-intensive, and irreversible.

Reconciling the fluctuations of oil markets and the long horizons of oil investments in a single framework remains challenging. Since Kilian (2009) the use of oil market structural VAR models to isolate the contributions of supply and demand shocks to oil price fluctuations has received much scholarship and scrutiny (e.g. Kilian and Murphy, 2014; Baumeister and Hamilton, 2019; Herrera and Rangaraju, 2019; Zhou, 2020). Similarly, a large body of theoretical and empirical models of irreversible investment highlight the need for sensitivity towards uncertainty and financial frictions (e.g. Bloom, 2007; Kellogg, 2014; Gilchrist, Sim, Zakraejšek, 2014). As production constraints, rather than oil prices, typically determine the rate of extraction, the timing of investment projects (i.e. drilling or capacity increases) are more sensitive to market shocks rather than price shocks (Anderson, Kellogg, and Salant, 2018).

The two-step methodology proposed here joins these streams to identify the sources and effects of market shocks on oil sector investments. First, I estimate a structural VAR model to disentangle the sources of market volatility. The model maps the responses of six market variables (crude oil production, global industrial activity, the price of crude oil, crude oil inventories, stock prices, and interest rates) to five sources of market shocks (oil supply, aggregate demand, oil demand, financial, and monetary). This setup allows for identifying and quantifying the source of oil market fluctuations and the influence of macroeconomic shocks.

Second, I use the estimated residuals of each identified shock to determine its effect on oil sector investment projects: expenditures on oil structures and equipment, refining capacity, and drilling activity. Using data on the size and timing of investment expenditures and realized projects brings multiple insights. Actualized irreversible investment projects provide information on the nature and execution of the entire project, which is equally useful as the impetus, as such investment projects

reap benefits only once actuated. Coupled with expenditures data, these investment variables allow for analyzing the influence of market shocks at various parts of the lengthy investment process.

The main results of this research are threefold. First, sector-specific and macroeconomic shocks resulted in persistent effects on investment, though each type of investment responded differently to each shock. Thus, understanding investment dynamics requires a multi-pronged approach and a project's idiosyncrasies may outweigh the umbrella terms of irreversibility or uncertainty. Second, the response of irreversible investment to market shocks is linked most closely to the scale, cost, and planning horizon of the project.

Finally, while investment in capital-intensive industries such as the oil sector is clearly sensitive to them, market shocks do not explain the bulk of fluctuations in investment expenditures or realized investment projects. Pinpointing the exact triggers for investment projects of various planning horizons remains theoretically and empirically challenging. The results from the aggregate data explored here find support in the micro-level empirical literature on the investment-uncertainty relationship, namely, that irreversibility dampens rather than heightens shock sensitivity. Certain shocks boost or depress investment over multiple quarters, but I find evidence that investment plans are often unaltered by market shocks.

Section 2 outlines the structural VAR and presents its results. Section 3 describes the second-stage regressions and the results. Section 4 discusses and contextualizes the findings. Section 5 concludes.

2 Structural VAR

2.1 Model

Consider a reduced form VAR model

$$y_t = \alpha + \sum_{i=1}^{24} B_i y_{t-i} + \varepsilon_t \tag{1}$$

where y_t is a $(N \times 1)$ vector of six endogenous variables N described below; α is a $(N \times 1)$ vector of constants; B_i is an $(N \times N)$ parameter matrix; and ε_t is a vector mutually uncorrelated i.i.d. white noise error term. The horizon is set to 24 months in concordance with the oil market literature, allowing for the lengthy and uneven transmission of fluctuations in the data to affect markets (Kilian, 2009; Bornstein, Krusell, and Rebelo, 2019). The reduced form error term ε_t can be decomposed according to $\varepsilon_t = Ae_t$,where A is a non-singular parameter matrix and e_t are the estimated structural innovations.

Data. The data are monthly and span from January 1973 to May 2018. I compute the growth rate of global oil production using monthly production data from the Energy Information Agency (EIA). The measure of global economic activity originally described in Kilian (2009) and updated in Kilian (2019) proxies for global aggregate demand. Based on dry cargo shipping rates, the Kilian index captures shifts in global demand for industrial commodities. The index is available on Kilian's website. I employ monthly U.S. refinery acquisition costs of imported crude oil from the EIA as the closest approximation of the global real price of oil. The cost data is deflated by the U.S. CPI and expressed in log-levels per Kilian and Murphy (2014). To proxy for global above-ground crude oil inventories, I follow Hamilton (2009) and use available data on monthly U.S. crude oil inventories and stocks provided by the EIA and OECD crude oil stocks to estimate OECD inventories, which serve the place for global inventories. The S&P 500 index is used to measure U.S. stock prices and the federal funds rate measures U.S. interest rates.

Estimation and identification. The structural VAR is estimated using Bayesian methods with diffuse priors as described in Furlanetto, Ravazzolo, and Sarferaz (2017). The reduced form shocks ε_t are mapped to structural shocks through restricting the responses of the data to be either positive or negative on impact. The contributions of each of the five identified shocks to innovations in the data are based on economic theory and empirical findings. A minimum number of restrictions are imposed to identify each shock and remain consistent with each shock's definition. The remaining responses are left unrestricted. Table 1 summarizes the restrictions.

	Oil supply	Agg. demand	Oil demand	Financial	Monetary
Oil supply	-	+	+	+	+
Econ. activity	-	+	-	+	+
Oil price	+	+	+	+	
Oil inventory		-	+	+	
Stock prices		+		+	
Interest rates		+		+	-

Table 1: Sign restrictions imposed to estimate equation 2. A plus denotes an increase in the variable; a minus denotes a decrease. Else, the movement is left unrestricted.

An oil supply shock results in a decrease in global crude oil supplies and global economic activity while increasing the real price of oil. The effects of changes in the demand for crude oil storage, the stock market, and interest rates are left unrestricted as there is structurally no need to restrict them nor are there sound economic justifications to do so.

An aggregate demand shock increases all variables save the demand for above-ground crude oil storage. The rationale for this negative response lies in the fact that in times of strong global demand the tightness of the market and the ensuing high price of oil would not justify the cost of holding crude oil above-ground for later use. Hamilton (2009) explores the relationship between inventories and oil prices particularly during the 2005-2008 price surge. In this period of strong global demand, inventory levels were low. Kilian and Murphy (2014) leave this relationship unrestricted and their results indicate a small but consistently negative relationship between global economic activity and crude oil inventories.

An oil demand shock, one that is unique from demand for other industrial commodities, increases global oil production, the real price of oil, and the demand for above-ground oil storage. The effect on global aggregate demand is negative, reflecting the effects of elevated oil prices on economic activity when the price increases are not driven by strong aggregate demand. Examples of an oil demand shock include both speculation in oil markets and precautionary demand for crude oil.

A financial shock represents a stock market or investment boom (or both) and increases all six variables in the model. The positive response of above-ground oil inventory to a financial shock, while not exhaustively explored in the literature, is rationalized by the assumption that high levels

of investment and capital inflows to the oil sector may outweight the costs of holding excess stocks of oil. The positive sign restriction distinguishes a financial shock from an aggregate demand shock, which lowers above-ground storage levels. A financial shock does not tighten an already taut supply chain, rather floods it extra capital. A monetary shock increases economy-wide output and prices, reflected here in increased oil production and oil prices, and by definition reflects a decrease in interest rates.

