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State of Wealth: Analyzing the Impact of Oil Dynamics on Regional Economies

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NON-TECHNICAL EXECUTIVE SUMMARY

RESEARCH MOTIVATION

Currently, the United States is the world's largest producer of oil, accounting for roughly 20% of the world's production [4]. Moreover, the US economy remains significantly dependent upon oil and natural gas:

- **80%** of the US's energy comes from oil and natural gas
- **$1.6 trillion** of federal and state tax generated from 2012 to 2025 (proj.)
- **19 million** jobs would be lost by 2025 (proj.) if hydraulic fracking halts [13]

However, in recent decades, with passing of legislation such as the 1992 Kyoto Protocol and 2015 Paris Climate Agreement, countries around the world have committed to gradually eliminating the use of oil and other fossil fuels. Considering the US government's current commitment to achieve a 50–52% reduction in net greenhouse gas pollution by 2030 (in comparison to 2005 levels) [9], it is of paramount importance for the US to understand the significance of the oil industry and consider how it can successfully transition to a cleaner future without devastating the economy. Thus, in this report, we investigate the economic impact oil has on a state's economies and how sustainably the wealth gained from increasing oil production and price was captured between the years 2010 and 2022.

KEY FINDINGS

We attempt to answer the following question: How does production and the price of oil affect economic growth at a state level? In particular, we leverage regression models and Welch's t-tests to understand oil's economic impact on state economies and local population wealth and concretely derive four key insights:

1. Increases in oil production heavily impact household income growth in states that produce large amounts of oil.
2. Changes in WTI price strongly correlate to household income changes in states that produce large amounts of oil.
3. During times of high oil prices, increased oil production per capita is correlated with higher income growth, but when oil prices fall the correlation reverses direction and lower production per capita is correlated with higher income growth.
4. In oil dependent states, unemployment is highly negatively correlated with oil production. per capita
5. Through diversifying the economy, states can effectively mitigate the drastic economic harms that arise from weaning off of oil dependence.

Our quantitative analysis corroborates key findings regarding the critical importance of oil to local economies and the significance of diversifying state economies for long-term financial sustainability and growth.

TECHNICAL SUMMARY

DATA EXPLORATION & PREPROCESSING

The data used in this report was selected to understand the relationship between economic metrics and oil production on a state-by-state basis. This includes datasets on oil production, unemployment, and housing prices by state, and US economic data per state.

The first task was processing the provided American Community Survey state economic dataset from the US Census Bureau. The original format did not have separate columns for the various metrics, so we reformatted the data using python's Pandas package in order to enable each metric to have a unique column, such that each row represents the data for one state per year. We also calculated year-over-year percent change for median household income for each state.

The remaining datasets (oil production, unemployment, and housing) were imported as Pandas data frames. Finally, these data frames were combined by state name and date, allowing for comparative analyses and visuals generated by PyPlot.

INCREASED OIL PRODUCTION RAISES HOUSEHOLD INCOME

We first used median household income as well as median household income growth as a proxy of how oil production affects the earning potential of the population of each state.

Leveraging information from the United States Census Bureau's American Community Survey (ACS) regarding the median wages of individuals, [3] for unemployment numbers for each state [1], for barrels of oil produced per year by each state, and the provided commodities dataset for West Texas Intermediate (WTI) crude oil values. We plotted year-over-year changes in median household income against per year median household income as shown below in figures 1.1–1.4. Furthermore, each data point was scaled by the number of barrels of oil produced per person by each state during that year.

From the graph we make the following observations:

- In states with relatively high oil production per capita, earning potential was **highly correlated** with the price of oil during a particular year.
- States with high oil production per capita experienced significant **income growth** and outperformed the national average between 2011 and 2016.

This growth appears directly tied to high oil prices (as measured by the WTI average). However, a sharp decline occurred around 2017, with a rebound from 2018 to 2022. While multiple factors contribute to economic trends, these oil-producing states show a clear correlation between oil prices and economic performance. It's important to note that income

changes can lag behind oil price fluctuations.

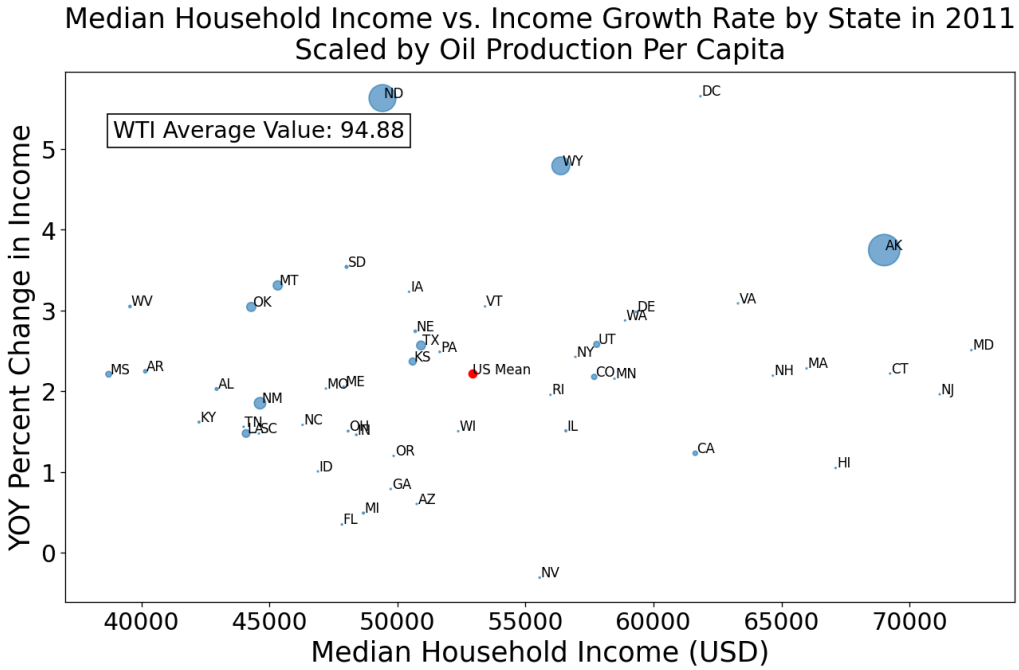
Based on these observations, we narrow the focus of our report to four states—North Dakota, Alaska, Wyoming, and Oklahoma—which produce significantly more oil per person than the national average. These case-study states will enable us to understand the impact that oil has on the United States. We will refer to these four states as heavily **"oil-dependent"** throughout this report.

For example, North Dakota offers a stark example. In 2014, it produced around 1,000 barrels of oil per working person (**50 times** the national average) and had the **highest increase** in household median income of any state. This coincided with WTI prices, which were seen to be around $90. However, as oil prices fell in the mid-2010s, North Dakota's economic outperformance faded. By 2019, with WTI averaging $57 a barrel, the bottom four states in median household income gains were North Dakota, Alaska, Wyoming, and Oklahoma—all major oil producers per capita.

The recent rise of fracking further amplifies these effects. Fracking's energy-intensive nature creates a break-even point of over $50 per barrel [10]. Areas like North Dakota's Bakken field lacked pipelines forcing transport by rail, further increasing costs. This makes the fracking industry highly vulnerable to low oil prices. Prolonged downturns can be devastating – Moody's Ratings, an agency that provides international financial research, concluded the industry never fully recovered from the 2015-2016 slump, with 208 producers declaring bankruptcy between January 2015 and December 2019 [11].

Given these trends across our four key states, we aim to better understand them by analyzing the impact of oil prices on year-over-year change in median household income. We'll isolate a state's relative outperformance by subtracting the national average change in median household income, thereby controlling for inflation and broader economic trends.

In addition, we observed that while Texas is the largest oil-producing state in the country, due to its large population and highly diversified economy, the impact of the oil industry differs with the four oil-dependent states mentioned above. We elaborate further on how oil impacts Texas on page 13.



