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OIL PRICE VOLATILITY: INDUSTRIAL PRODUCTION AND SPECIAL AGGREGATES

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Previous research shows that volatility in oil prices has tended to depress output, as measured by nonresidential investment, gross domestic product, and aggregated measures of industrial production in several countries. This paper investigates the effect of oil price volatility on disaggregated measures of industrial production. The disaggregated measures that we examine are the special aggregates by market groups as calculated by the Federal Reserve Board. Our results are reported for three categories of special aggregates: indexes for industrial production excluding two major industries (technology and motor vehicles), energy-related special aggregates, and non-energy-related special aggregates. Our results indicate that among energy-related market groups, the effects of oil price volatility are concentrated in activities related to primary energy generation and oil and gas drilling. Among non-energy-related market groups, oil price volatility affects a broad range of special aggregates, including aggregates sorted by consumer goods and business equipment.

Keywords: Oil Volatility, Uncertainty, Multivariate GARCH VAR, Real Options

1. INTRODUCTION

Elder and Serletis (2010) find that volatility in oil prices has tended to depress some components of aggregate investment. The motivation for their analysis is based on "real option" models, also known as investment under uncertainty [cf. Brennan and Schwartz (1985), Majd and Pindyck (1987), and Brennan (1990)]. That is, real option theory predicts that firm investment decisions—irreversible investment decisions that have uncertain future cash flows may be viewed as a call option. In this context, firms view the investment decision as a joint decision of whether and when to invest. Bernanke (1983) tailored a model to oil price volatility and showed how uncertainty about oil price may have macroeconomic effects. Hamilton (2013) provides a historical perspective on oil shocks.

This theory is often applied to large investment decisions. Dixit and Pindyck (1994) also provide numerous examples of relatively small but very common

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investment decisions, such as the hiring and training of labor, that fall into this category. Bredin et al. (2011) provide a relevant summary and illustrate that, in practice, the application of the theory is both broad and deep, with potentially wide ranging effects. The broad relation between output, oil prices, and oil price volatility is illustrated in Figure 1, which is suggestive of some relation, as oil price volatility tends to be high around recessions, as well as during the episode of the mid-1980s when oil prices dropped precipitously but output did not increase.

In this paper, we examine the effect of oil price volatility on components of industrial production in a systematic fashion. The particular components that we examine are the special aggregate indexes of industrial production. These special aggregates are presumably constructed in such way to represent measures of output of particular interest. The special aggregates, as released by the Federal Reserve Board, are sorted in three groups. The first group consists of special aggregates that are based on the exclusion of two industries—technology and motor vehicles/parts. The second group focuses on the energy sector and includes aggregates sorted by user (consumer versus commercial). The third group of special aggregates focuses on non-energy-related sectors, that also includes aggregates sorted by user, such as consumer versus business.

There are two important notes about our analysis. First, the special aggregate indexes are overlapping in terms of the industries on the production side. Second, the indexes may be aggregated by the consumer of the product rather than the producer. For example, the special aggregates for the energy sector consist of special aggregates for "consumer energy products" and "producer energy products." These features suggest that, while the data provide important insights into the propagation of oil price volatility, they may not completely isolate industries in which the effects of oil price volatility are the strongest.

We use the empirical model of Elder (1995, 2004) as our baseline specification, although the results are not likely firmly tied to this particular specification. It has now been shown that considerably different model models, such as Jo (2014), generate very similar results, even with different data over different samples. For example, Jo (2014) uses an index of global production, while Elder and Serletis (2010) use data on U.S. output, consumption, and investment. Therefore, in this paper we are less interested in the particular econometric methodology and more interested in attributes of production data that are most strongly affected by oil price uncertainty.