2.2 Results

Figures 1-7 present the results of the structural VAR. In each figure, the dotted blue line corresponds to the most likely structural model, while the shaded area corresponds the 68% highest posterior density joint credible set. Figure 6 reports the residual shock results.

(1) An oil supply shock has a small negative effect on oil production that mostly recovers within six months, as shown in Figure 1. Global economic activity and stock prices also recover quickly and show little sensitivity to an unanticipated decrease in oil supply. Oil prices, however, react sharply and significantly and do not recover over the full 24-month horizon. Oil inventory appears to increase as a precautionary step to further oil supply shortages—a trend that persists over the 24 months—though the results are not significant. Interest rates have a positive, persistent reaction, but this result is not significant.

(2) The aggregate demand shock depicted in Figure 2 results in a positive, though not significant response in global oil production. Again, global economic activity and stock prices react on impact and recover within a few months. Oil prices remain elevated, though without major spikes. Oil inventory decreases in the first few months and slowly recovers over the 24 months. Lastly, interest rates react ambiguously and not significantly.

(3) An oil demand shock has a negligible, positive effect on oil production, though the result is not significant (see Figure 3). Global economic activity reacts negatively on impact but recovers within the first months. Likewise, stock prices show next to no response to an oil-specific demand

	Horizon	Oil Sup.	Agg Dem.	Oil Dem.	Fin.	Mon.	Res.
Oil supply	1	0.205	0.121	0.398	0.046	0.227	0.002
	6	0.155	0.152	0.424	0.041	0.228	0.001
	18	0.127	0.162	0.437	0.052	0.221	0.001
Agg. demand	1	0.566	0.066	0.511	0.182	0.184	0.001
	6	0.069	0.086	0.480	0.191	0.173	0.001
	18	0.075	0.087	0.475	0.193	0.170	0.001
Oil demand	1	0.583	0.188	0.098	0.116	0.015	0.000
	6	0.569	0.069	0.098	0.228	0.036	0.000
	18	0.526	0.124	0.098	0.199	0.052	0.000
Oil inventory	1	0.008	0.450	0.057	0.484	0.0001	0.000
	6	0.049	0.377	0.071	0.495	0.008	0.000
	18	0.395	0.299	0.105	0.547	0.009	0.000
Stock prices	1	0.193	0.105	0.003	0.087	0.611	0.000
	6	0.207	0.105	0.048	0.102	0.537	0.000
	18	0.205	0.112	0.052	0.106	0.526	0.004
Interest rates	1	0.037	0.243	0.021	0.351	0.347	0.000
	6	0.146	0.020	0.028	0.661	0.145	0.000
	18	0.147	0.005	0.054	0.669	0.125	0.000

Table 2: Median forecast error variance decompositions. Horizons are monthly.

shock. On the other hand, oil prices and inventories react positively on impact and peak after three months. They remain positive and significant over the 24 months. Interest rates increase steadily only after the first month, though this trend is not significant.

(4) A financial shock positively affects oil production, economic activity, and stock prices on impact only and recover within the first months following the shock (see Figure 4). Oil prices and inventory react strongly and spike in the months following, remaining significantly elevated over the 24 months. Likewise, interest rates rise on impact and maintain an elevated level throughout the subsequent two years.

(5) A monetary shock results in persistently elevated oil production, as shown in the top-left panel of Figure 5. After a positive response on impact, global economic activity recovers quickly. Responding negatively on impact, stock prices similarly recover almost immediately. Oil prices and inventories respond ambiguously: while the effect on oil prices is probably small and positive and oil inventory fluctuates, the confidence bands are wide and the results are not significant.

Figure 7 presents the variance decomposition for each estimated shock over the 24 months (se-

lected results are reported in Table 2). On impact, supply, aggregate demand, oil demand, and monetary shocks contribute equally to oil production fluctuations. After three months, monetary shocks dominate. The contributions of each shock to global economic activity varies little over the two years with oil demand accounting for the bulk. Oil price fluctuations are due most to oil supply shocks followed by financial and oil demand shocks. Oil inventory is influenced most by financial shocks and to a lessening degree aggregate demand shocks.

The first four columns of table 1 are of particular interest for this research. Initially, an oil supply shock accounts for a minute part of the variance of oil inventory, but grows to 0.3950 after 18 months, suggesting the lingering, important effect of unexpected oil supply shortfalls on the precautionary demand for oil. In contrast, global economic activity responds sharply on impact to an oil supply shock, yet recovers within six months. Stock prices are driven predominantly by monetary shocks and interest rates are overwhelmingly driven by financial shocks.

3 Second-stage regression: Shocks and oil sector investment

3.1 Framework

After extracting the series of structural oil shocks from the model, I estimate the effects of these shocks on U.S. real private nonresidential fixed investment expenditures in structures and equipment, refinery capacity increases, and average exploratory and developmental well depth. I assume the structural shocks are approximately mutually uncorrelated at lower than monthly frequencies and are contemporaneously predetermined (Kilian and Vega, 2011).

The assumption that these measures of investment are predetermined with respect to the estimated shocks is justified through the lower frequency of the data in the regression model than in the structural VAR. Monthly data strengthens the identification strategy of the structural VAR; quarterly aggregates in the second-stage regression mitigate reverse causality concerns. In addition, while it has grown in recent years, the U.S. petroleum industry remains a part of the larger global

petroleum industry in both terms of oil supply and demand. Thus, it is reasonable to assume that oil sector investments in the U.S. are not driving market shocks. Thus, with far enough distance between the variables in section 2 and 3 and the longer frequencies in section 3, I estimate the response of investment to oil sector and financial shocks via ordinary least squares for shocks j according to the following equation:

$$\Delta z_t = \alpha_j + \sum_{t=0}^{12} \phi_{jt} \hat{\theta}_{jt-1} + u_{jt}, j = 1, \ldots, 6 \tag{2}$$

where Δz_t is the investment variable of interest, α_j is the constant, ϕ_{jt} is the impulse response coefficient, and u_{jt} is the error term. A lag of 12 quarters is motivated by the long planning and execution horizons of oil investment projects and the long-run effects of oil sector and macroeconomic shocks (Bornstein, Krusell, and Rebelo, 2019). Data on U.S. investment expenditures are available at the quarterly frequency and well depths at a yearly frequency, necessitating a quarterly and yearly measure of market shocks, $\hat{\theta}_{qt}$ and $\hat{\theta}_{yt}$ respectively. Refinery capacity data is available at monthly frequencies, but I convert it to quarterly to avoid any correlation with the variables in the structural VAR. I average the monthly structural innovations $etji$ (shock j, month i, of year t) derived from the structural VAR for each quarter according to

$$\hat{\theta}_{qt} = \frac{1}{3} \sum_{t=0}^{3} e_{tji}, j = 1, \ldots, 6. \tag{3}$$

Yearly shocks are averaged according to

$$\hat{\theta}_{yt} = \frac{1}{12} \sum_{t=0}^{12} e_{tji}, j = 1, \ldots, 6. \tag{4}$$

Data. The U.S. Bureau of Economic Analysis's National Income and Product Accounts compiles quarterly data for nonresidential fixed investment in structures and equipment with the subcategory of "Structures: Mining exploration, shafts, and wells" and "Equipment: Other: Mining and oil field machinery." Structures and equipment figures are expressed in percent change. The data are

reported in billions of USD and expressed in percent change.