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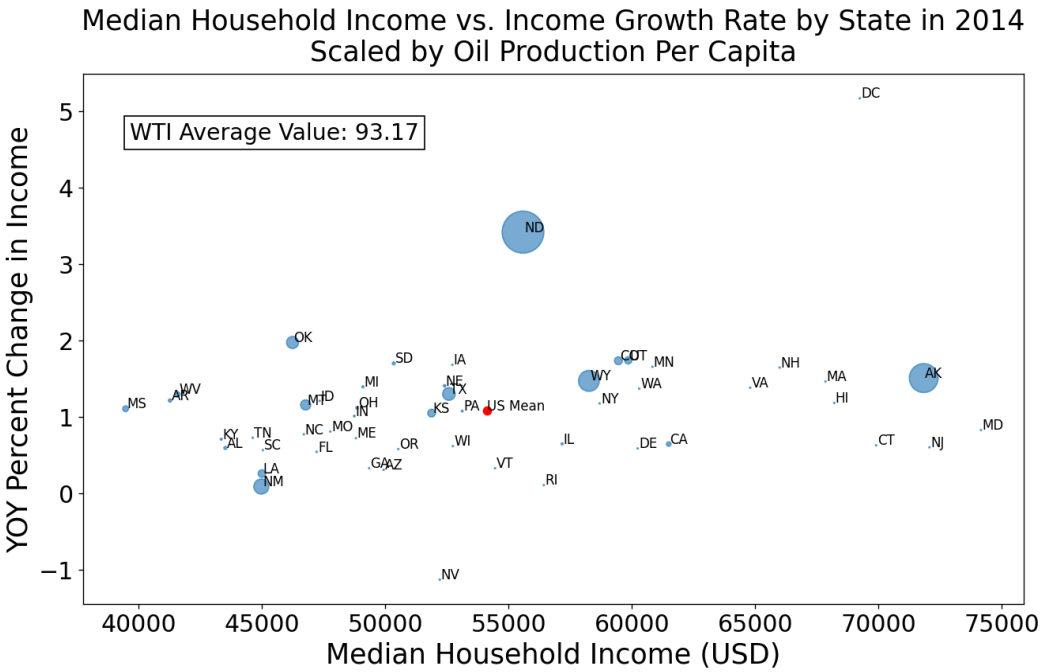
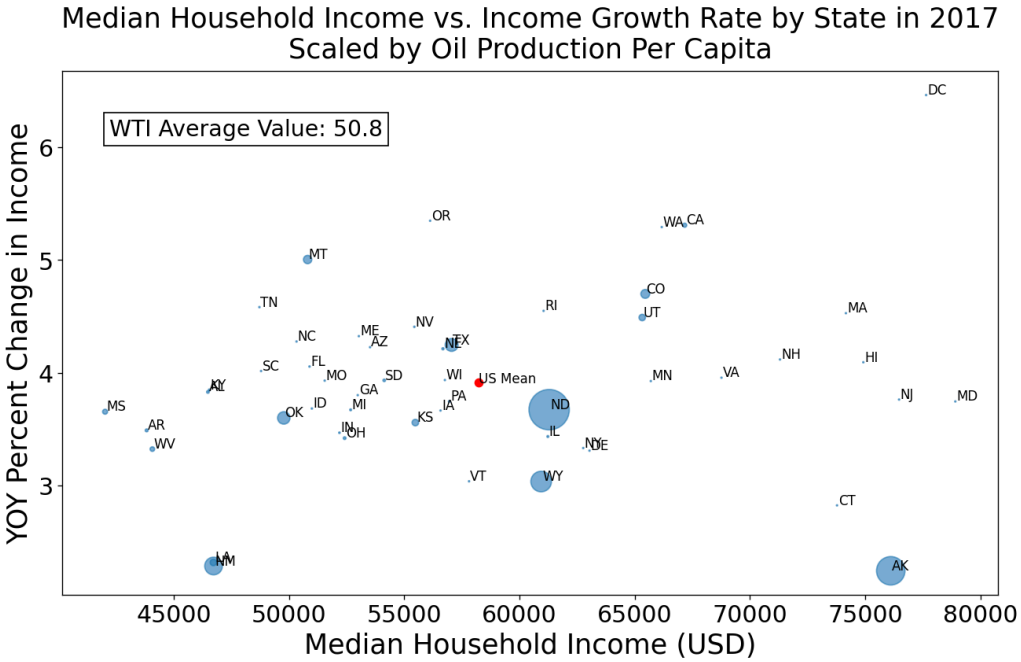


(figure 1.2)

Figures 1.1, 1.2: In the early 2010s, WTI traded in the $90s and high oil prices lead to increases in median household income in oil heavy states like North Dakota, Wyoming and Alaska far above the national average.



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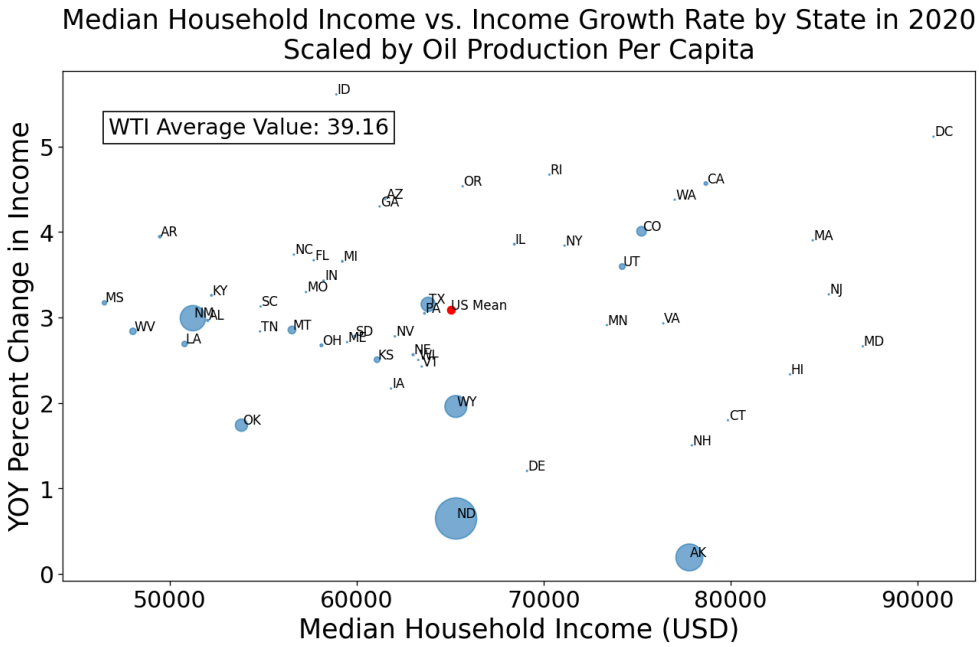
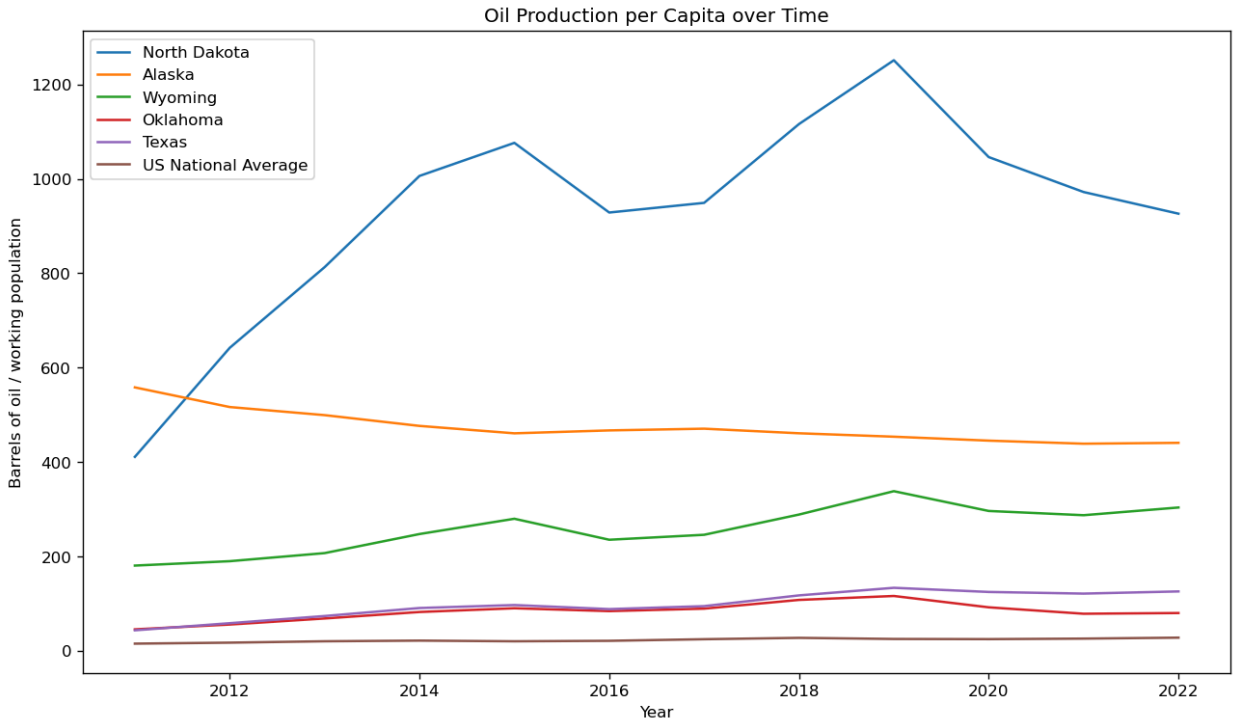


