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The Impact of Disaggregated Oil Shocks on State-Level Consumption of the United States

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Abstract

We analyse the impact of oil supply, global economic activity, oil-specific consumption demand and oil inventory demand shocks on state-level consumption of the United States (U.S.) over the period of 1975:Q1 to 2012:Q2. We find that positive economic activity shocks and oil production shocks (associated with increase and decrease in oil prices respectively) increase consumption growth. At the same time oil specific consumption and inventor demand shocks raise oil prices and reduce the growth rate of state-level consumption. Across the shocks, the strongest effect originates from the global demand shock. In addition, our above observations are virtually invariant to the degree of oil dependency (oil consumed minus oil produced as ratio of oil consumed) of the states. Our results have important policy implications.

Keywords: Oil shocks, state-level consumption, oil dependency, local projection model, impulse response functions
JEL Codes: C23, E21, Q41

1. Introduction

Theoretically, there are multiple channels through which an "exogenous" change in oil prices can impact economic activity in both oil-producing and oil-importing countries and/or regions within a country. On the supply side, lower oil prices raise output in the non-oil sector by reducing production costs of firms and causing investment and output to rise, with this cost channel likely to be stronger in countries, regions or sectors that heavily rely on oil as an input in production. Conversely, falling oil prices may depress energy-related investment across oil-producing countries or regions, dragging down aggregate or regional activity. On the demand side, lower oil prices transfer wealth towards oil-importing countries or regions and away from oil-exporting (producing) countries or regions (Bodenstein et al., 2012), to cause a windfall income gain for consumers, and thus shift consumption towards oil-importing countries or regions. This wealth effect may in turn cause output to rise through multiplier effects, and may be larger in sectors that produce goods that are complementary to consumption of oil.

Given these key channels, in a recent paper De Michelis et al., (forthcoming), *inter alia*, analysed for the first time the impact of oil price on a panel data set of state-level consumption (proxied by registration of new cars) of the United States (U.S.), by accounting for oil dependency of these states. The authors show that the benefits from oil-price decreases are smaller than the losses from oil-price increases across the U.S. states.[1] In sum, the U.S. state-level evidence highlighted the fact that varying oil dependency may imply differences in

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[1] The study also found that shocks pushing up oil prices are followed by a national decrease in car registrations, with this decline being larger than the increase in registrations following a comparable oil price drop.

consumption responses across regions, even though the standard perception is that common monetary and fiscal policy implies somewhat similar regional responses.

Though De Michelis et al., (forthcoming) recognize the fact that oil price changes can be a result of a variety of shocks, such as supply, global economic activity, oil-specific consumption demand and oil inventory demand, they do not make any attempt to identify the reasons, i.e., what is the underlying structural shock that has resulted in the oil price to change in the first place. As Kilian (2009) notes, depending on the nature of the shock, in particular whether a change in oil price is due to innovations in global aggregate demand or specific to the oil market, the impact on economic activity (consumption) is likely to be different. In particular, if the oil shocks reflect disruptions in oil supply due to geopolitical or natural events, or are from precautionary (oil inventory) or speculative (oil-specific consumption) shifts in the demand for oil, resulting in oil price increases, one would expect consumption to go down. But if, oil price increase is due to expansion of global economic activity, a majority of which is likely to come from the U.S., intuition suggests that consumption will increase. Understandably, the associated policy responses if any to prevent an economic slowdown (given that consumption constitutes the dominant part of output), would also be contingent on the type of oil shock that results in oil price increases and affects consumption, with the size of impact also likely to be different under the alternative shocks. Given this, the objective of our study, is to analyse the impact of the above-mentioned four oil price shocks on state-level consumption by accounting for oil dependency, with the latter being also possibly important in determining the size and direction of the impact of the oil shocks on consumption. This in turn might suggest that, aggregate policy measures would need to be designed keeping this heterogeneity across the states in mind.

