The Impact of Oil Expenses and Credit on the U.S. GDP.

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Section 1

Introduction
Hamilton (1983) made the case that most of the post-war U.S. recessions occurred after an oil-price increase.

Mork (1986) showed that the transmission channel of oil price in the U.S real GDP growth is nonlinear. By splitting oil returns in two time series, first, the positive part, second, the negative counterpart Mork found significant evidence that the positive returns of oil price significantly explains GDP growth whereas the negative counterpart doesn’t reach the significant level.

\[ o_t^+ := \max(0, o_t - o_{t-1}) \]  \hspace{1cm} (1)

\[ o_t := \log(\text{Oil price}) \]

Hooker (1996) showed that Mork’s nonlinear form does not hold when adding new data (from 1986 to 1996).
Hamilton (1996) acknowledged Hooker’s work and demonstrated that by considering the following nonlinear specification, the 1-year net oil price increase

\[ o_{t}^{Net,+1-year} := \max(0, o_{t} - \max(o_{t-1}, \ldots, o_{t-4})) \]  

(2)

the relation is stable over time.

Hamilton (2003) proved that the relation is enhanced when one considers the 3-year high.

\[ o_{t}^{Net,+3-year} := \max(0, o_{t} - \max(o_{t-1}, \ldots, o_{t-12})) \]  

(3)

Hamilton (2011) made clearly the case that the relation between oil price and the real U.S. GDP is nonlinear.
The ratio : Introduction

The ratio is defined as follow:

\[ \text{ratio}_t := \frac{\text{Oil price}_t \times \text{Oil consumption}_t}{\text{debt}_t} \]  \hspace{1cm} (4)

The data sets is:

- Producer Price Index for petroleum products\(^2\).
- Total consumption of Petroleum product (Monthly) by EIA\(^3\)
- United States, Flow of Funds, Debt Outstanding, Domestic Non Financial Sectors, Total, Federal Reserve code: LA384101005 :Q

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2. A sensitivity analysis among all the different oil prices (RAC imports, RAC exports, RAC composite and WTI) of oil will be perform.
3. The time serie starts in January 1973, our analysis starts at this date.
In order to understand the rationale behind the ratio, let’s think about its growth rate:

\[
\Delta \log(ratio_t) = \log \left( \frac{ratio_t}{ratio_{t-1}} \right) \\
= \log \left( \frac{Expenses_t}{Expenses_{t-1}} \right) - \log \left( \frac{Debt_t}{Debt_{t-1}} \right) \\
= \log \left( \frac{Expenses_t}{Expenses_{t-1}} \right) - \log \left( \frac{Oilprice_t}{Oilprice_{t-1}} \right) + \log \left( \frac{Oilconsumption_t}{Oilconsumption_{t-1}} \right)
\]
The ratio

\[ o_{t, +, 3-year}^{Net} := \max(0, o_t - \max(o_{t-1}, \ldots, o_{t-12})) \]
The ratio

\[ \text{ratio}_{t, +3-\text{year}}^{\text{Net}} := \max(0, \text{ratio}_t - \max(\text{ratio}_{t-1}, \ldots, \text{ratio}_{t-12})) \]
Section 2

OLS regressions

\[
\begin{align*}
\Delta y_t &= 0.62956^{**} + 0.21465 \Delta y_{t-1} + 0.07075 \Delta y_{t-2} - 0.01051 \Delta y_{t-3} \\
&\quad + 0.03932 \Delta y_{t-4} - 2.09821 o_{t-1}^{Net,+3-year} - 0.21844 o_{t-2}^{Net,+3-year} \\
&\quad - 2.42041 o_{t-3}^{Net,+3-year} - 2.42654 o_{t-4}^{Net,+3-year} + \varepsilon_t 
\end{align*}
\]