(figure 1.4)

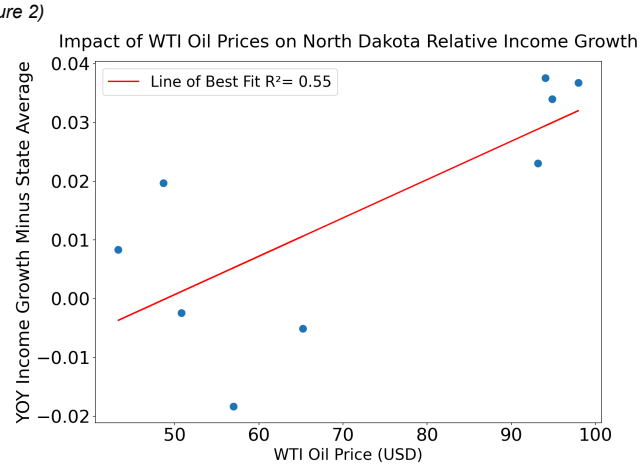
Figures 1.3, 1.4: However in the late 2010s, oil prices fell drastically, and median household incomes in those same oil-dependent states lagged far behind the national average with states that had previously been near the top now following to the bottom.



(figure 2)

In the four oil-dependent states, we seek to understand these trends in greater detail by exploring the effect of oil prices on year-over-year median household income growth. To control for inflation and general economic trends, we subtract the average change in median household income across all states to measure the relative outperformance of a given state relative to the national average in a given year.

Performing a linear regression, we observe an average R^2 value of 0.4, which indicates that approximately 40% of the variance in the outperformance of wage growth can be explained solely by the average WTI value for each year.



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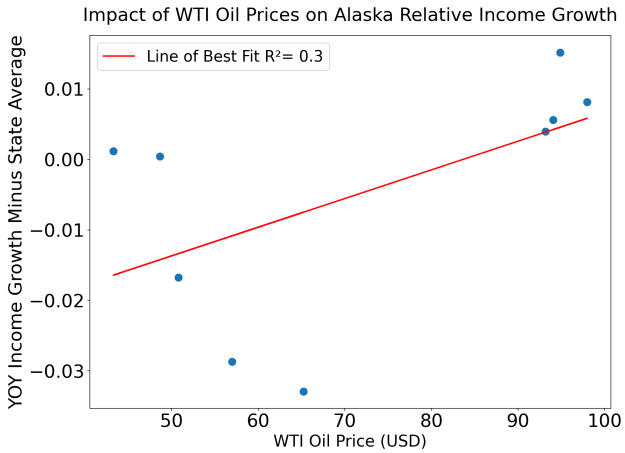

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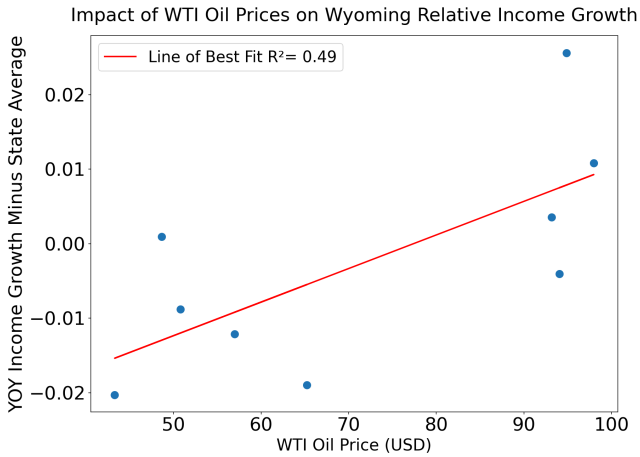

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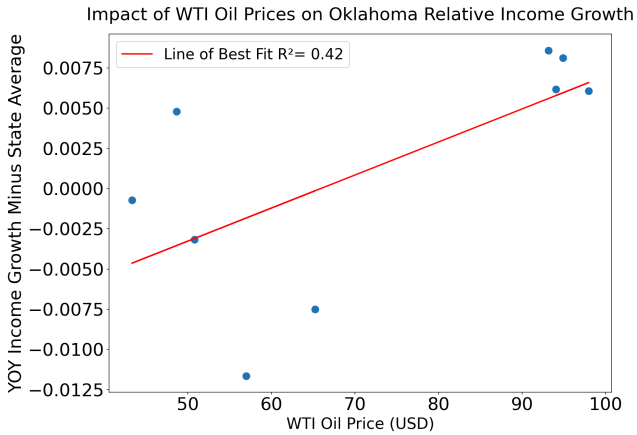

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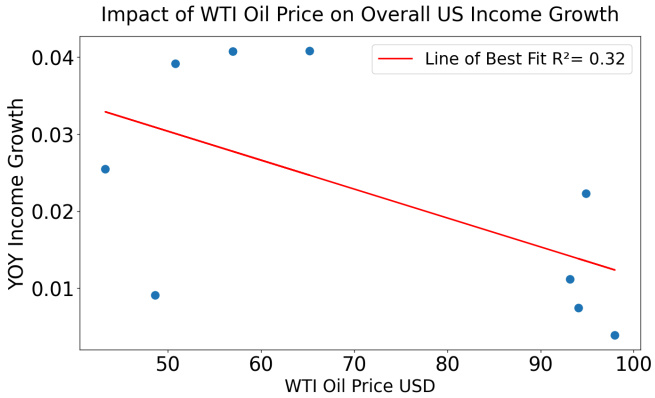


(figure 3.5)

These observations are logically sound, as these states produce vast amounts of oil per capita. During periods of high WTI, companies are incentivized to drill more, creating an abundance of high-paying jobs in oil fields. A secondary effect of this economic growth is the creation of thousands of new housing units for oil workers moving to the state, as well as increased spending on areas such as food and goods, bolstering overall economic growth in heavily oil-dependent states. However, as a result of this reliance, the household median income far exceeds the US national average when WTI values are high, and significantly drops when WTI values fall.

To further investigate the impact that WTI prices have on **median wage changes**, we perform a 2-sided Welch's T-test. We grouped the data into two distinct time frames—periods where WTI was higher than $90/barrel, and periods when WTI was lower than $70 a barrel. We also split the states into two groups—states that produced more oil per capita than

the national average (oil-dependent states) and states that produced less oil per capita than the national average (oil-independent states). The null hypothesis for the T-test is that there is no difference between the means, whereas the alternative hypothesis is that there is indeed a difference.

In years with high oil prices, oil-dependent states had an average yearly increase in median household income of 3.13%, compared with 2.55% for oil-independent states. This has a **p-value of 0.369**, so at a power level of 0.05 we don't have enough evidence to reject the null hypothesis. For years with lower prices, oil-dependent states had an average yearly increase in median household income of 2.88%, compared with 3.57% for oil-independent states. This had a p-value of 0.007, which is low enough to reject the null hypothesis. Thus, when WTI prices are low (below $70), there is a **statistically significant change** in median household income growth between states that **produce above and below-average** barrels of oil per capita.

	Years where WTI > $90	Years where WTI < $70	Results
States with per capita oil production greater than national production levels	3.13% median household income growth	2.255% median household income growth	T stat = 0.900 p = 0.369 df = 258.0
States with per capita oil production less than national production levels	2.88% median household income growth	3.57% median household income growth	T stat = -2.725 p = 0.007 df = 362.0

2 Sided (Welch T-test)

Interestingly, on a national level, the correlation between oil prices and median household income growth is inversely related—wages grew slower when WTI values were high and grew faster when WTI values were low. This phenomenon may be explained by the fact that the general population's demand for oil is highly inelastic in the short term—if one needs to drive to work or purchase groceries, one has no choice but to accept the higher oil prices. Similarly, corporations cannot suddenly cancel orders or deliveries due to rising costs of oil and increasing transportation costs. These observations are corroborated by a report from the Congressional Budget Office, which noted that "real household income has grown less rapidly in the past few years than it would have if energy prices had not risen substantially" [2].

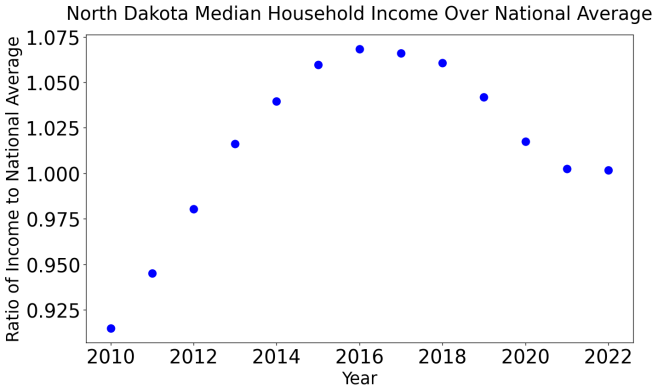
CHANGES IN WTI PRICE CORRELATES WITH HOUSEHOLD INCOME

Considering how important oil is to these economies and current US efforts to transition away from fossil fuels in the long run, having a quantitative understanding of how oil prices impact the incomes is key for economic forecasts of these states.