Anticipating the principal results, we find that oil price volatility affects a very large proportion of the special aggregate indexes. In energy-related industries, among energy-related market groups, the effects of oil price volatility are concentrated in activities related to primary energy generation and oil and gas drilling, but aggregates grouped by consumer versus commercial user are not affected. Among non-energy-related market groups, oil price volatility affects a broad range of special aggregates, including aggregates sorted by consumer goods and business equipment. The effect of oil price uncertainty is notably absent in the computer and

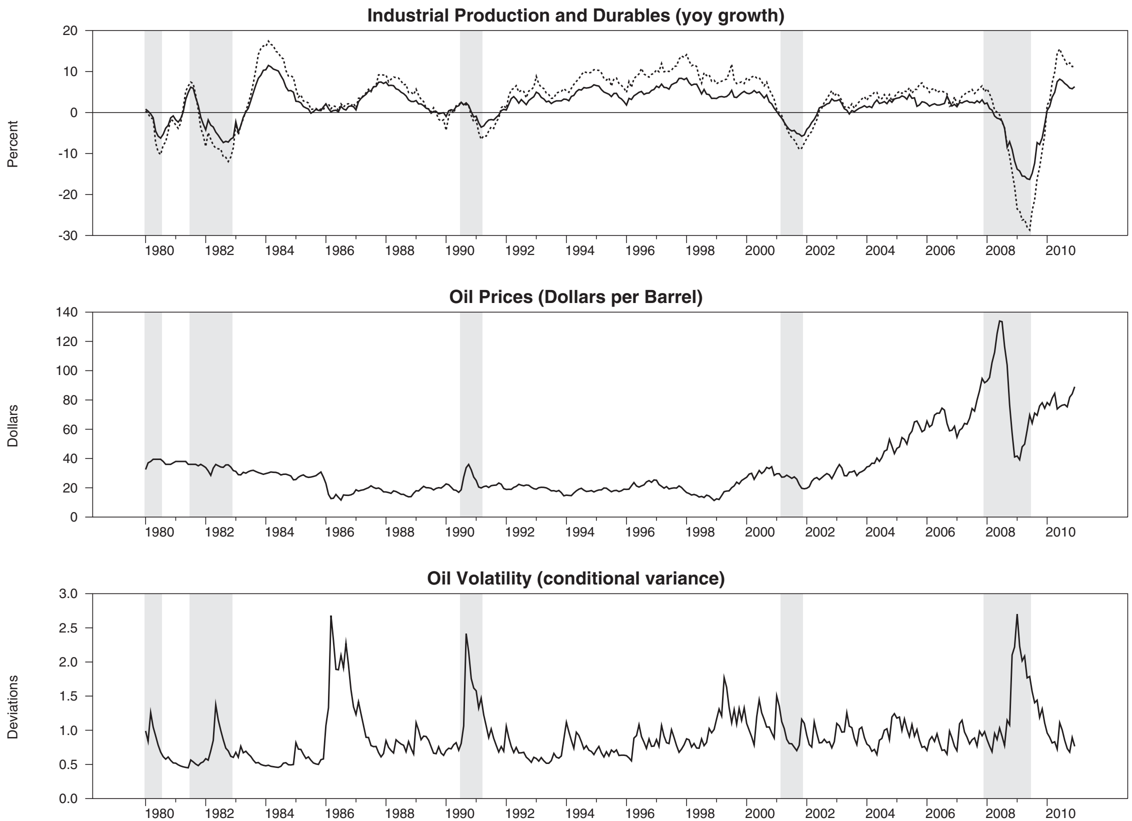

FIGURE 1. Output and oil price volatility. NBER recessions are shaded.

electronics industries. These results are generally robust to different samples, such as prefinancial crisis, post-1987, and over the full sample. Our analysis offers an important lesson for the oil price collapse of 2014. To the extent that the collapse in oil prices has increased uncertainty, we should expect any positive response of manufacturing activity to be substantially moderated.

2. BASELINE EMPIRICAL MODEL

We use the empirical model described in Elder (1995, 2004) as our baseline model, with some modification. This is a structural VAR model adapted to accommodate structural identification and multivariate GARCH-in-Mean. Since the model is described elsewhere, the presentation here is brief.