If one adds the linear terms, namely the return of oil price, \(\{\Delta o_{t-1}, \ldots, \Delta o_{t-4}\}\) to this regression calculates the p-value of the hypothesis that the coefficients \(\{o_{t-1}^{Net,+3-year}, \ldots, o_{t-4}^{Net,+3-year}\}\) are zero, one gets the p-value of 0.003461.
Results for the 3-year net ratio increase:

\[ \Delta y_t = 0.5802^{***} + 0.2499^{**} \Delta y_{t-1} + 0.08666\Delta y_{t-2} - 0.01827\Delta y_{t-3} \]

\[ - 0.01827\Delta y_{t-4} - 232.6^{***} \text{ratio}_{t-1}^{\text{Net, } +, 3-\text{ year}} - 47.16 \text{ratio}_{t-2}^{\text{Net, } +, 3-\text{ year}} \]

\[ - 130.5 \text{ratio}_{t-3}^{\text{Net, } +, 3-\text{ year}} - 143.0^{*} \text{ratio}_{t-4}^{\text{Net, } +, 3-\text{ year}} + \epsilon_t \] (6)

By adding the linear terms as previously, the p-value of the hypothesis that the coefficients \( \{ \text{ratio}_{t-1}^{\text{Net, } +, 3-\text{ year}}, \ldots, \text{ratio}_{t-4}^{\text{Net, } +, 3-\text{ year}} \} \) are zero is 0.0002586.
Evidences

- The adjusted-$R^2$ of model (5) is 0.209 and becomes 0.2377 for (6).

- The first lag of the real return of the U.S. GDP increases in strength when one considers the regression with the nonlinear ratio. Additionally, the first lag of the nonlinear term in the second regression is significant up to the 0.1% level.

- One can suppose that the net ratio (rather than oil) increase is a better candidate to explain short-term evolution of the real GDP movement.

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Section 3

The Parameters Stability
Few structural break tests have been executed (SupF test, Bai and Perron (2003) test, among others) to both regressions (5) and (6). None of them have detected a structural break.

- In order to study the impact of the oil shocks in our parameters, one can perform an OLS regression from the starting date to, say, 1990 :Q1 and expanding the window by adding a quarter to the subsample at each step.
**Figure**: The evolution of the 3-year net oil price increase parameters of equation (5)
None of the parameters have remained significant for every time period considered.

Each pattern is stepwise constant, meaning that the value of each parameter is slightly changing from one episode to another.
The evolution of the 3-year net ratio increase parameters of equation (6)
The first lag of the nonlinear net oil price increase has always been significant.

The stepwise behavior is far more muted for the ratio while comparing with the oil price.

Since the very beginning of 2000, the 4th lag of the 3-year net ratio increase is significant.

At the aftermath of the 07/08 financial crisis the 3rd lag became significant.
Comparing the oil price and the ratio

We are considering the following equation:

$$\Delta y_t = \sum_{i=1}^{4} \beta_i \Delta y_{t-i} + \sum_{i=1}^{4} \alpha_i o_{t-i}^\# + \sum_{i=1}^{4} \gamma_i ratio_{t-i}^\# + \varepsilon_t$$

And proceeding to an LR test:

- $\alpha_1 = \ldots = \alpha_4 = 0$ (in Black)
- $\gamma_1 = \ldots = \gamma_4 = 0$ (in Red)
**Figure**: *p*value when extending the sample.

- $\alpha_1 = \ldots = \alpha_4 = 0$ (in Black)
- $\gamma_1 = \ldots = \gamma_4 = 0$ (in Red)
Remarks

- There is an overwhelming evidence that oil price had been a better candidate to explain real U.S. GDP growth pre-2000s'.

- At the aftermath of the Dot-com bubble burst and for the remaining of the period, the ratio has been the more significant factor.