Next, we observe how rises in oil prices impact the ratio of median household income in heavily oil-dependent states and the national average. We

note in figures 4.1-4.4. that the state average income growth rate has an inverse correlation to WTI prices.

For the four oil-dependent states, there was a rise of median household income in comparison to the national average in the first half of the decade, before reaching a peak around 2016 and subsequently decreasing compared to the national average. It is important to note here that the perceived reduction in median household income **does not arise** from a drop in income in oil dependent states, but rather a **stagnation in those states** while other states experienced wage growth arising from other sectors such as tech.



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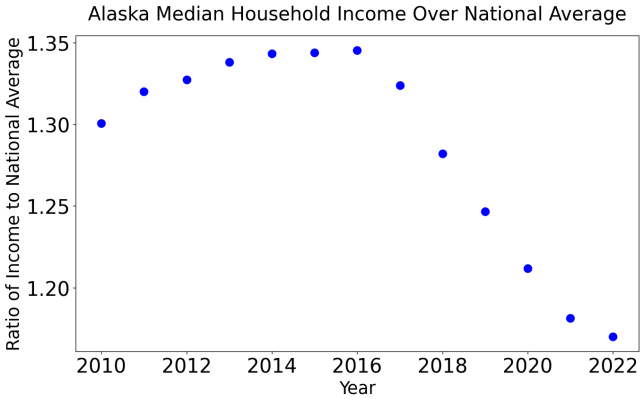

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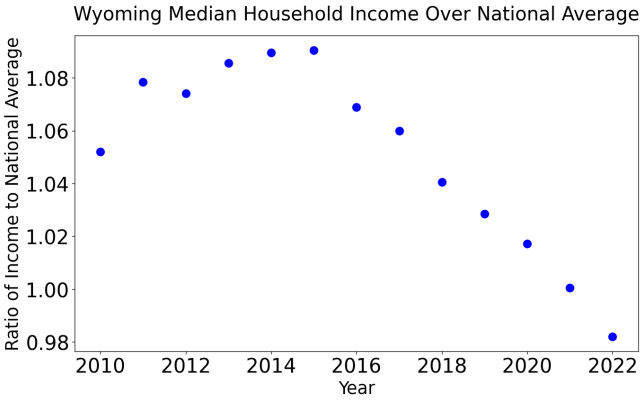

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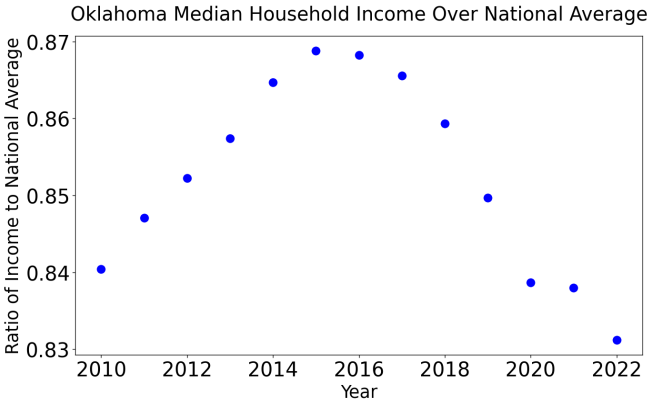
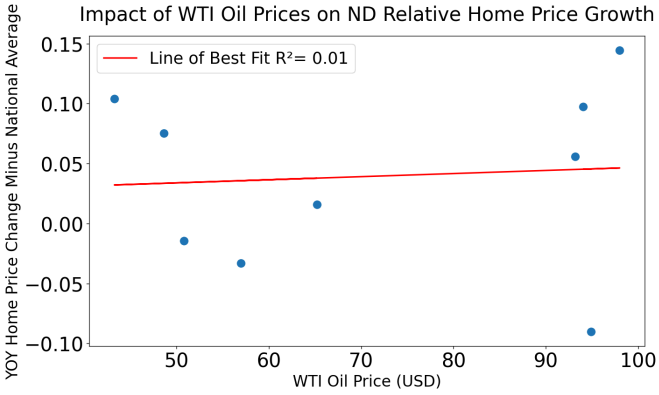


(figure 4.4)

Not to mention, median household income appears to be highly correlated to the average price of homes in the 5 states. Intuitively, this makes sense—the household's level of income is broadly proportional to how much a household can spend on housing. In fact, according to the Pew Research Center, the median use homeowner derives 45% of their net worth from the value of their home [12].

Thus, efforts to transition away from oils, whose prices are inextricably tied to median household income and the prices of houses, will lead to a measurable reduction in US household's net worth.



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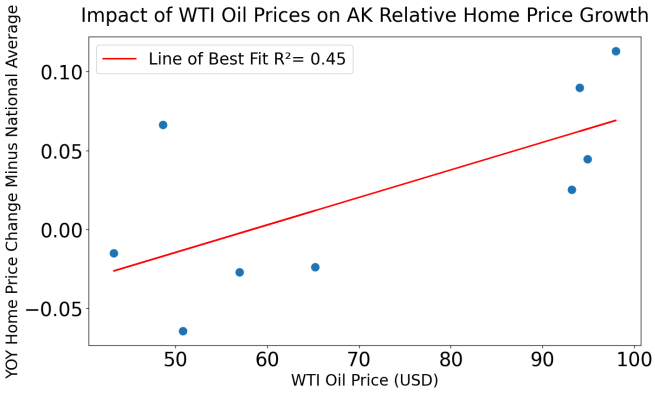

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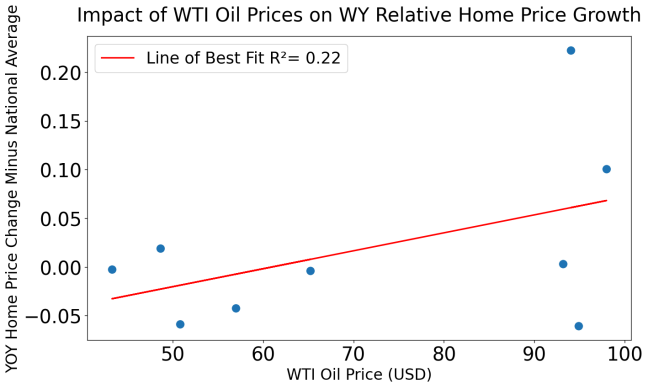

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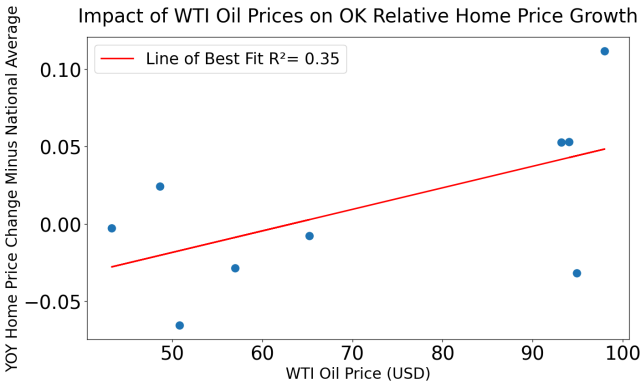

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INCREASES IN OIL PRODUCTION LOWERS UNEMPLOYMENT

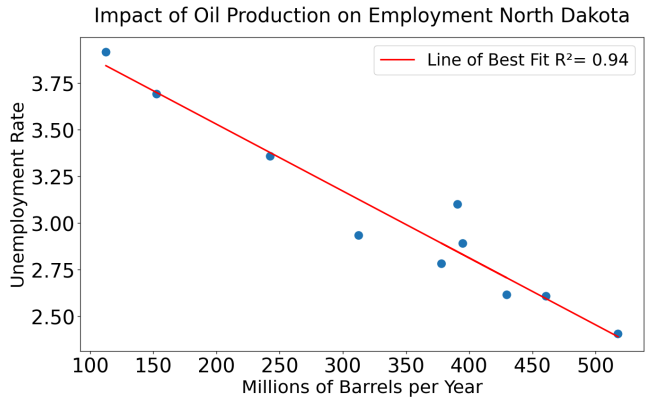
Next, we observed the relationship between state's unemployment rates and levels of oil production to determine the impact that transitioning away from oil will have on different states. Utilizing data from [1] for state's monthly unemployment rates from the years 2010 to 2019 (the years 2020-2022 were not investigated, due to the once-in-a-century effects of the COVID-19 pandemic) a yearly average was calculated to normalize and account for seasonal trends. This data was combined with the aforementioned data on barrels of oil produced per capita, and a regression model was constructed.