The model is a standard linear vector autoregression, with the conditional volatility of oil permitted to effect the conditional mean

$$\mathbf{B}\mathbf{y}_t = \mathbf{C} + \Gamma_{1\mathbf{y}t-1} + \Gamma_{2\mathbf{y}t-2} + \cdots\cdots + \Gamma_{\mathrm{p}\mathbf{y}t-\mathrm{p}} + \Lambda \mathrm{H}_{\mathrm{Oil}}(\mathrm{t})^{1/2} + \varepsilon_{\mathrm{t}}, \qquad \mathbf{(1)}$$

where $\dim(\mathbf{B}) = \dim(\Gamma_{\mathrm{i}}) = (\mathrm{N} \times \mathrm{N})$, $\epsilon_{\mathrm{t}}|\psi_{t-1}$ iid $\mathrm{N}(\mathbf{0}, \mathbf{H}_{\mathrm{t}})$, $\mathbf{H}_{\mathrm{t}}$ is diagonal, $\mathrm{H}_{\mathrm{Oil}}(\mathrm{t})^{1/2}$ is the conditional standard deviation of oil, and ψ_{t-1} denotes the information set at time $\mathrm{t} - 1$, which includes variables dated $\mathrm{t} - 1$ and earlier. Λ is a vector of coefficients that relates oil price volatility to the conditional mean of the variables in the VAR.

This empirical model allows the conditional variance of the structural disturbances to be heteroskedastic, and it allows the volatility of, say, oil prices to affect the conditional mean of other variables through the parameter matrix Λ. The vector ϵ_{t} represents the orthogonalized structural innovations, which are related to the choice of $\mathrm{N}(\mathrm{N} - 1)/2$ free parameters in the matrix **B**. The diagonal elements are normalized to one and the exclusion restrictions are imposed in such a way that **B** is of full rank.

In the baseline model, the conditional variance matrix $\mathbf{H}_{\mathrm{t}}$ may follow a multivariate GARCH process. As described by Elder (2004), taking advantage of the common identifying assumption in structural VARs that the structural errors are orthogonal implies that the conditional variance matrix $\mathbf{H}_{\mathrm{t}}$ is diagonal, so that the relevant dynamics can be summarized as

$$\begin{pmatrix} H_{\mathrm{CPI}}(t) \\ H_{\mathrm{IP}}(t) \\ H_{\mathrm{Oil}}(t) \\ H_{\mathrm{Rate}}(t) \end{pmatrix} = \begin{pmatrix} C_1 + & F_1 \varepsilon_{\mathrm{CPI}}(t-1)^2 + & G_1 H_{\mathrm{CPI}}(t-1) \\ C_2 + & F_2 \varepsilon_{\mathrm{IP}}(t-1)^2 + & G_2 H_{\mathrm{IP}}(t-1) \\ C_3 + & F_3 \varepsilon_{\mathrm{Oil}}(t-1)^2 + & G_3 H_{\mathrm{Oil}}(t-1) \\ C_4 + & F_4 \varepsilon_{\mathrm{Rate}}(t-1)^2 + & G_4 H_{\mathrm{Rate}}(t-1) \end{pmatrix}, \qquad \mathbf{(2)}$$

$$\mathbf{z}_{\mathrm{t}} \sim \text{iid } \mathbf{N}(\mathbf{0}, \mathbf{I});$$

$$\varepsilon_{\mathrm{t}} = \mathbf{H}_{\mathrm{t}}^{1/2} \mathbf{z}_{\mathrm{t}}.$$

Estimation by full information maximum likelihood is then straightforward as described by Elder (2004).

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Our baseline model consists of a four variable VAR on the consumer price index, industrial production (IP), oil prices, and interest rates. The nonstationary variables are transformed to the first difference of the log, so that the variables become inflation, IP growth, oil returns, and the Federal funds rate. This is similar to specifications used by, for example, Hamilton and Herrera (2004), Bernanke et al. (1997), Bredin, Elder, and Fountas (2010), and others. Under this specification, the vector y_t is therefore

$$\mathbf{y_t} = \begin{pmatrix} \Delta \ln(\mathrm{CPI}_t) \\ \Delta \ln(\mathrm{IP}_t) \\ \Delta \ln(\mathrm{Oil}_t) \\ i_t \end{pmatrix}.$$

The model specified by equations (1) and (2) has the advantage of being a fully specified structural VAR and internally consistent. The measure of oil price shock is the one-step ahead forecast error, and the measure of oil price volatility is the variance of the one-step ahead forecast error.

We examine the effects of oil price volatility on a large number of subindices of industrial production. These subindices are too numerous to include in a single specification, in that the number of parameters to estimate may result in no degrees of freedom.

We therefore adapt this model by substituting the different measures of industrial production as the second equation in the system, permitting the conditional variance of oil to vary as described in equation (2), and permitting the conditional variance of oil to enter the industrial production equation.