The EIA reports monthly operable refinery capacity. Refinery capacity is a measure of the total crude oil inputs in barrels a refinery can process in a 24-hour period, including operating and idle capacity. Increasing capacity generally requires the refinery to shut down part of its operations. Once installed, the equipment may be used to perform similar processes, also at additional shut-down and switching costs (Cross, Desrochers, and Shimizu, 2013).

The EIA reports the number and total depth of exploratory and development wells, from which I compute the average yearly depth for each type of well. Exploratory wells include wells drilled for three purposes: to find and produce oil or gas in an area previously considered unproductive; to find a new reservoir in a known field; or to extend the limit of a known oil or gas reservoir. A development well is a well within a proved area of an oil or gas reservoir to the depth known to be productive. Both wells represent large sunk costs, though the decision to drill one of these wells reflects varying levels of information and market expectations. The decision to drill an exploratory well reflects years and perhaps decades of geological research. Furthermore, if the well is not located near existing oil infrastructure (drilling crews, pipelines, etc.), the decision to drill may be coupled with further investment costs. Development drills represent surer bets: the presence of crude oil reserves is confirmed and the infrastructure to extract and transport crude oil is likely in place.

3.2 Results

Figures 8-13 depict the responses of oil sector investment to each structural shock. The solid line represents the most likely structural model with the dashed and dotted lines marking the first and second standard deviation.

Investment in oil structures, while not largely overall significant, display distinct trends and responses: slightly positive (oil demand, financial, monetary), slightly negative (aggregate demand), and inconclusive (supply, residual) (Figure 8). Investment in oil equipment is slightly negative on impact for supply and financial shocks, but recovers after the initial few months (Figure 9). An

oil demand, monetary, and aggregate demand shock display positive trends; an oil demand shock is sustained and significant, while monetary and aggregate demand shocks are transient and not significant. Combining expenditures on structures and equipment, total oil investment responds most positively to oil demand shocks for at least eight quarters (Figure 10). The other shocks are either slightly positive (financial, monetary) or inconclusive (supply, aggregate demand, monetary).

Refinery capacity investments display little response on impact and varied trends following the first two months (Figure 11). The effect of an oil supply shock is inconclusive with large standard deviations. Financial and oil demand shocks are positive in the medium horizon, while aggregate demand lowers capacity in the medium run before recovering.

Depth for both exploratory and developmental wells increased steadily following an oil supply shock. Aggregate and oil demand shocks negatively and persistently effected depth. Well depth decreased following a financial shock, but recovered after ten quarters. For exploratory wells, a monetary shock has no impact in the short run, a slight negative impact in the medium run, and finally a slight positive effect after the second year. Developmental well depth responds increasingly positive to a monetary shock, though at a lower magnitude than to the supply or demand shocks.

4 Discussion

4.1 Oil market shocks

The shocks identified and estimated in the structural VAR model fall largely in line with the oil market literature (Herrera and Rangaraju, 2020). Supply and demand shocks play an equally important role in accounting for fluctuations in oil prices and the contributions of financial and monetary shocks, while financial and monetary shocks play a tertiary role (Caldara, Cavallo, and Iacoviello, 2019). The robust responses of oil inventories and the effects of oil demand shocks reaffirm the need to account for both above-ground oil storage and the roles of speculation and precautionary demand (Kilian and Murphy, 2014).

The persistent, positive response of oil production to a decrease in interest rates indicate the sensitivity of production costs and infrastructure investments to monetary policy, and to a lesser extent financial shocks (Bornstein, Guerriri and Kilian, 2012). Also of interest is the positive response of oil prices to a monetary shock even with higher supply and negligible changes to demand. The results here to do not readily suggest an explanation—inventory levels are also weakly affected—but a possible source of both higher supply and higher prices is an increase in oil consumption, for which we do not have a direct measure.

The estimates from Section 2 indicate the limited impact of market shocks on oil production and the responsiveness of global industrial activity and the price of oil (Figure 3). This result is in accordance with estimates of production elasticities and the observation that production is more sensitive to technological and geological constraints than to prices (Anderson, Kellogg, and Salant, 2018; Caldara, Cavallo, and Icoviello, 2019). While Bjôrnland, Nordvik, and Rohrer (2021) find evidence of increased flexibility in shale oil production due to different contraints, shale oil production appears highly sensitive to financial market conditions.

4.2 Oil sector investment

The results here confirm the long lags and delayed transmissions of market shocks on investment data (Lee, Kang, and Ratti, 2011; Bornstein, Krusell, and Rebelo, 2019). Investment expenditures respond most positively and persistently to monetary and oil demand shocks, highlighting the key role of demand conditions in determining the uncertainty-investment relationship. Though Bloom, Bond, and Van Reenen (2007) find evidence of a weaker effect of demand uncertainty on irreversible investment as opposed to flexible investment, demand conditions appear highly relevant to investment spending and project completion. Whereas Ahmadi, et al. (2019) conclude oil market uncertainty lowers investment only when it is caused by aggregate demand shock, the results here indicate that supply and financial conditions are equally relevant. Expenditures on oil equipment respond negatively over the first year to an oil supply shock.

Refinery capacity investment displays consistent lags of 2-3 quarters in response to a shock, with the majority of the shocks dissipating within three years. These projects require parts of production to stop, interrupting the sophisticated manufacturing schedule, and adjustments to the product slate. Refinery investment responds positively to financial shock after three quarters and the overall large standard deviations underscore the high fixed and adjustment costs and lags that largely insulate refinery capacity investments from market shocks.

The differences between the responses of exploratory and developmental wells to market shocks emphasize the key differences in types of investment projects and why the irreversibility of a project may not be the most salient attribute. Exploratory wells involve higher risks and react more strongly to a supply shock than developmental wells, perhaps a move to counteract the shortfall in crude oil production and take advantage of the ensuing increased price and market uncertainty. Also, exploratory wells reflect the outcome of substantial investment in procuring and analyzing potential reserves and are completed with long run production outcomes in mind. As such, the timing of drilling is less likely to be influenced by market shocks than overall market and firm forecasts.

Developmental wells carry far less risk of negative returns on investment and display greater sensitivity to market shocks. Once tapped, production is geologically and technically constrained. This constraint is evidenced by the sharp response of developmental well depth to both aggregate demand and oil demand shocks: the firm may choose to wait and tap the known reserve at a later date. These shocks increase the price of oil, but increasing the supply may in turn dampen that increase and producers may choose to "store" their reserves below ground.

4.3 Uncertainty and investment

The relationship between investment, uncertainty, and irreversibility remains under debate (Gilchrist, Sim, and Zakrajek, 2014)); and while this research is not expressly designed to isolate the exact contributions of uncertainty and irreversibility on investment, it does speak into this field. The size and sign of investment response to uncertainty may ultimately depend on the model setup (Koetse,

de Groot, and Florax, 2009), and as this research takes no stance a priori to the investment decision, it provides an outside perspective, albeit on the aggregate level. For example, the delayed response of refinery capacity may be interpreted as the "wait-and-see" effect, or it may reflect the longer planning horizons inherent to these projects. Expenditures on oil structures and equipment respond more positively to an oil demand shock than to an aggregate demand shock, tightening the relationship between product demand uncertainty and investment. Therefore it is not unreasonable to take demand conditions hand-in-hand with project characteristics.