The data presents a strongly negative correlation between oil production and unemployment rate – further evidence for the first-order explanations where an increase in oil production leads to an increased demand for workers to process the oil, which in turn employs more people.

There are also second order effects of a booming industry—it creates demand for jobs servicing the oil industry. Indeed, North Dakota saw a large increase of

jobs in home building during this decade, increasing by almost 150% according to data from the St. Louis Federal Reserve [15]

In summary, we note that total oil production and unemployment rates are inversely related.



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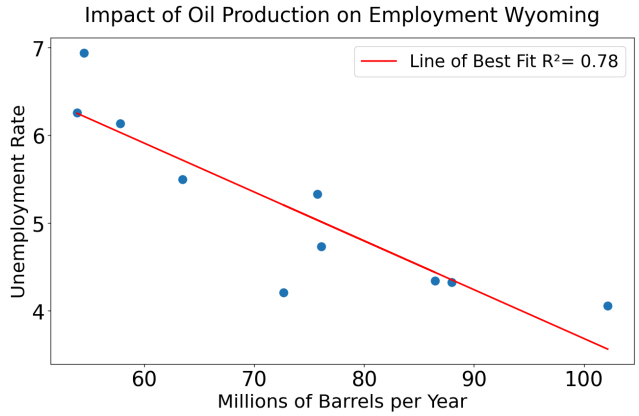

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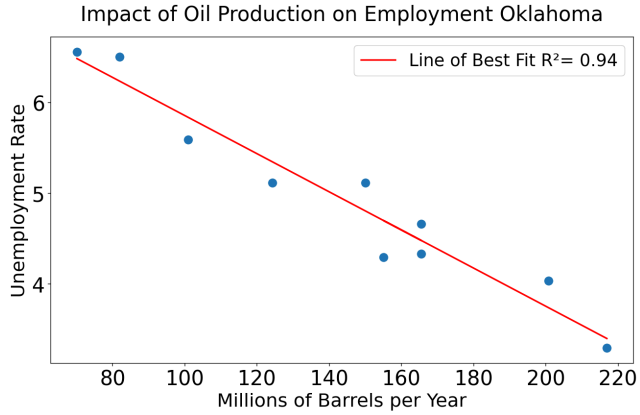

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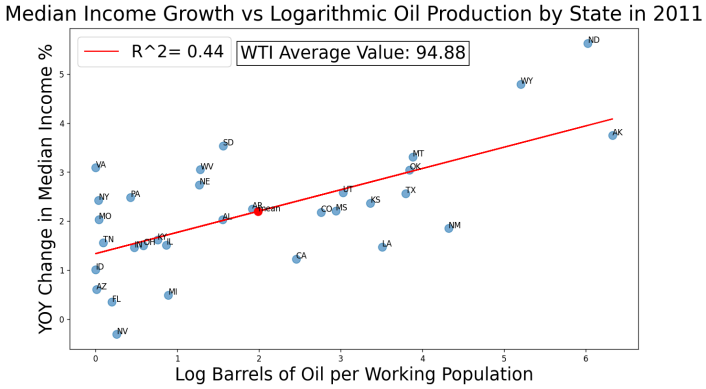
CHANGES IN MEDIAN INCOME CORRELATES WITH PER CAPITA OIL PRODUCTION

To estimate the impact of oil on a state's economy, we regressed year over year change in median income against the natural log of the number of barrels produced per capita per state (excluding states that produced 0 oil). In years where oil prices are high (WTI > $90), there is a positive correlation between the amount of oil produced and the increase in household median wages. However as the decade progressed and oil prices fell, this correlation went to zero and then reversed, as states that produced less oil experienced more economic growth.



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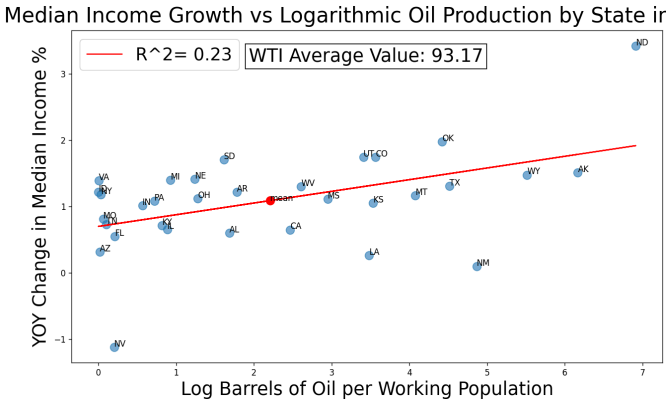

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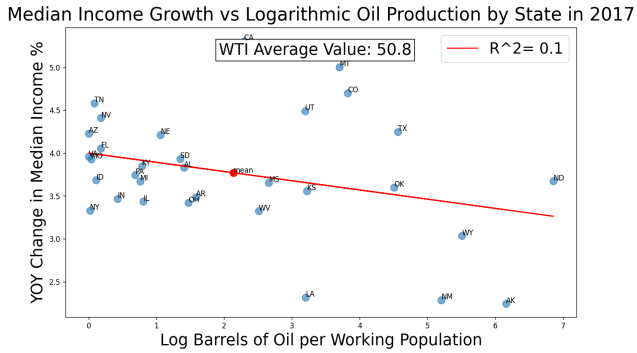

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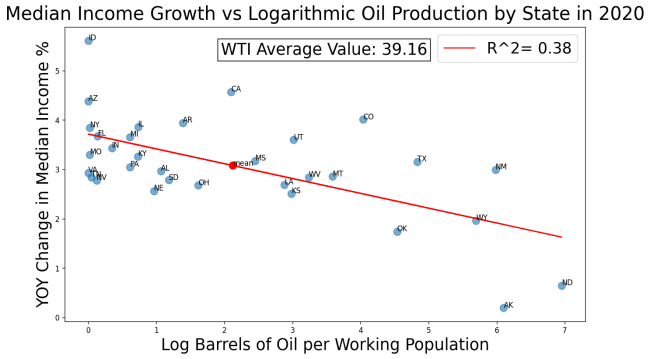

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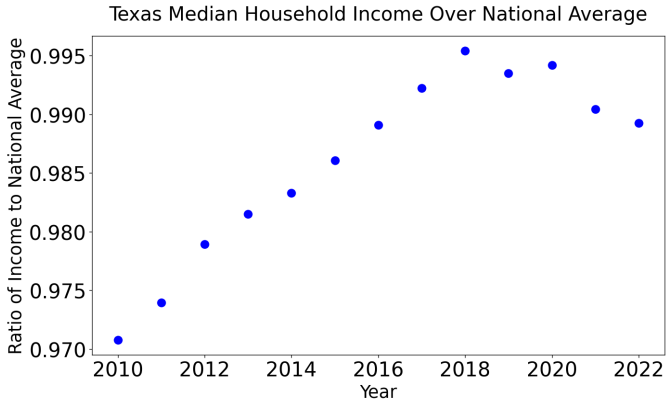
THE IMPACT OF OIL ON TEXAS

As noted above on page 4 of the report, despite its large oil production, Texas functions differently from the four oil-dependent states due to its large population and highly diversified economy.

More concretely, compared to the other states, the correlation between WTI prices and YOY income growth has very little correlation. For Texas, the R^2 value is 0.06 while for oil-dependent states like North Dakota and Wyoming, the R^2 values are 0.55 and 0.49 respectively. Furthermore, we observe that oil prices are substantially more predictive of median wage growth in these oil-dependent states than in Texas, which suggests that other sectors like tech drive Texas wage growth. Furthermore, when looking at the graph of Texas's relative income to the rest of the country, we don't see the same rapid fall in the late 2010s. Oil production is still tightly correlated with employment, however, so Texas which would imply oil drives employment levels. These observations and analyses corroborate with 2019 state-wide analyses from PricewaterhouseCoopers. [16]



CONCLUSION

KEY FINDINGS

In summary, our investigation concludes that increases in oil production meaningfully boost economies of states that are reliant upon them in times of high oil prices, but that the wealth gained is not sustainable. While West Texas Intermediate (WTI) prices were high in 2011-2015, the states with the most growth in median household income were those that produced the most oil per capita. However, as the price of oil fell from 2016-2020 those same states experienced some of the least growth in median household income.

Across the whole time period, in these oil dependent states unemployment was strongly negatively correlated with oil production per capita - a clear indication that employment was driven by the fossil fuel industry. Money spent by people in the oil industry flows into the local economy and drives demand.