These results are qualitatively similar to those produced by an alternative methodology, in which we estimate the full model described by equations (1) and (2), and then estimate the following auxiliary regression:

$$\Delta \ln(\mathrm{IPS}_t) = c + \sum_{j=1}^{6} \beta_{1,j} \Delta \ln\left(\mathrm{CPI}_{t-j}\right) + \sum_{j=1}^{6} \beta_{2,j} \Delta \ln\left(\mathrm{IPS}_{t-j}\right)$$
$$+ \sum_{j=1}^{6} \beta_{3,j} \Delta \ln\left(\mathrm{Oil}_{t-j}\right) + \sum_{j=1}^{6} \beta_{4,j} \mathrm{Rate}_{t-j} + \Lambda \hat{H}_{\mathrm{Oil}}(t)^{1/2} + \varepsilon_t, \qquad \mathbf{(3)}$$

where $\hat{H}_{\mathrm{Oil}}(t)^{1/2}$ is the measure of oil price volatility extracted from our baseline structural multivariate GARCH VAR and IPS_t denotes the industrial production subindex for various industries. This second method generates a single measure of oil price volatility, to be used as a regressor in a large number of auxiliary regressions. The disadvantage is that, depending on the order or equations in the system, $\hat{H}_{\mathrm{Oil}}(t)^{1/2}$ in the auxiliary regression given by equation (3) may be a generated regressor.

We estimate the model over three samples—a full 30-year sample beginning in 1980, a financial precrisis sample ending in 2007, and a post-1987 sample. The post-1987 sample is motived by the concerns described in Kilian (2008), who suggests that the Tax Reform Act of 1986 may account for some nonlinearity in the full-sample.

3. DATA ON SPECIAL AGGREGATES

The industrial production data that we use in our analysis are compiled by the Federal Reserve Board. The total index consists of output in the broad areas of manufacturing, mining, and utilities, with a very large share of the index, about 75%, attributed to manufacturing activity, 13% attributed to mining, and 11% attributed to the output of utilities. The dollar value added from the total industrial production index for the United States is about 20% of gross domestic product.[1]

The index can be decomposed in different dimensions. One dimension is the "special aggregates" released by the Federal Reserve in their "G.17" release on "Industrial Production and Capacity Utilization," particularly their Table 2. The special aggregates are grouped by the production of energy and nonenergy products, as well as by the end-user of the products, such as consumer versus commercial of business entities. The aggregates also include indexes that are of special interest, such as output of selected high-technology industries, motor vehicles, and other industries excluding technology and motor vehicles.

These special aggregates are listed in Tables 1–3, and their proportion to the value added of the total industrial production index is listed in the first column of Tables 1–3. The bottom two sections of Table 1 include several broad aggregates. These are the total index, manufacturing, and durables manufacturing, with each excluding technology and/or motor vehicles and parts.

Table 2 lists special aggregates associated with the production of energy-related products. Energy-related production consists of about 26% of the total index, while non-energy-related products accounts for about 74% of the index. Among energy-related products, the largest component is primary energy, which accounts for about 13% of the total index. Primary energy includes the extraction of natural gas, crude oil and coal, and hydroelectric and nuclear power generation. The other components include the production of consumer energy products (such as automotive gasoline, fuel oil and residential electricity, and gas sales), commercial energy products, converted fuel production (such as gas transmission and fossil fuel electric power generation). The final component of energy-related production is the drilling of oil and gas wells.

Table 3 lists special aggregates for non-energy-related production. There include special aggregates for technology (computers, communications equipment, and semiconductors, which account for about 3% of the total index) and motor vehicles and parts (about 5% of the total index). There are also several aggregates excluding both technology and motor vehicles for consumer goods (about 19%), business equipment (about 8%), construction supplies (about 6%), and materials (about

TABLE 1. Effect of oil price volatility on special aggregates of industrial production