The results here find support in micro-level studies of the investment-uncertainty relationship. Fuss and Vermeulen (2004) find empirical support for investment responses to demand uncertainty, but not to price uncertainty, as well as little evidence that firms update their investment plans to reflect lower levels of uncertainty. This trend may explain the persistent nature of the responses of well depth to shocks, whereas refinery capacity increases tend to recover. Previous empirical studies of oil sector investment confirm the patterns prescribed by real options theory (Dunne and Mu, 2010; Kellogg, 2014; Ahmadi, Manera, and Sadeghzadeh, 2019), though Bachmann, Elster, and Sims (2013) find no evidence of "wait-and-see"–large declines of economic activity on impact and subsequent fast rebounds, and conclude rather that recessions breed uncertainty. Closely related to this study, Ahmadi et al. (2019) find no evidence of a positive relationship between irreversible investment and oil market uncertainty

4.4 Limitations and extensions

This research rests heavily on the workhorse oil market structural VAR approach pioneered by Kilian (2009) to identify sources of market innovations and analyze their effects on oil investments. The aggregated data and empirical framework do not, however, allow for identifying or quantifying firms' perceptions and responses to market uncertainty as in the work of Kellogg (2014). As such, the results here do not directly answer whether firms regard investment projects as real options or how shocks influence the value of the option to postpone an investment.

Including a measure of uncertainty measure, such as in recent work by Cross, Nguyen and Tran (2020), is unlikely to alter the results. After constructing a novel measure of oil price uncertainty, they disentangle speculation from precautionary demand for crude oil. The former outweigh the later in driving oil price spikes and precautionary demand for oil reduces GDP by while speculative demand shocks are inflationary. The role of speculation in oil markets is considered limited (Kilian and Murphy, 2014; Kilian and Leee, 2014); the contribution to investment certainly falls behind the role of precautionary demand shocks in influencing oil-sector investments. Thus, it is doubtful that splitting oil demand shocks would make the channels of transmission of market shocks to investment any clearer.

Speculation is likely linked to a financial shock, whereas fluctuations in precautionary demand reflect the market's beliefs in the ability of supply to meet demand in the near future. Given the current size of global crude oil production and the attention placed on developing and promoting renewable energy, it is unlikely that precautionary demand will exert enough pressure on oil prices to drive investment patterns. What is more likely is that investment incentives and corporate boardrooms will exert enough pressure to diversify away from crude oil infrastructure investments. In this sense, the effects of renewable energy investment subsidies and green investing on oil investment levels may be a shock in and of itself.

5 Conclusion

This paper identifies the contributions of oil market and macroeconomic shocks on refinery and oil sector investments. The results indicate that investments respond to market shocks, though not equally. I find evidence of both the importance of demand conditions in determining the investment-uncertainty relationship as well as the benefit in disentangling market-specific from macroeconomic shocks. In addition, I find that financial shocks are key determinants of crude oil inventory levels, on par with global economic activity, indicating the role of speculation in fueling oil demand shocks.

Positive oil demand and financial shocks boost investment. Expenditures are most sensitive to oil demand shocks, whereas well depth also response strongly to oil supply shocks. Refinery capacity increases display the most sensitivity to financial and monetary shocks due to the long lags, high adjustment costs, and lumpy nature of these investment projects. Average exploratory well depth display weaker responses than developmental wells to all shocks but oil supply shocks. Overall, market-specific and macroeconomic shocks explain a small, but appreciable part of irreversible investment patterns in the oil sector.

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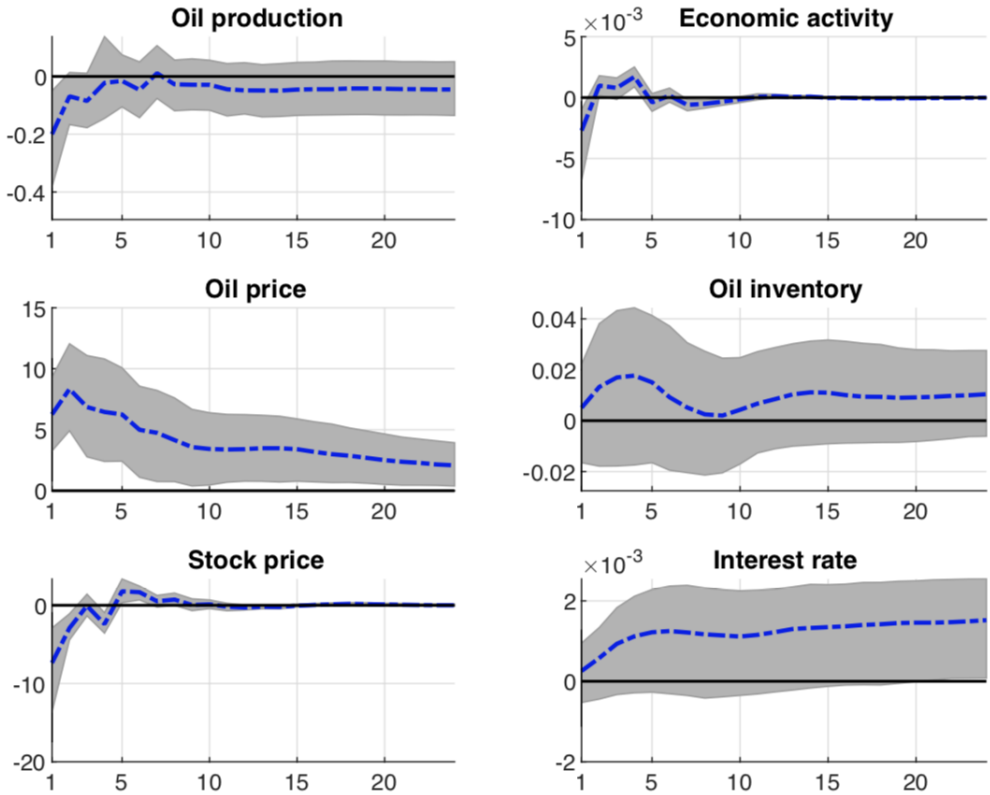

Figure 1: Structural impulse responses for an oil supply shock.