- Nevertheless, one cannot exclude neither the 3-year net oil price increase nor the 3-year net ratio increase since their p-values are below the significant level.
Section 4

Out-of-Sample Analysis
The methodology

In line with the methodology of Kilian and Vigfusson (2011a, 2011b, 2013, 2014), forecasts are constructed by Montecarlo integration based on 50,000⁴ draws. Forecasts are computed as averages of the simulated forecast path in order to compute the conditional MSPE.

\[
MSPE_t(h, \Omega_{t-1}) = \sum_{i=1}^{h} \left( \sum_{j=1}^{i} \Delta y_{t+j} - \mathbb{E}_{t-1} \left[ \sum_{j=1}^{i} \Delta y_{t+j} \right] \right)^2
\]

(7)

4. The amount of draws had been tested in order to have a stability on the final result.
Model 2 - 3-year net ratio increase (PPI)

Model 2:

\[ \Delta \text{ratio}_t = \sum_{i=1}^{4} B_{11,i} \Delta \text{ratio}_{t-i} + \sum_{i=1}^{4} B_{12,i} \Delta y_{t-i} + \epsilon_{1,t} \]

\[ \Delta y_t = \sum_{i=1}^{4} B_{21,i} \Delta \text{ratio}_{t-i} + \sum_{i=1}^{4} B_{22,i} \Delta y_{t-i} + \sum_{i=1}^{4} \delta_i \text{ratio}^{Net,+3-year}_{t-i} + \epsilon_{2,t} \]

Following Kilian and Vigfusson, we test the forecasting performance with different specifications:

- \( B_{12} = 0 \) (bis): unrestricted exogenous model.
- \( B_{21} = 0 \) (ter): restricted model.
- \( B_{12} = B_{21} = 0 \) (quart): restricted exogenous model.
Model 3 - 3-year net oil price increase (RAC)

\[
\Delta ratio_t = \sum_{i=1}^{4} B_{11,i} \Delta ratio_{t-i} + \sum_{i=1}^{4} B_{12,i} \Delta y_{t-i} + \epsilon_{1,t}
\]

\[
\Delta y_t = \sum_{i=1}^{4} B_{21,i} \Delta ratio_{t-i} + \sum_{i=1}^{4} B_{22,i} \Delta y_{t-i} + \sum_{i=1}^{4} \delta_i o_{t-i}^{Net,+3-year} + \epsilon_{2,t}
\]
Kilian and Vigfusson (2013) showed that the 3-year net oil price change model tends to have the best out-of-sample accuracy among a set of economic meaningful nonlinear oil price specifications.

\[
\begin{align*}
O_t^\# &:= o^{Net,+3\text{-year}} + o^{Net,-3\text{-year}} \\
O_t^{Net,-3\text{-year}} &:= \min(0, o_t - \min(o_{t-1} - \ldots - o_{t-12}))
\end{align*}
\]
Model 7 - 3-year net oil price change (RAC)

Model 7:

\[
\Delta o_t = \sum_{i=1}^{4} B_{11,i} \Delta o_{t-i} + \sum_{i=1}^{4} B_{12,i} \Delta y_{t-i} + \epsilon_{1,t}
\]

\[
\Delta y_t = \sum_{i=1}^{4} B_{21,i} \Delta o_{t-i} + \sum_{i=1}^{4} B_{22,i} \Delta y_{t-i} + \sum_{i=1}^{4} \delta_i o_{t-i} + \epsilon_{2,t}
\]
Model 9 - Net ratio change

**Model 9:**

\[
\Delta ratio_t = \sum_{i=1}^{4} B_{11,i} \Delta ratio_{t-i} + \sum_{i=1}^{4} B_{12,i} \Delta y_{t-i} + \epsilon_{1,t}
\]

\[
\Delta y_t = \sum_{i=1}^{4} B_{21,i} \Delta ratio_{t-i} + \sum_{i=1}^{4} B_{22,i} \Delta y_{t-i} + \sum_{i=1}^{4} \delta_{i} \Delta ratio_{t-i} + \epsilon_{2,t}
\]
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## Results period-per-period - for horizon = 1

<table>
<thead>
<tr>
<th>Model</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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</thead>
<tbody>
<tr>
<td>Model 03</td>
<td>0.32</td>
<td>1.56</td>
<td>1.05</td>
<td>1.18</td>
<td>0.98</td>
<td>1.07</td>
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<td>1.15</td>
<td>1.11</td>
<td>0.85</td>
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<tr>
<td>Model 09</td>
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<td>1.01</td>
<td>0.99</td>
<td>0.96</td>
<td>0.99</td>
<td>0.92</td>
</tr>
</tbody>
</table>