Industrial production: special aggregates	Proportion (%)	1980:1-2009:12 Coeff	1980:1-2009:12 *t*-stat	1987:01–2009:12 Coeff	1987:01–2009:12 *t*-stat	1980:01–2007:12 Coeff	1980:01–2007:12 *t*-stat
Total index	100.00	−0.048***	−4.07	−0.134***	−3.47	−0.045***	−3.28
Total Industry ex. hi-tech	96.62	−0.051***	−4.24	−0.165***	−4.24	−0.047***	−3.63
Manufacturing ex. hi-tech	71.95	−0.050**	−2.06	−0.127***	−3.27	−0.033**	−2.26
Durable mfg. ex. hi-tech	34.70	−0.338***	−4.19	−0.338***	−4.19	−0.059**	−2.43
Total ex. motor vehicles and parts	94.67	−0.032***	−3.31	−0.086***	−3.23	−0.035***	−2.83
Manufacturing ex. motor vehicles and parts	70.01	−0.029***	−2.90	−0.070***	−2.75	−0.028***	−3.40
Durable manuf ex. motor vehicles & parts	32.75	−0.031***	−2.76	−0.064***	−5.52	−0.039***	−2.71
Total ex. selected hi-tech, motor veh & pts	91.29	−0.037***	−3.77	−0.093***	−4.04	−0.037***	−3.20
Manufacturing ex. hi-tech, motor veh & pts	66.63	−0.035***	−3.53	−0.089***	−3.25	−0.021**	−2.14
Nonenergy materials for finished goods producers	11.19	−0.069***	−7.66	−0.147**	−2.33	−0.033***	−2.80

Notes: This table reports the coefficient on oil price volatility as specified in equations (1)–(3). The column labeled "Proportions" reports the proportion of the valued added to the total industrial production index from the selected aggregate for 2011. If the aggregate corresponds to a particular NAICS, that code is given. These special aggregates overlap in the industrial production index, and so do not sum to 100 percent. *, **, *** represent significance at the 10%, 5%, and 1% levels. The indicated samples include the presample period.

TABLE 2. Effect of oil price volatility on energy-related market groups

		1980:1-2009:12		1987:01–2009:12		1980:01–2007:12	
Industrial production: Special aggregates	Proportion (%)	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat
Total index	100.00	−0.048***	−4.07	−0.134***	−3.47	−0.045***	−3.28
Energy, total	26.40	−0.064***	−2.82	−0.027	−0.54	−0.039	−0.38
Consumer energy products	5.39	−0.021	−0.46	−0.041	−0.46	−0.035	−0.41
Commercial energy products	2.93	−0.037	−1.42	0.069	1.19	−0.007	−0.23
Drilling oil and gas wells (213111)	0.68	−0.224***	−3.10	−0.001	−0.91	−0.247***	−2.78
Converted fuel	3.98	−0.072	−1.53	−0.022	−1.19	−0.016	−0.66
Primary energy	13.43	−0.046**	−1.98	−0.037	−1.08	−0.067***	−2.76

Notes: This table reports the coefficient on oil price volatility as specified in equations (1)–(3). The column labeled "Proportions" reports the proportion of the valued added to the total industrial production index from the selected aggregate for 2011. If the aggregate corresponds to a particular NAICS, that code is given. These special aggregates overlap in the industrial production index, and so do not sum to 100 percent. *, **, *** represent significance at the 10%, 5%, and 1% levels. The indicated samples include the presample period.

TABLE 3. Effect of oil price volatility on nonenergy special aggregates of industrial production