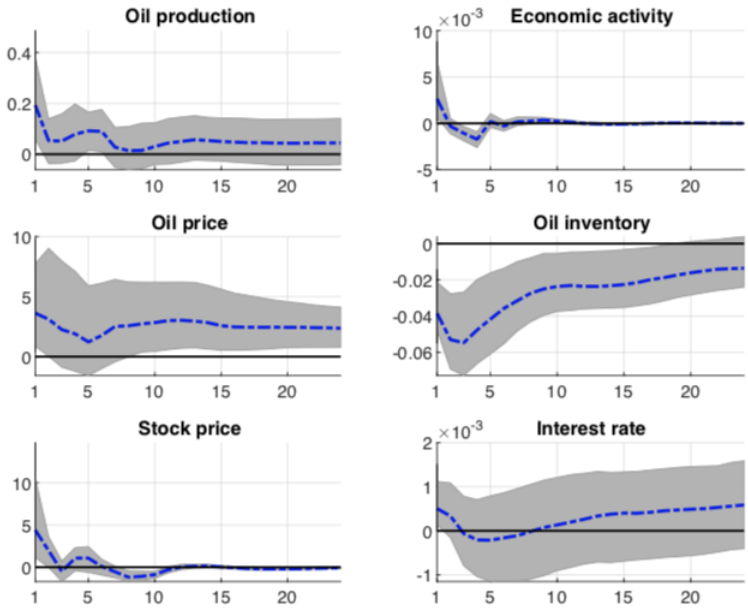

Figure 2: Structural impulse responses for an aggregate demand shock.

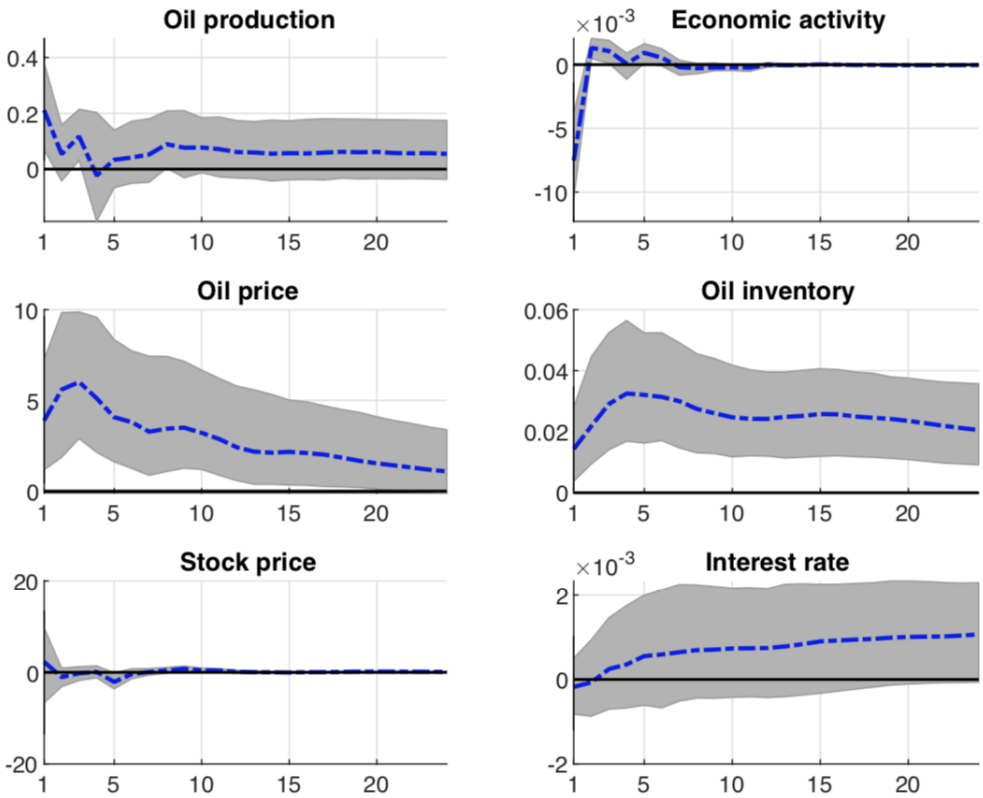

Figure 3: Structural impulse responses for an oil demand shock.

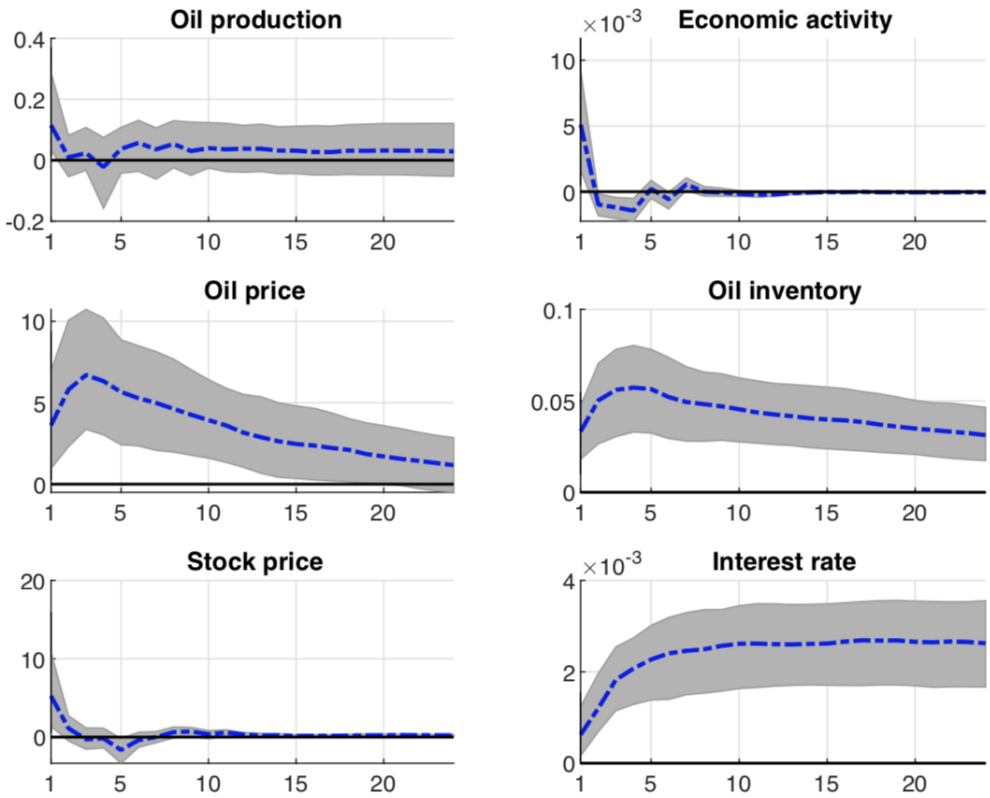

Figure 4: Structural impulse responses for financial shock.