From an econometric perspective, we model both the long- and short-run dynamics of the state-level consumption function using a panel data approach over the quarterly period of 1975:Q1 to 2012:Q2, and simultaneously estimate the short-run impact of the oil price shocks at the state-level, conditional upon their oil dependency, using impulse response functions (IRFs) generated from the local projection (LP) approach of Jordà (2005). Note that, the smooth transition function approach is used to switch the oil dependence of U.S. states into high- and low- regimes within the LP framework. To the best of our knowledge this is the first study to analyse the impact of oil price shocks accounting for oil dependency on state-level consumption.[2] The remainder of the paper is organised as follows: Section 2 discusses the data and methodology, while Section 3 presents the empirical results, with Section 4 concluding the paper.

2. Data and Methodology

In this paper we employ the state-level data for household consumption spending and personal income from Case et al., (2005, 2013), with consumption proxied by total retail sales, for each of the 50 U.S. states (plus D.C.) over a relatively long time-span covering the quarterly period of 1975:Q1-2012:Q2.[3] Note that, we could not use the data set of De Michelis, et al. (forthcoming) to proxy consumption as it is not publicly available. As far as the four structural oil-shocks, i.e., oil supply shock (oss), global economic activity shock (eas), oil-specific consumption demand shock (ocds) and oil inventory demand shock (oids), are concerned, these are obtained from the structural vector autoregressive (SVAR) model of Baumeister and

[2] For a detailed review of literature on alternative specification of the consumption function, along with variables included in the model, the reader is referred to Coskun et al., (2018).
[3] The data set is available from Dr. Guo Li (at the Fannie Mae) upon request.

Hamilton (2019),[4] who formulate a less restrictive framework (than what has been traditionally used in the literature following Kilian (2009)), by incorporating uncertainty about the identifying assumptions of the SVAR. In other words, the obtained oil shocks can be considered to be relatively more accurately estimated. Following De Michelis et al., (forthcoming), we also construct a state-specific oil dependency series using U.S. Energy Information Administration (EIA) data on oil production and oil consumption, with oil dependency defined as oil consumed minus oil produced as ratio of oil consumed for each state.

In terms of the methodology for analysing the impact of the oil shocks on consumption, we use the LP method of Jordà (2005) to calculate the impulse response functions of consumption to the oil shocks. The LP approach is appropriate in our case compared to a SVAR, as we use the shocks obtained by Baumeister and Hamilton (2019) from a structural oil market model, and do not need to identify the oil shocks within our model specifically.[5] The linear model for calculating IRFs is as follows:

$$\Delta C_{i,t+s} = \alpha_{i,s} + \beta_s Oil\ Shock_{i,t} + \gamma_s(L)X_{i,t-1} + \delta_s ECM_{i,t-1} + \epsilon_{i,t+s}, \text{ for } s = 0,1,2, \dots S, \tag{1}$$

where $C_{i,t+s}$ represents the log of consumption of state *i* at time *t*, $\alpha_{i,s}$ captures the fixed effect, $Oil\ Shock_t$ represents an identified oil shock at time *t*, X is a vector of control variables, $\gamma_s(L)$ is a lag polynomial, s is the length of forecast horizons with S being the maximum length of forecast horizons.[6] The vector of control variables X contains lagged oil shocks and state-level income growth rates to account for the short-run impact of changes in those variables on consumption growth. X also includes lagged consumption growth rates to account for autocorrelation in the variable. $ECM_{i,t-1}$is an error correction term obtained by estimating the Pooled Mean Group/Autoregressive Distributed Lag (PMG/ARDL) Model of Pesaran et al., (1999, 2001), with the log of consumption as the dependent variable, and log income as the regressor. [7] $ECM_{i,t-1}$ captures the information contained in the long-run/cointegrating relationship between consumption and income in levels. β_s measures responses of consumption at time *t*+*s* to an oil shock at time *t*. Each of the four identified structural oil-shocks is included one at a time in the model. The IRFs can be calculated as a series of β_s estimated by the OLS method for each horizon (s).[8]

We also investigate the impacts of oil price shocks on the consumption growth contingent on the oil dependence of the U.S. states. Following the method by Ahmed and Cassou (2016), a smooth transition function approach is used to switch the oil dependence of U.S. states into high- and low- regimes. The nonlinear model is defined as follows:

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[4] The data is available for download from the research segment of the website of Professor Christiane Baumeister at: https://sites.google.com/site/cjsbaumeister/research. Note that the oil shocks data are monthly, but are converted into quarterly using three-month averages to match our consumption and income data.