1. 90 :Q3 to 91 :Q1
2. 91 :Q2 to 00 :Q4
3. 01 :Q1 to 01 :Q4
4. 02 :Q1 to 07 :Q3
5. 07 :Q4 to 09 :Q2
6. 09 :Q3 to 12 :Q1
Results

- The performance of models with oil price are far better for the first recession (the Koweït invasion) when comparing with the ratio.
- When comparing the results over the periods (either recession periods or boom periods), models with the ratio have remain more stable over time.

We now turn to the 1-year horizon.
## Results period-per-period - for h=4

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
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<th>4</th>
<th>5</th>
<th>6</th>
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</thead>
<tbody>
<tr>
<td>Model 03</td>
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<td>0.97</td>
<td>3.21</td>
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<td>0.88</td>
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<td>0.94</td>
<td>0.69</td>
<td>0.97</td>
<td>0.97</td>
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<td>0.80</td>
<td>4.18</td>
<td>1.42</td>
<td>0.74</td>
<td>2.29</td>
<td>0.95</td>
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<tr>
<td>Model 09</td>
<td>0.97</td>
<td>0.92</td>
<td>1.77</td>
<td>1.00</td>
<td>0.83</td>
<td>0.94</td>
<td>0.80</td>
</tr>
</tbody>
</table>

1. 90 :Q3 to 91 :Q1
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4. 02 :Q1 to 07 :Q3
5. 07 :Q4 to 09 :Q2
6. 09 :Q3 to 12 :Q1
7. 02 :Q4 to 07 :Q1
The results are confirming the previous comments but few remarks are worth making.

- When one considers the period 7, namely between 2002 :Q4 to 2007 :Q1, when the run-up of oil price occurred, the ratio is doing better than the oil price in both cases.
- Model 09, the 3-year net oil price change is remarkably stable from one period to another.
Section 5

Network Analysis
Information theory - Network analysis

Used in systemic risk theory, recently developed by Addo et al. (2015), network analysis has emerged as a leading tool to understand the interdependence of a system. The core ideas of the method are:

- Identify existing causal dependencies between components of a multivariate time series,
- assess the strength of their association through a meaningful causal coupling strength measure,
- the measure is causal and lag-specific.

The information theoretic measure of causal dependencies: The Momentary Information Transfer (MIT) links — Based on the conditional Shannon entropy (1948).
Figure: MIT linkage between oil price returns and the U.S. GDP growth
**Figure**: MIT linkage between the ratio returns and the U.S. GDP growth
**Figure**: MIT linkage between oil price returns, the ratio returns and the U.S. GDP growth
Results

- On the one hand, RAC imports price growth doesn’t help to reduce U.S. real GDP entropy.
- On the other hand, the ratio (lag 1 and 4) is causal to U.S. real GDP growth.
- When considering all the variables, the interconnection between the ratio and the GDP remain the same and additionally the ratio reduces the entropy of the RAC growth.
Using the ratio rather than the price of oil enhances the explanatory strength on the short term evolution of the real U.S. GDP growth.

Especially during the Dot-com bubble burst, the ratio would have been a better indicator than the oil price to forecast the real U.S. GDP growth.
Concerning Kilian and Vigfusson (2014) comment on the time-varying recessionary effects of oil price shock, the ratio seems to give an hint on the time-varying behavior since when one is considering the ratio, the forecasting performance remains fairly stable when we are either in boom or in recession time.

By using a model-less method one finds that the ratio helps to reduce the entropy (uncertainty) of the U.S real GDP whereas the oil price measure does not have such a property.
At the light of the last result and the fact that the ratio has a good explanatory strength and a good out-of-sample performance for the period 2002-2007, while oil price was steadily running up, lead to the conclusion that indebtedness helped the U.S. to postpone the recessionary effect of the third oil shock until the the financial turmoil of 07/08.