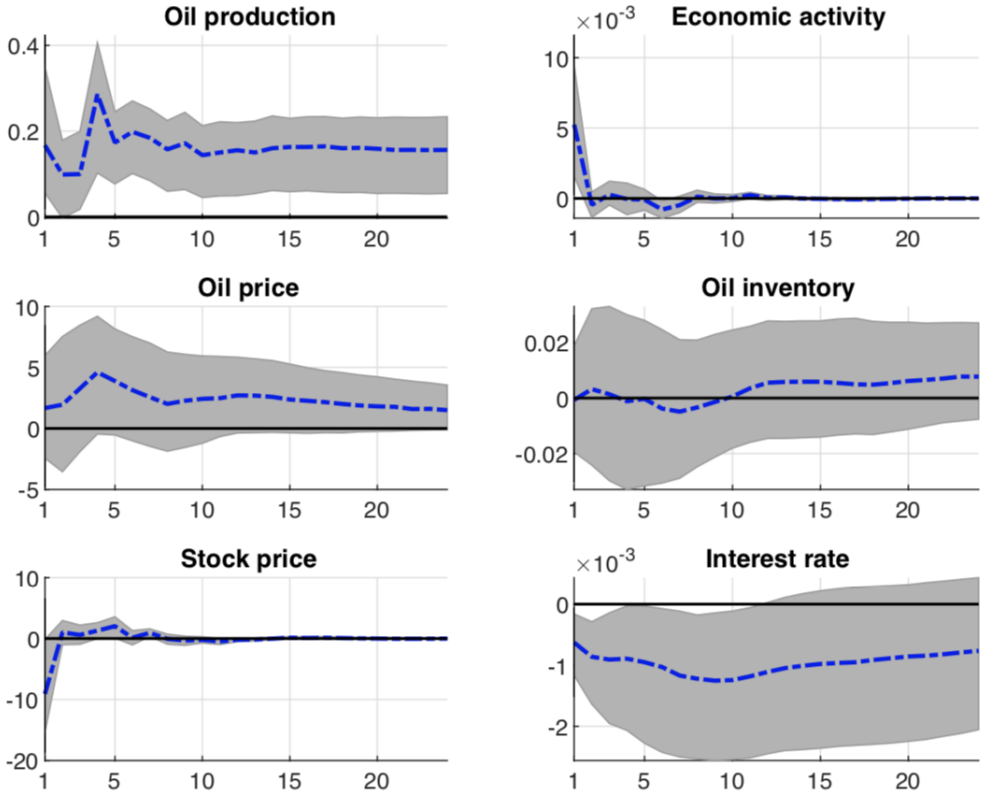

Figure 5: Structural impulse responses for a monetary shock.

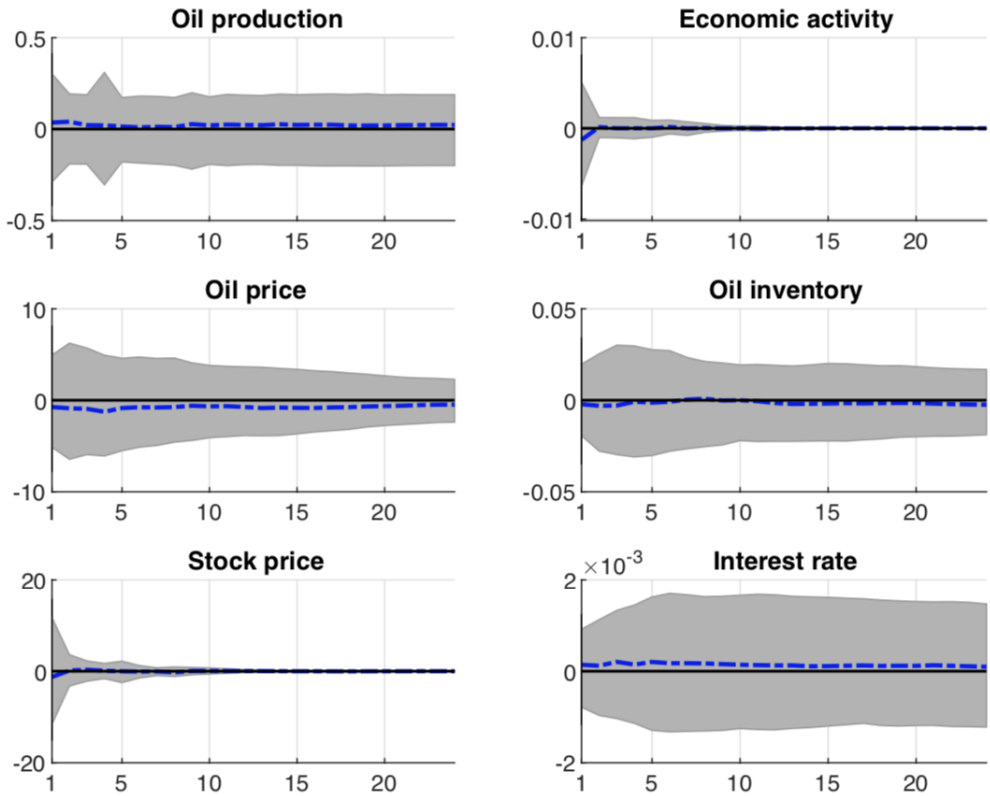

Figure 6: Structural impulse responses for residuals.