[5] Besides the issue of identification, with the IRFs being independent of the data generating process, the LP approach allows us to estimate the iRFs on a variable-by-variable basis, and hence overcomes the degrees of freedom problem associated with standard VARs.

[6] The maximum length of forecast horizons is set to 12, which corresponds to 12-quarter forecast horizons. $\gamma_s(L)$ is a polynomial of order 4, which corresponds to 4-quarter lags for control variables.

[7] We use the Akaike Information Criterion (AIC) and select a maximum of 4 lags (1 year) for automatic lag detection. The optimal lags for the dependent variable and the dynamic regressor are 3 and 1, respectively. The long-run relationship indicated a positive and statistically impact of income on consumption. Complete details of the estimation results are available upon request from the authors.

[8] Further details about LP IRF techniques can be found in Jordà (2005).

$$\Delta C_{i,t+s} = \left(1 - F\left(z_{i,t}\right)\right)\left[\alpha_{i,s}^{R_H} + Oil\ Shock_{i,t}\beta_s^{R_H}\right] + F\left(z_{i,t}\right)\left[\alpha_{i,s}^{R_L} + Oil\ Shock_{i,t}\beta_s^{R_L}\right] + \gamma_s(L)X_{i,t-1} + \delta_s ECM_{i,t-1} + \epsilon_{i,t+s},\ \text{for } s = 0,1,2,\ldots S, \quad (2)$$

where $z_{i,t}$ is a switching variable which measures oil dependence in U.S. states (standardised to have unit variance and zero mean). The smooth transition function $F\left(z_{i,t}\right) = \exp(-\gamma z_{i,t})/1 + \exp(-\gamma z_{i,t}), \gamma > 0$, varies between 0 and 1, with $F\left(z_{i,t}\right) \approx 1$ indicating very low oil dependence in state i (denoted by R_L), and 0 otherwise (denoted by R_H).

3. Empirical Results

In Figure 1, we present the impact of the four structural oil shocks on the growth of state-level consumption. The figure tracks the responses calculated by local linear projections to 1-unit of the disaggregated oil shocks on the future path of consumption growth for 1 to 12-quarter-ahead, along with the 95% confidence bands. The first observation that we can make is that all the oil shocks have statistically significant impacts over the 3-year horizon. Next we turn to the sign of the impacts. We find that consumption growth increases following a positive global economic activity shock, with the effect staying positive till around just below two years, and then becoming primarily negative till the end of the forecast horizon. A positive shock to oil production, i.e., oil supply, also briefly increases consumption growth, and then turns negative within the second quarter, but recovers within the next quarter to stay positive for over two years after the shock, and then turning negative as we approach the end of the 12-quarter-ahead-horizon. When we look at the oil inventory demand shock, the effect is negative for about a year, but then becomes positive for about two quarters and then turns negative again after two quarters, to only become positive and then finally negative towards end of the forecast horizon. Finally, the impact of the oil-specific consumption demand shock is initially negative for about half a year, before becoming positive and fluctuating with strong negative impacts between 3- to below 7-quarter-ahead, and then being again negative from around 30 (7 and half quarter) till 38-month-ahead (9 and half quarter). In sum, the effects of the four oil shocks are in line with intuition. A decline in oil price due to increase in oil production, and expansion of global economic activity (and a booming US economy) with oil price increases, leads to increase in consumption growth In contrast, a speculative oil-specific consumption demand shock and precautionary oil inventory demand shock increase oil price and reduce the growth in state-level consumption.[9] Further, with all the shocks being of the same magnitude, i.e., 1-unit, we find that the strongest initial impact results from the economic activity shock, followed by the effect from the oil inventory demand shock, and then the oil-specific supply and demand shocks.