Texas stands out as an outlier – although it produces above the national average in terms of oil production per capita, income growth is much less correlated with the price of oil than in other states, and it has sustained much more of the relative wealth gain from the early 2010s. We conclude that Texas's differential situation arises from its greater population size and diversification of economy, meaning that the state's overall economic performance is not as dependent upon the fluctuations of oil prices and production.

POLICY RECOMMENDATIONS

As we look forward to a future transitioning away from fossil fuels, the International Energy Agency has forecasted that demand for oil and gas will peak by 2030. [14] Our results corroborate this narrative and quantitatively shows that states that oil-dependent states are at risk and that diversification, like the case of Texas, provides a viable solution to enabling this transition while minimizing impact to US households.

From the perspective of a policy maker or economic planner, there is an imperative to diversity away from the oil industry in these states. From an investor perspective, one should take into consideration a high likelihood of economic stagnation in states whose economies are largely concentrated in oil.

FUTURE RESEARCH DIRECTIONS

Throughout our report, we have noted that correlations hold much stronger from 2010 to 2019, before the COVID-19 pandemic, than during and after. Furthermore, unprecedented events in recent years, such as the 2022 Russian invasion of Ukraine and subsequent sanctions of Russian oil have further complicated our data. With improved information and

time, we can formulate a better understanding of the immediate, residual, and confounding effects of these international events that would enable an even more concrete understanding of how oil impacts the lives of Americans in the status quo.

Moreover, by incorporating data from other heavily oil-dependent regions around the world such as Alberta, Canada and the Orinoco Belt in Venezuela, we can further understand if our insights generalize beyond the United States.

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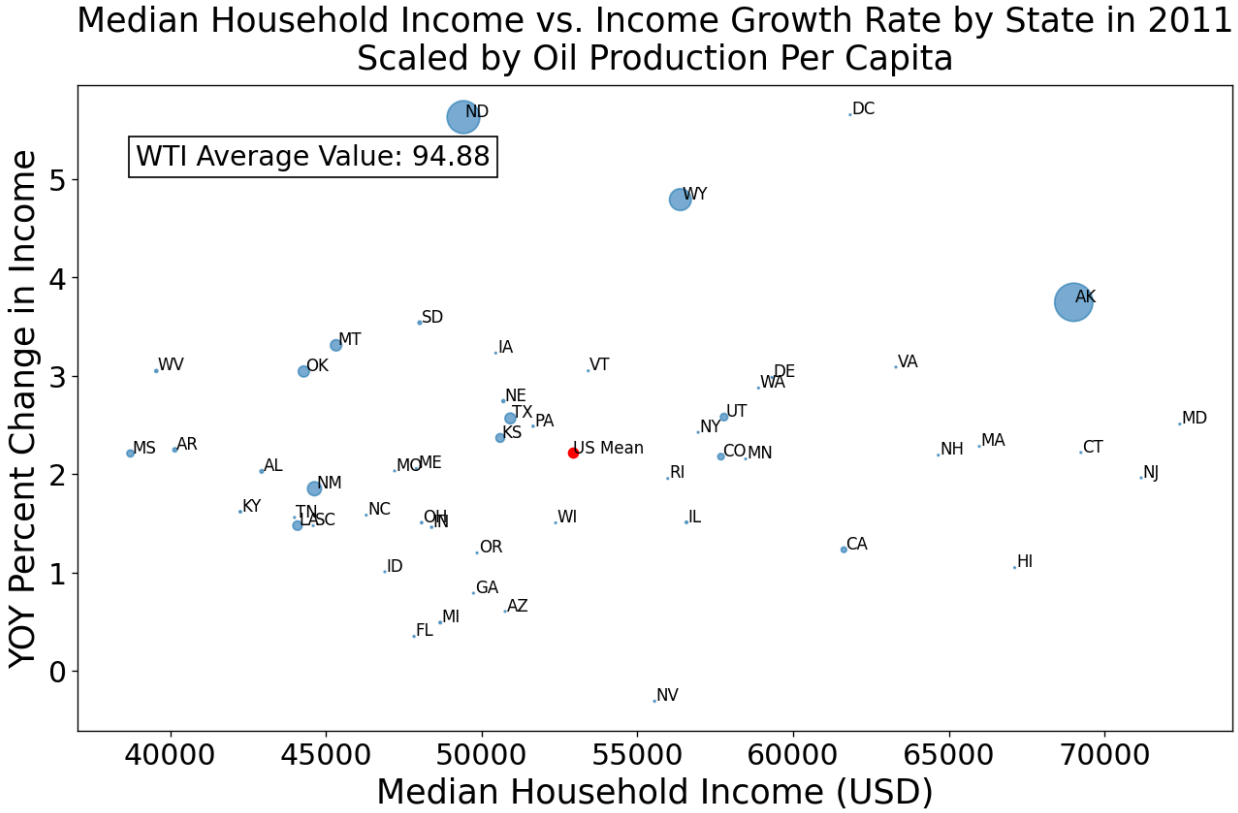
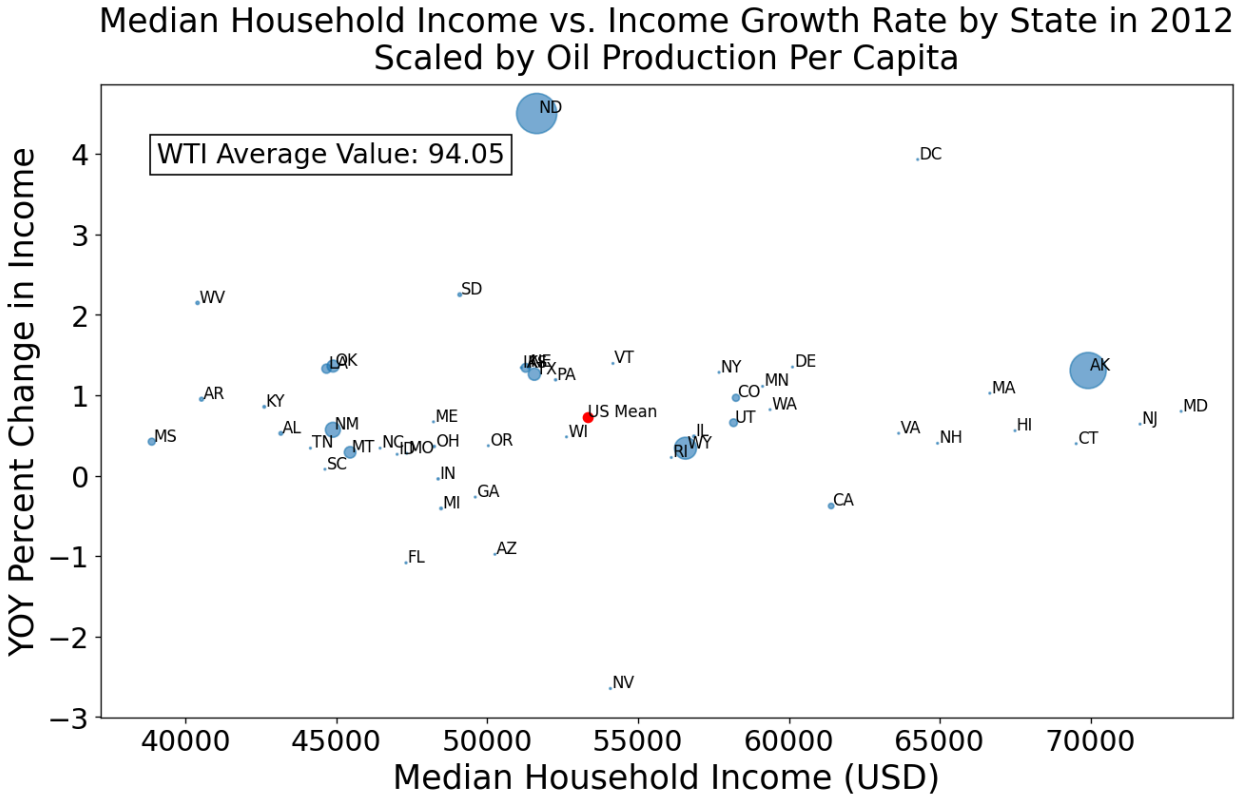
APPENDIX