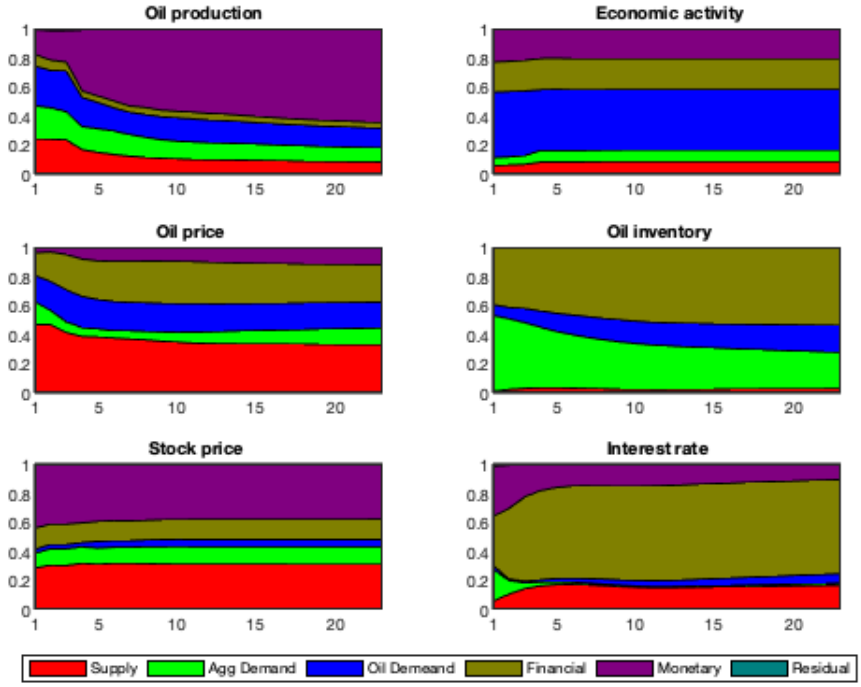

Figure 7: Variance decomposition

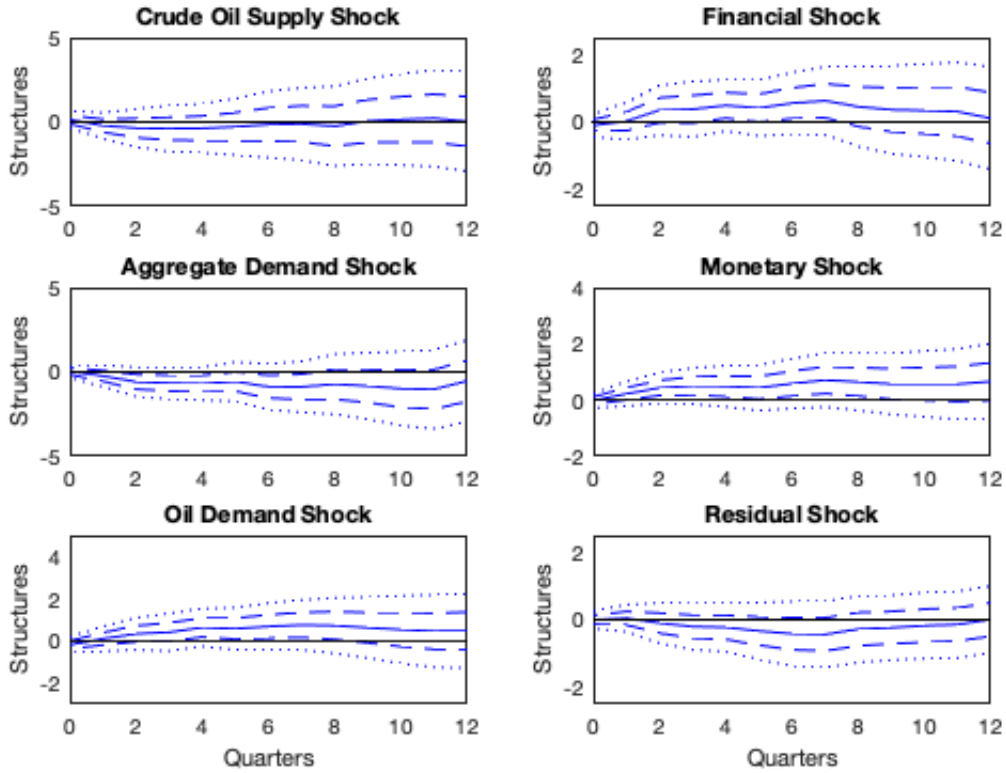

Figure 8: Responses for real private nonresidential fixed investment expenditures on structures (mining exploration, shafts, and wells).

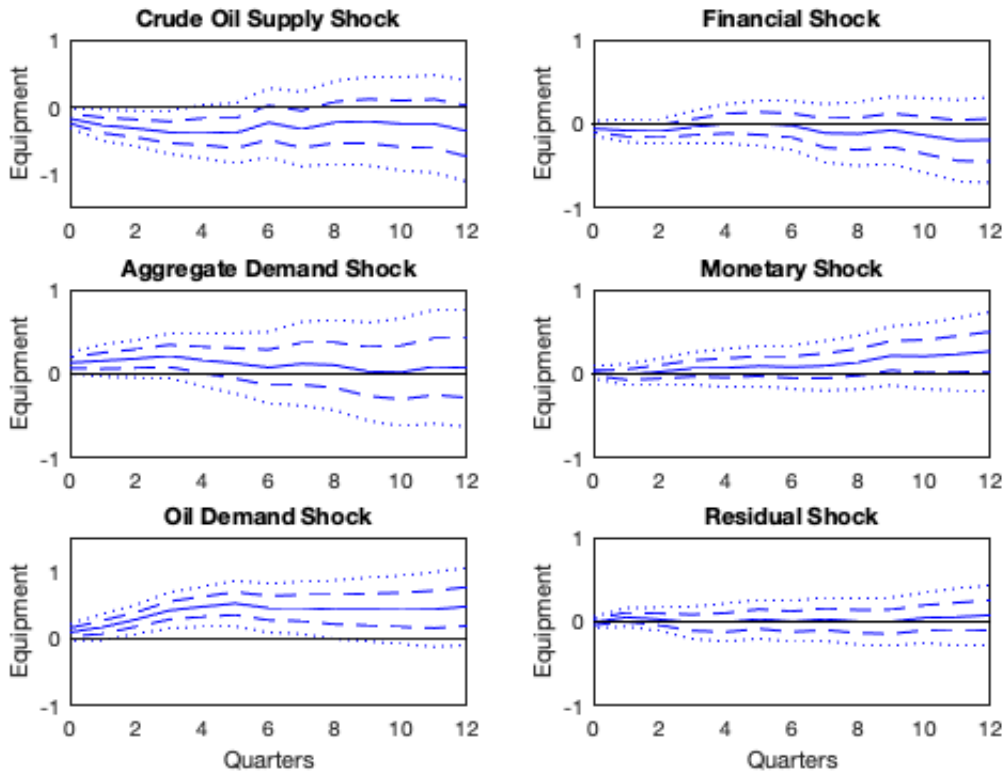

Figure 9: Responses for real private nonresidential fixed investment expenditures on equipment (mining and oil field machinery).

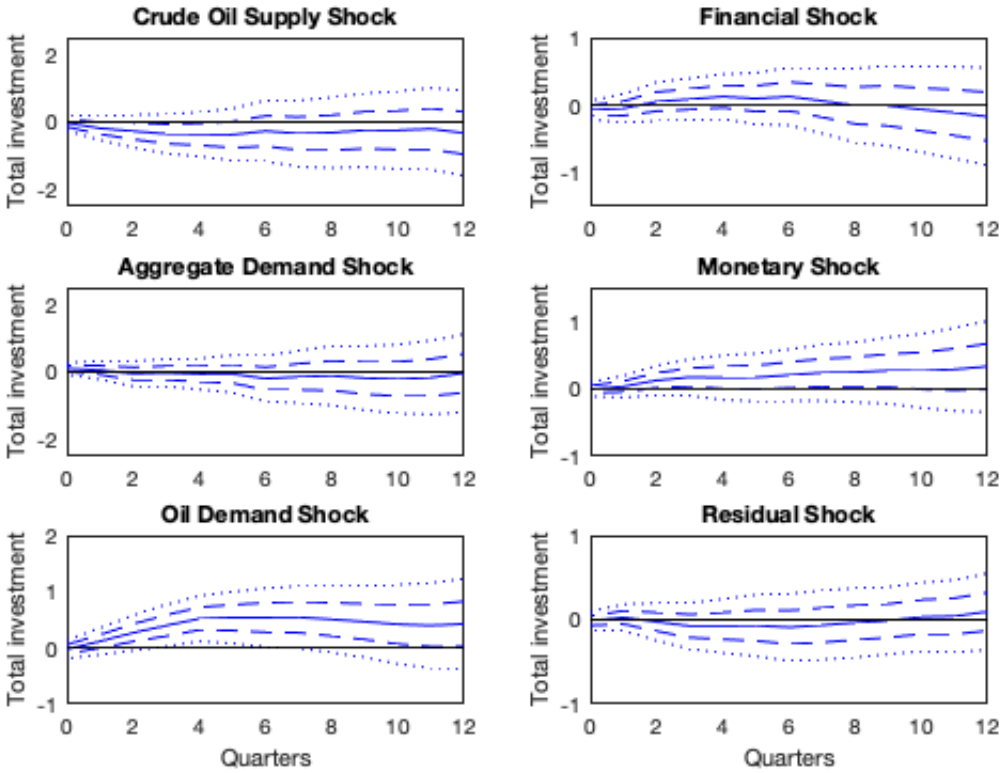

Figure 10: Responses for total oil investment expenditures on real private nonresidential fixed structures and equipment.