Industrial production: Special aggregates	Proportion (%)	1980:1–2009:12 Coeff	1980:1–2009:12 t-stat	1987:01–2009:12 Coeff	1987:01–2009:12 t-stat	1980:01–2007:12 Coeff	1980:01–2007:12 t-stat
Nonenergy, total	73.60	−0.041***	−3.57	−0.098***	−3.74	−0.029***	−2.71
Computers, communication eq & semiconductors	3.38	−0.010	−0.46	−0.066	−1.49	−0.009	−0.18
Computer and peripheral equipment (3341)	0.46	−0.022	−0.88	0.006	0.29	−0.006	−0.26
Communications equipment (3342)	0.63	0.002	0.22	0.046	1.19	−0.022	−0.50
Semiconductor and related equip	2.29	−0.006	−0.07	−0.175**	−2.26	0.012	1.28
Nonenergy ex. hi-tech	70.21	−0.048	−0.99	−0.119***	−3.64	−0.031***	−2.89
Motor vehicles and parts (3361-3)	5.33	−0.390***	−7.71	−1.107***	−4.04	−0.200**	−2.10
Motor vehicle NAICS = 3361	2.86	−0.595***	−4.17	−1.888***	−5.38	−0.249*	−1.69
Motor vehicle parts NAIC S = 3363	2.15	−0.229***	−4.42	−0.591***	−3.25	−0.127***	−3.01
Nonenergy ex. motor vehicles & hi-tech	64.88	−0.034***	−3.12	−0.085**	−2.61	−0.032***	−2.62
Consumer goods ex. hi-tech, motor vehicles	19.09	−0.029***	−5.06	−0.077**	−2.52	−0.022	−1.54
Business equip ex. hi-tech, motor vehicles	7.84	−0.048**	−2.07	−0.111***	−2.49	−0.051**	−2.28
Construction supplies ex. hi-tech	4.10	−0.067***	−3.03	−0.155***	−5.36	−0.040***	−2.65
Business supplies ex. energy, motor vehicle	6.35	−0.044***	−3.51	−0.089***	−2.82	−0.030**	−2.15
Materials ex. energy, vehicles	25.30	−0.059***	−4.91	−0.154***	−5.13	−0.042***	−3.00

Notes: This table reports the coefficient on oil price volatility as specified in equations (1)–(3). The column labeled “Proportions” reports the proportion of the valued added to the total industrial production index from the selected aggregate for 2011. If the aggregate corresponds to a particular NAICS, that code is given. These special aggregates overlap in the industrial production index, and so do not sum to 100 percent. “Motor vehicles” refers to Motor Vehicles and Parts.” *, **, *** represent significance at the 10%, 5%, and 1% levels. The indicated samples include the presample period.

25%, which includes metals, plastics, paints, textiles, paper, chemicals, containers, and food products).

4. RESULTS FOR SPECIAL AGGREGATES WITH EXCLUSIONS

The results for our baseline model are reported in Table 1, along with special aggregate subindexes. We estimate the multivariate GARCH-in-Mean VAR described in the methodology, but we report just the coefficient on oil price volatility, since that represents the relation that we are interested in. Impulse-response functions, which summarize interactions of all of the coefficients, are reported for different data in Bredin et al. (2011), for example.

The first line of Table 1 reports the estimate for the effect of oil price uncertainty on the total industrial production index. The coefficient on the total index is negative and highly significant over the full post-1980 sample as well as the post-1987 sample and the precrisis (i.e., pre-2007) sample, which is consistent with Elder and Serletis (2010) and Bredin et al. (2011).

In a closer examination of the data, we next substitute different subindexes in equation (3), to estimate the effects of oil price uncertainty on these more disaggregated measures. The first set of special aggregates is reported in Table 1.

We should note again that the special aggregates in Table 1 are overlapping, and so many industries are duplicated in the same index. In this sense, the number of negative and significant coefficients in Table 1 overstates the scope of the effects of oil price volatility. For example, it is possible that the effect is strong in only one industry, but that industry is represented in each of the subindexes. This issue is especially relevant for this first set of special aggregates, which are calculated based on exclusions or particular industries from the total index.

The first set of special aggregate indexes excludes the technology industry. These are as follows: the total index excluding technology, manufacturing excluding technology, and durable manufacturing excluding technology. In each of these special aggregates, the effect is negative and significant over each of the three samples.

The next set of special aggregate indexes includes technology, but excludes motor vehicles and parts. These indexes are as follows: the total index, manufacturing, and durable manufacturing, each excluding motor vehicles and parts. Again, the effect of oil price volatility is negative and significant for each of the indexes over each of the samples, and in most cases, highly significant.

The next set of special aggregate indexes excludes *both* technology and motor vehicles and parts. These are again calculated for the total index with these exclusions and for the manufacturing index with these exclusions. Once again, the effect of oil price uncertainty is negative and significant for each of the indexes over each of the samples, and in most cases, highly significant.

Our results thus far indicate that excluding either technology or motor vehicles and parts or both does not alter the qualitative result that oil price uncertainty tends to reduce production.

5. RESULTS FOR ENERGY-RELATED SPECIAL AGGREGATES

Perhaps more interesting is to examine the effects of oil price volatility on energy-related industries. A priori, we might expect the effects of oil price volatility to be concentrated in these industries. These results are reported in Table 2.