A. STATE MEDIAN HOUSEHOLD INCOME VS CHANGE IN INCOME FROM 2011-2022




Median Household Income vs. Income Growth Rate by State in 2012
Scaled by Oil Production Per Capita
WTI Average Value: 94.05
YOY Percent Change in Income
Median Household Income (USD)
US Mean
ND
DC
WV
SD
VT
NY
DE
AK
MN
CO
WA
MA
AR
KY
US Mean
UT
MD
NJ
MS
AL
NM
ME
WI
VA
NH
HI
CT
TN
MT
OH
OR
RI
WY
SC
IN
GA
MI
CA
FL
AZ
NV
4
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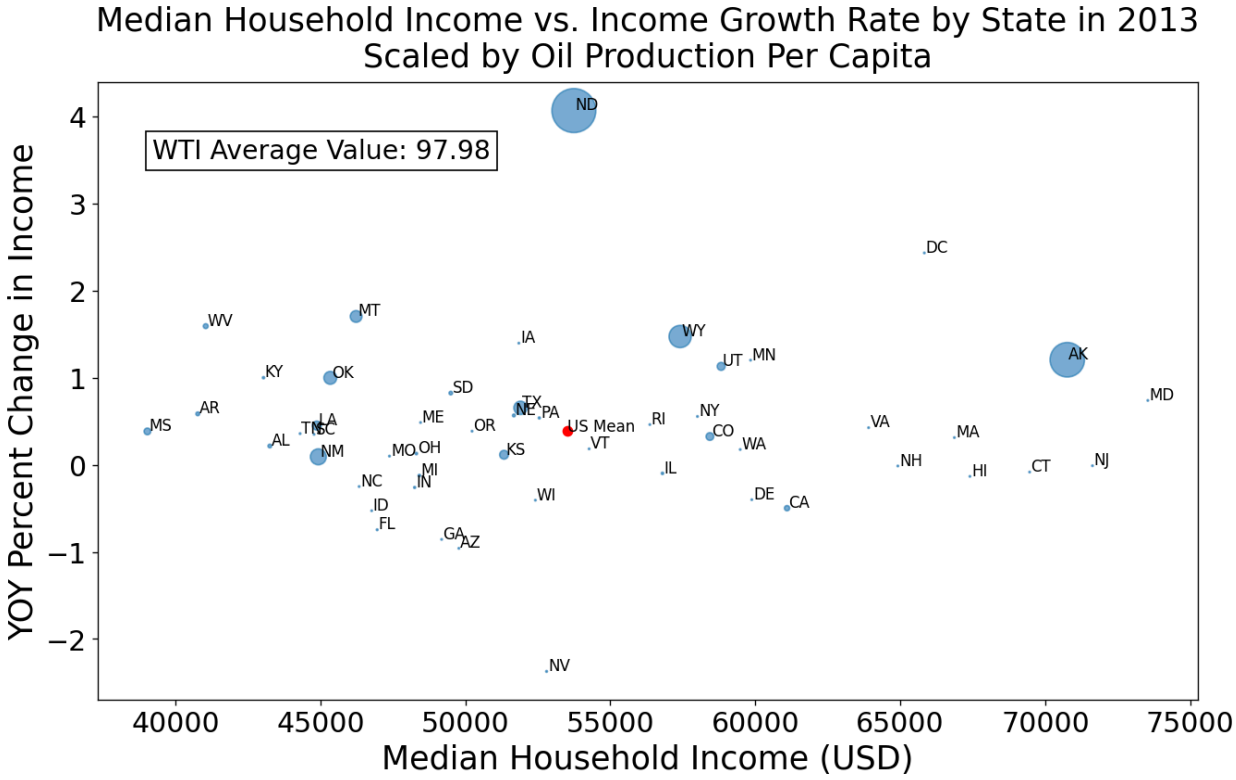
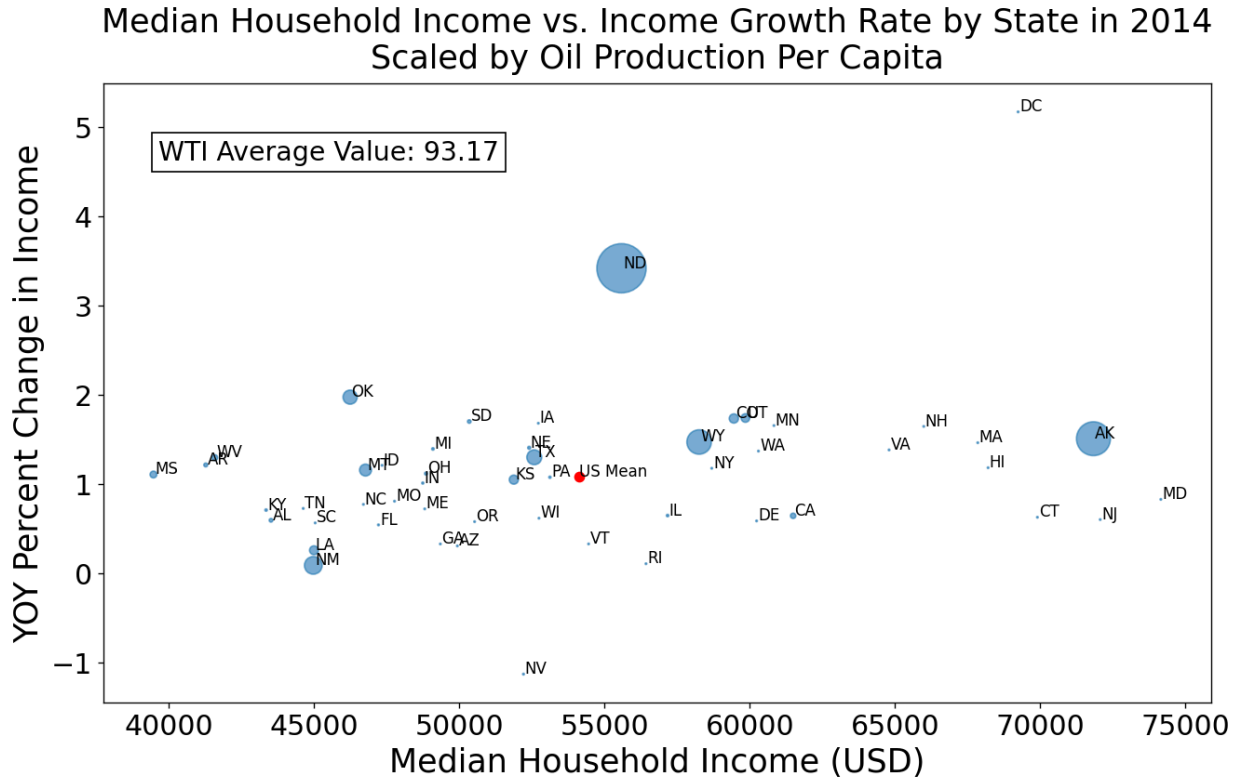
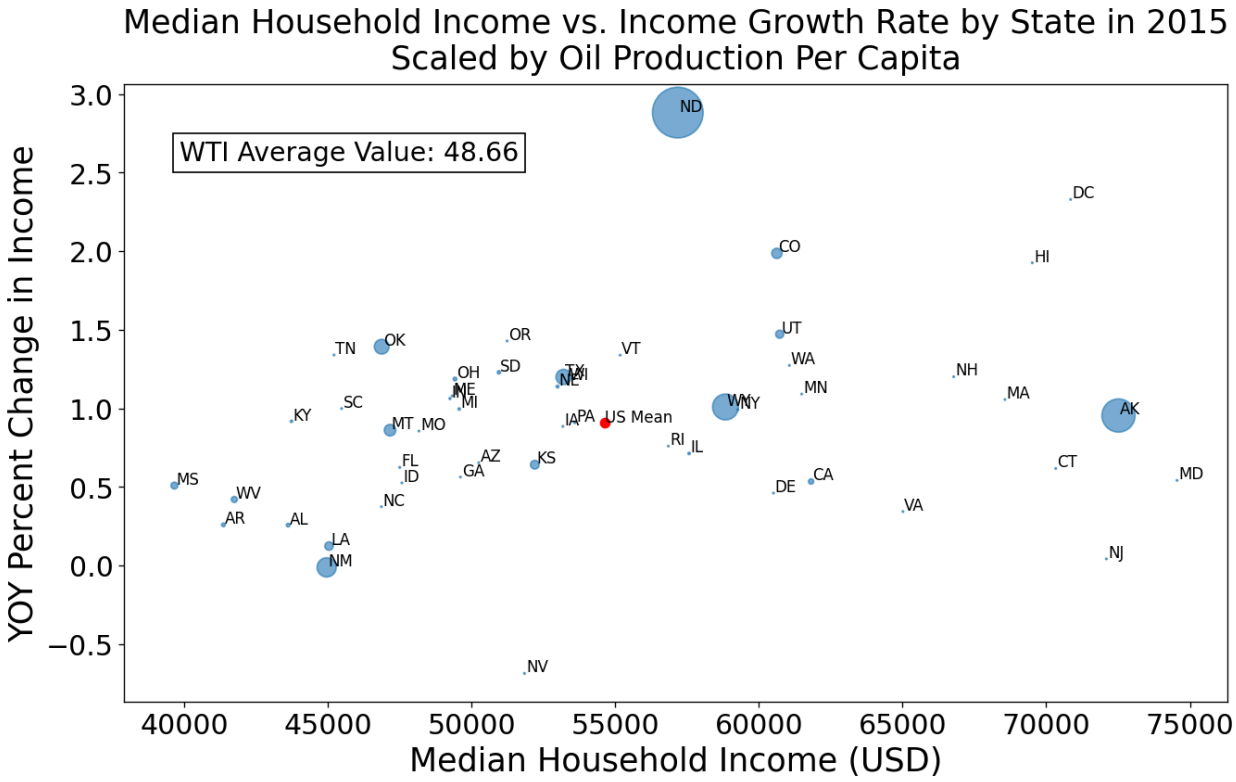
2
1
0
−1
−2
−3
40000
45000
50000
55000
60000
65000
70000