[INSERT FIGURE 1 ABOUT HERE]

Next, in Figure 2, we re-analyse the impact of the four structural shocks with the IRFs now contingent on the oil dependence of the states, derived based on the nonlinear model outlined

[9] Figures A1 and A2 in the Appendix of the paper shows the effect on consumption growth (based on the LP model in equation (1)) from alternative approaches of identifying oil supply and oil demand shocks by Caldara et al., (2019) and oil supply shock by Kilian (2008) respectively. Note that Caldara et al., (2019) combine narrative analysis, as in Kilian (2008) who used country-specific episodes of exogenous disruptions in oil production, with a panel of observations on country-specific oil production and consumption to estimate oil supply and demand elasticities. They then embed these elasticities in a VAR to identify the oil supply and demand equations and, consequently, the associated oil supply and oil demand shocks. As can be seen from the IRFs, our basic results are robust to these other measures of oil supply and oil demand shocks, with a positive supply shock (i.e., increase in oil production) increasing consumption growth, and a positive demand shock (i.e., an increase in oil price due to speculative or precautionary reasons) negatively impacting consumption growth.

in equation (2). As can be seen, the behaviour of consumption growth from the four shocks is similar to those derived from the linear model as reported in Figure 1.[10] But more importantly, the difference in the size of the effect across the regimes of high- and low- oil dependence is virtually negligible, though we do find that the size of the impact is slightly muted under the low-oil dependence regime. This is not surprising since, high-oil dependence states are the ones that can basically be considered as oil-importers, or more precisely they are regions that consume more oil than they produce. In essence, our results, as in De Michelis et al., (forthcoming), suggest that for the net oil-producing regions, the effect of increases in oil price due to a negative oil supply shock or positive speculative and precautionary oil demand shocks is not strong enough to raise income and hence consumption, or cause windfall gains via the wealth effect to increase consumption.

[INSERT FIGURE 1 ABOUT HERE]

4. Conclusion

In this paper we analyse the impact of disaggregated oil (supply, global economic activity, oil-specific consumption demand and oil inventory demand) shocks on state-level consumption growth of the U.S. over the quarterly period of 1975:Q1 to 2012:Q2. We find that, even though economic activity shock raises oil price due to increase in global demand, consumption growth is found to be impacted strongly in the positive direction, the magnitude of which outweighs the positive impact of an increase in oil production shock (resulting in a decrease in oil price), and the negative effect associated with oil specific consumption demand and oil inventory demand shocks, which raises oil price. In addition, we find that the oil dependence of the states, defined as oil consumed minus oil produced as ratio of oil consumed, does not change the nature and size of the impact of the four oil shocks on consumption growth drastically. From a policy perspective, our results imply that policymakers would need to undertake the strongest expansionary policies when the decline in consumption is due to a fall in global demand for oil because of shrinking global economic activity. Moreover, with our results being independent of oil dependence across the states, it ensures that policymakers do not need to design regime-specific policy measures to revive consumption in the wake of the oil shocks. As part of future research, it would be interesting to extend our analysis to a cross-country level involving oil exporters and importers.

[10] The impact across the two regimes were also statistically significant, and the IRFs for the high and low oil dependence regimes with their respective 95% confidence bands are available upon request from the authors.