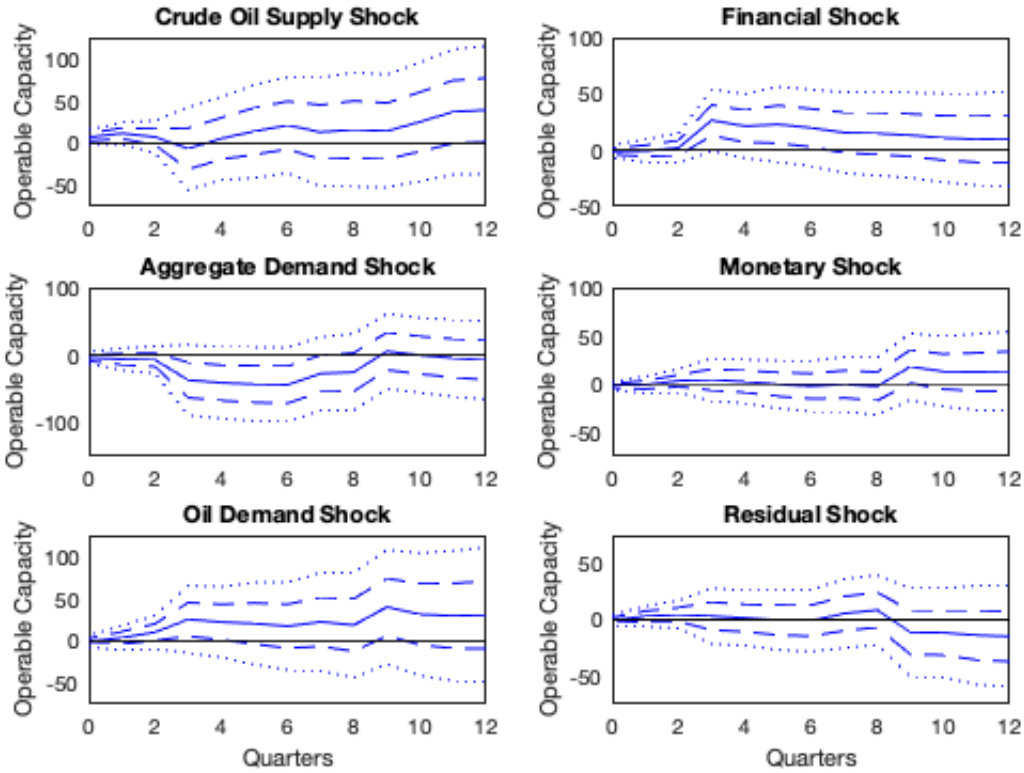

Figure 11: Impulse responses for operable refinery capacity.

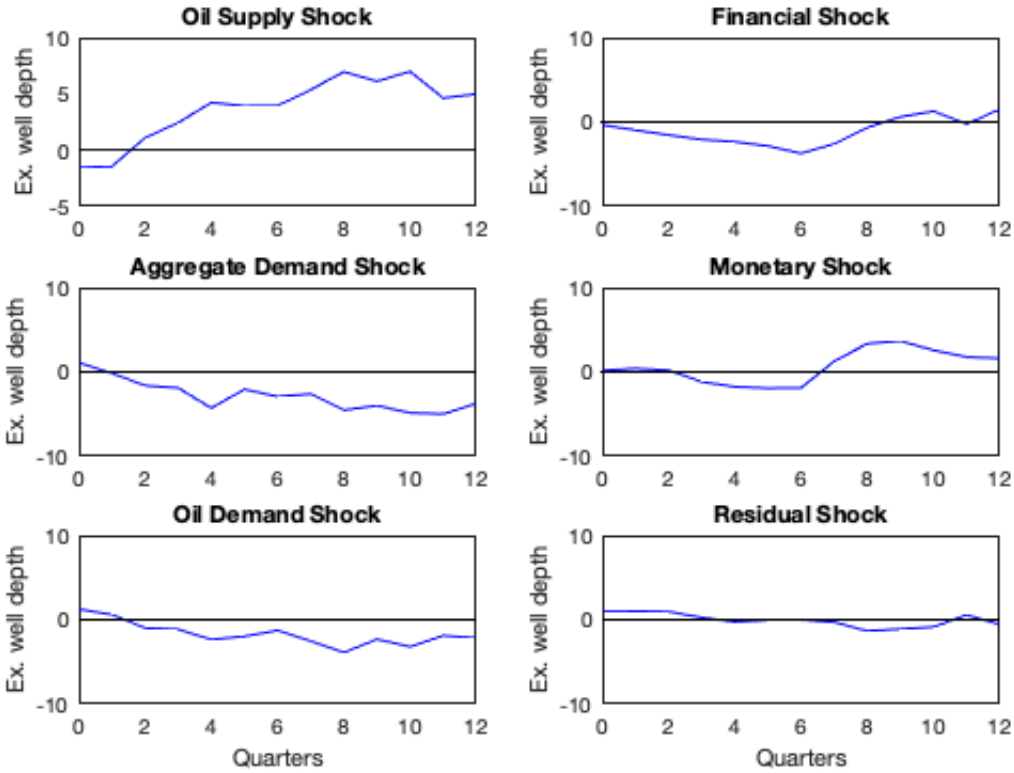

Figure 12: Responses for average exploratory drill depth expressed in log growth rate.

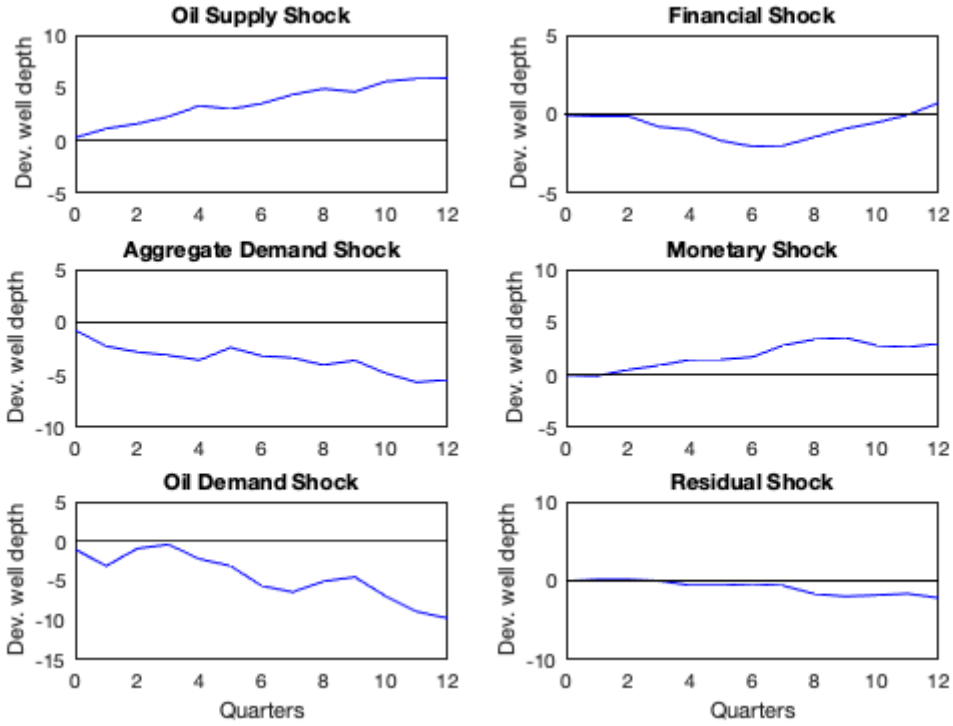

Figure 13: Responses for average developmental drill depth expressed in log growth rate.