The first listed subindex is the special aggregate for the production of energy-related output, which accounts for approximately one quarter of value of the total industrial production index. The coefficient is negative and significant for all three subsamples. Further examination, however, suggests that this result is driven by particular subcomponents of this index, as three subcomponents are relatively insensitive to oil price volatility. For example, aggregates grouped by the user of the products, consumer energy products and commercial energy products, are both not sensitive to oil price uncertainty. Consumer energy products include the production of fuels (including gasoline and propane), residential electricity, and gas sales. Commercial energy product includes commercial sales of electricity, gas, and kerosene. Similarly, oil price uncertainty also has a weaker effect on the production of converted fuels, which includes some electric power generation, sales of electricity to industrial users and transmission of natural gas. Perhaps the source of the insensitivity of these industries to oil price volatility might be the sale and use of electricity, which is still highly regulated, with relatively inelastic demand in the short run.

The components of energy production that are sensitive to oil price volatility are the drilling of oil and gas wells, which accounts for a relatively small proportion, less than 1%, of the total index, and, primary energy, which accounts for a much larger share (about 13%).

Primary energy consists of the production, i.e., mining, of primary energy materials, such as the extraction of crude oil, coal mining, support activities for oil and gas operations, and hydropower and nuclear power generation. The estimated coefficient on oil price volatility is negative and significant over the full sample, but not over the subsamples. In this sense, this subcomponent is less sensitive to oil price volatility than drilling of oil and gas wells. To the extent that this subcategory includes hydro and nuclear power generation and coal mining, it may not be surprising that it is less sensitive to oil price volatility than drilling activity.

The drilling of oil and gas wells is the most sensitive to oil price volatility, judging by the magnitude of the coefficient for the full and third samples. Again, this result may not be surprising, in that decisions to drill on-shore oil and gas wells can be implemented over relatively short-time frames on existing leases, and is supplied by mobile and responsive oil field service firms such as Bake Hughes, Haliburton, and Schlumberger. The implication for our results is as follows: a decrease in oil prices that is associated with a spike in volatility, will eventually magnify any decline in drilling activity, as firms further delay new investment. A rapid increase in oil prices that is associated with greater volatility will tend to dampen the response of drilling activity, relative to an oil price increase without additional volatility.

To summarize, the effect of oil price uncertainty on energy-related market groups, as reported by the Federal Reserve Board, is concentrated primarily in the drilling of oil and gas wells. This is a relatively small proportion of the total index, but the effect is evidently particularly strong.

6. RESULTS FOR NON-ENERGY-RELATED SPECIAL AGGREGATES

The special aggregates for non-energy-related production are listed in Table 3. These special aggregates account for nearly three-quarters of the value of the total industrial production index. Among the production of nonenergy materials, special aggregates are reported for selected technology industries (approximately 3% of total value), motor vehicles and parts (approximately 5% of total value), and non-energy-related production excluding technology and motor vehicles.

The effect of oil price uncertainty on the nonenergy production is negative and highly significant over all three subsamples. The first market group under non-energy-related production is computers, communications equipment, and semiconductors. For this market group, oil price uncertainty has no significant effect, as t-statistics for this market group are not significant. Similar results hold for each of the submarket groups in this area, with just one exception over one subsample. These submarket groups include the following: Computer and peripheral equipment, communications equipment and semiconductors, and related equipment. This suggests that the technology industry may be relatively insulated from oil price volatility, or that the dynamics of this sector are driven by other factors.

The next market group is motor vehicles and parts, which is the decomposed into its two components. The effect of oil price volatility is negative and significant on each of these components, over each of the three samples. This may not be surprising, since the automotive industry is often perceived to be susceptible to volatility in oil prices.

The subsequent market groups include nonenergy production *excluding* motor vehicles and technology. Excluding technology from nonenergy production does not diminish the effects of oil price volatility. For other nonenergy components, business equipment, construction supplies, and business supplies, the effect of oil price uncertainty is negative and generally highly significant over the first two subsamples, but not the third.

Thus far, our empirical results are revealing. Oil price uncertainty has a negative and significant effect on the production of the energy-related output, and non-energy-related output. Among industries involved in the production of energy, the effect of oil price uncertainty is concentrated on the drilling of oil and gas wells, which accounts for a relatively small proportion of total production, and the production of primary energy. The effect is insignificant for the market groups of consumer and commercial energy products and converted fuel.