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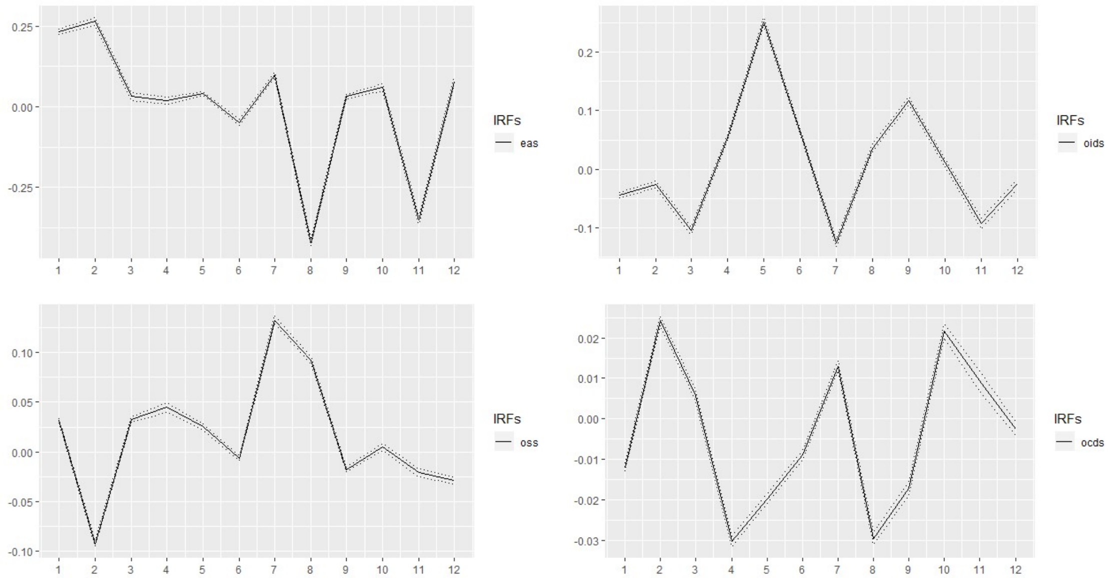
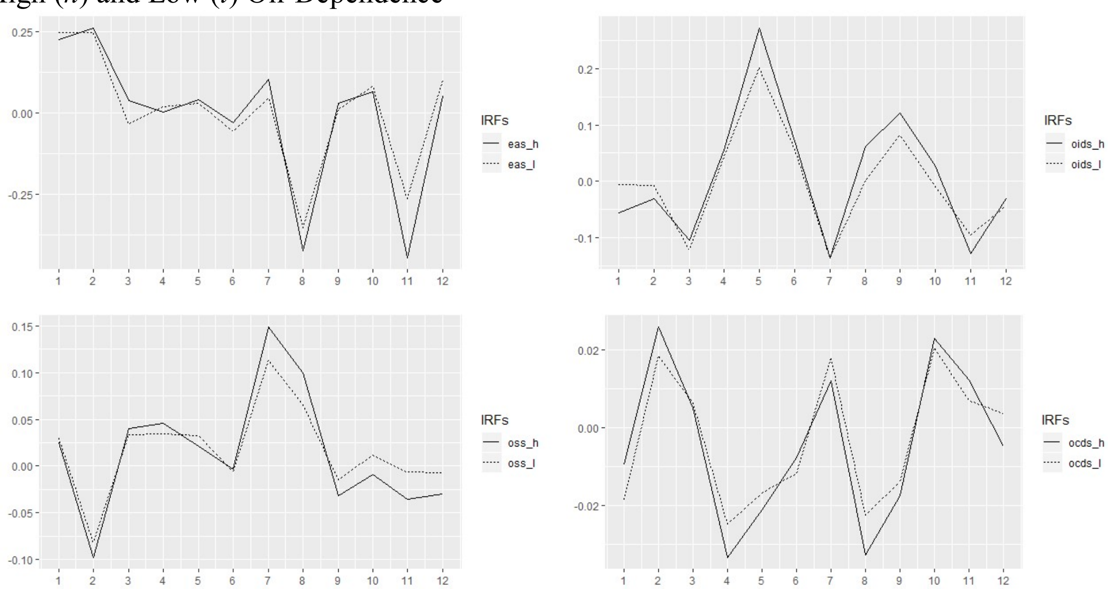
Figure 1. Response of Consumption Growth to the Four Oil Structural Shocks



Note: oss: oil supply shock; eas: global economic activity shock; ocds: oil-specific consumption demand shock; oids: oil inventory demand shock.

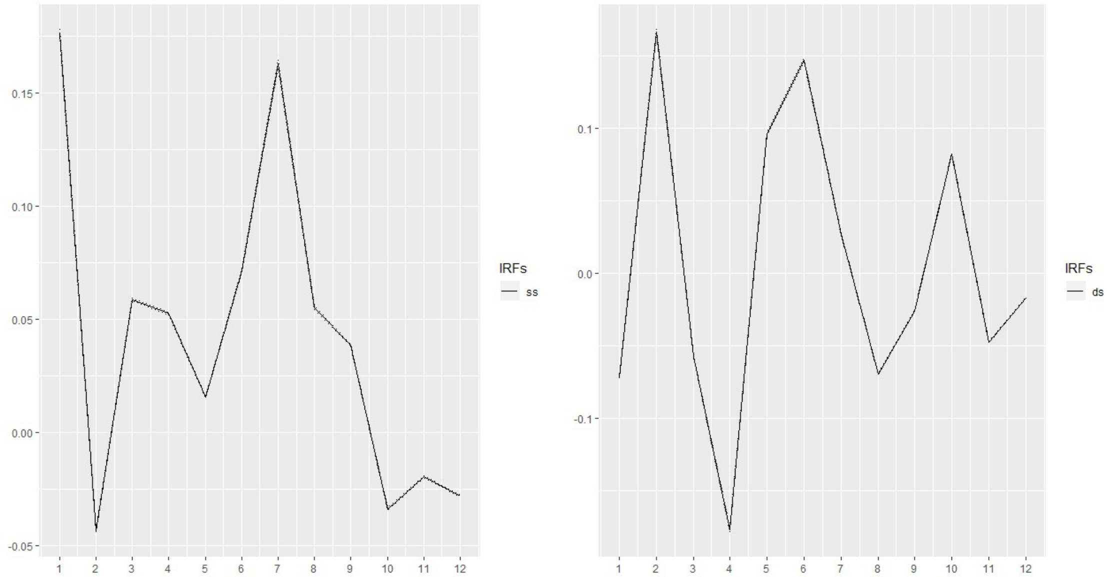
Figure 2. Response of Consumption Growth to the Four Oil Structural Shocks Contingent on High (*h*) and Low (*l*) Oil-Dependence



Note: See Notes to Figure 1. Oil Dependence: oil consumed minus oil produced as ratio of oil consumed, with *h* and *l* corresponding to high- and low-levels of oil dependence respectively.

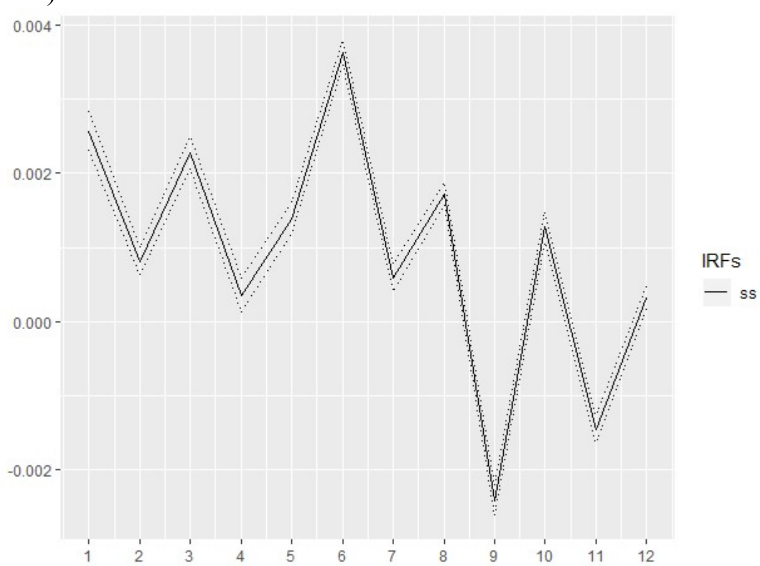
Appendix:

Figure A1. Response of Consumption Growth to Oil Supply and Demand Shocks as Identified by Caldara et al., (2019)



Note: ss: oil supply shock; ds: oil demand shock.

Figure A2. Response of Consumption Growth to Oil Supply Shock as Identified by Kilian (2008)



Note: ss: oil supply shock.