Among industries involved in the production of nonenergy output, the effect of oil price uncertainty is virtually nonexistent in the production of technology such as computers and communication equipment. Oil price uncertainty affects the other non-energy-related special indexes, and the effect is discernibly strongest for the production of motor vehicles and parts. Among the nonenergy market groups, oil price volatility affects both consumer goods and business equipment, as well as the industry including motor vehicle and parts.

7. CONCLUSION

We estimate the effects of oil price volatility on subindexes of industrial production, known as special aggregates, which are sorted by market group. We use as a baseline the multivariate GARCH-in-Mean model of Elder (1995, 2004). Our results are reported for three categories of special aggregates: indexes for industrial production excluding two major industries (technology and motor vehicles), energy-related special aggregates, and non-energy-related special aggregates. We find that oil price volatility negatively affects a broad range of non-energy-related market groups, including markets groups by user, which are consumer goods and business equipment, as well as motor vehicles and parts. Among the energy-related market groups, the effects of oil price volatility are concentrated in activities related to oil and gas drilling and the production of primary energy. We find that oil price volatility has no discernable effect on energy products grouped by either consumers or commercial entities. Our results are robust over the full 30-year sample beginning in 1980, the subsample prior to the financial crisis, and a subsample after the Tax Reform Act of 1986.

Our analysis offers an important lesson for the oil price collapse of 2014. To the extent that the recent collapse in oil prices has increased uncertainty about the future path of oil price, the response of firm investment and production should be substantially moderated, at least until that uncertainty is resolved.

NOTE

1. A description of the industrial production index is available from http://www.federalreserve.gov/releases/g17/SandDesc/sdtab1.pdf.

REFERENCES

Bernanke, Benjamin S. (1983) Irreversibility, uncertainty, and cyclical investment. *Quarterly Journal of Economics* 98, 85–106.

Bernanke, Benjamin S., Mark Gertler and Mark Watson (1997) Systematic monetary policy and the effects of oil price shocks. *Brookings Papers on Economic Activity* 1, 91–142.

Bredin, Don, John Elder and S. Fountas (2011) Oil volatility and the option value of waiting: An analysis of the G-7. *Journal of Futures Markets* 31, 679–702.

Brennan, Michael J. (1990) Latent assets. *Journal of Finance* 45, 709–730.

Brennan, Michael J. and Eduardo Schwartz (1985) Evaluating natural resource investment. *Journal of Business* 58, 1135–1157.

Dixit, Avinash K. and Robert S. Pindyck (1994) *Investment Under Uncertainty*. Princeton, NJ: Princeton University Press.

Elder, John (1995) *Macroeconomic and Financial Effects of Monetary Policy and Monetary Policy Uncertainty*. Doctoral Dissertation, University of Virginia.

Elder, John (2004) Another perspective on the effects of inflation volatility. *Journal of Money, Credit and Banking* 36, 911–28.

Elder, John and Apostolos Serletis (2010) Oil price uncertainty. *Journal of Money, Credit and Banking* 42, 1137–1159.

Hamilton, James D. (2003) What is an oil shock? *Journal of Econometrics* 113, 363–398.

Hamilton, James D. (2009) Causes and consequences of the oil shock of 2007–08. *Brookings Papers on Economic Activity* 1, 215–259.

Hamilton, James D. (2013) Historical oil shocks. In Randall E. Parker and R. Whaples (eds.), *Routledge Handbook of Major Events in Economic History*, pp. 239–265. New York: Routledge Taylor and Francis Group.

Hamilton, James D. and Ana Herrera (2004) Oil shocks and aggregate macroeconomic behavior: The role of monetary policy. *Journal of Money, Credit and Banking* 36, 265–286.

Jo, Soojin (2014) The effect of oil price uncertainty on global real economic activity. *Journal of Money, Credit and Banking* 46, 1113–1135.

Kilian, Lutz (2008) The economic effects of energy price shocks. *Journal of Economic Literature* 46, 871–909.

Majd, Saman and Robert S. Pindyck (1987) Time to build, option value, and investment decisions. *Journal of Financial Economics* 18, 7–27.