Median Household Income vs. Income Growth Rate by State in 2013
Scaled by Oil Production Per Capita
WTI Average Value: 97.98
YOY Percent Change in Income
Median Household Income (USD)
US Mean


Median Household Income vs. Income Growth Rate by State in 2014
Scaled by Oil Production Per Capita
WTI Average Value: 93.17
YOY Percent Change in Income
Median Household Income (USD)
US Mean


Median Household Income vs. Income Growth Rate by State in 2015
Scaled by Oil Production Per Capita
WTI Average Value: 48.66
YOY Percent Change in Income
Median Household Income (USD)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
40000
45000
50000
55000
60000
65000
70000
75000
ND
DC
CO
HI
UT
TN
OK
OR
VT
WA
OH
SD
NH
MN
MA
SC
KY
MT
MO
IA
PA
US Mean
AK
RI
IL
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MS
WV
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CA
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NM
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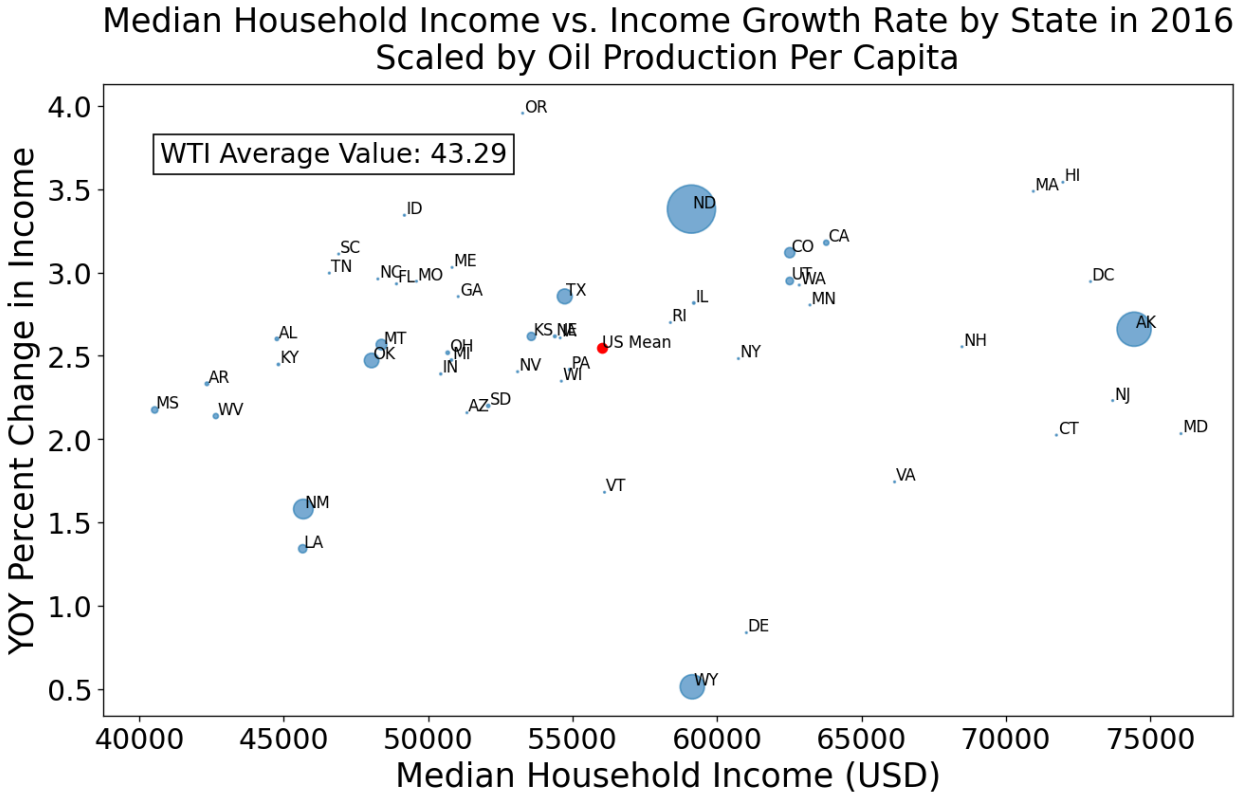
Median Household Income vs. Income Growth Rate by State in 2016
Scaled by Oil Production Per Capita
WTI Average Value: 43.29
YOY Percent Change in Income
Median Household Income (USD)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
40000
45000
50000
55000
60000
65000
70000
75000
OR
ND
ID
MA
HI
CA
CO
SC
TN
NC
FL
MO
ME
GA
TX
UT
WA
MN
IL
RI
DC
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KY
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US Mean
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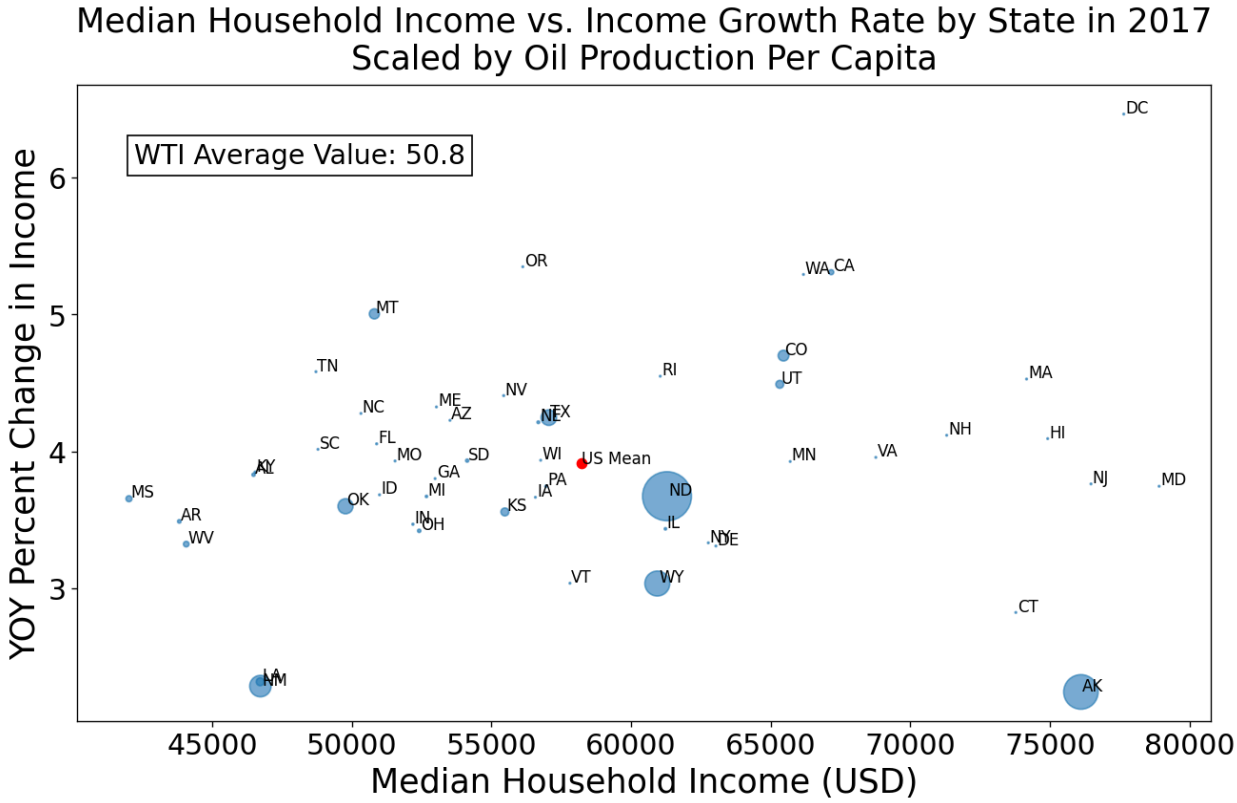
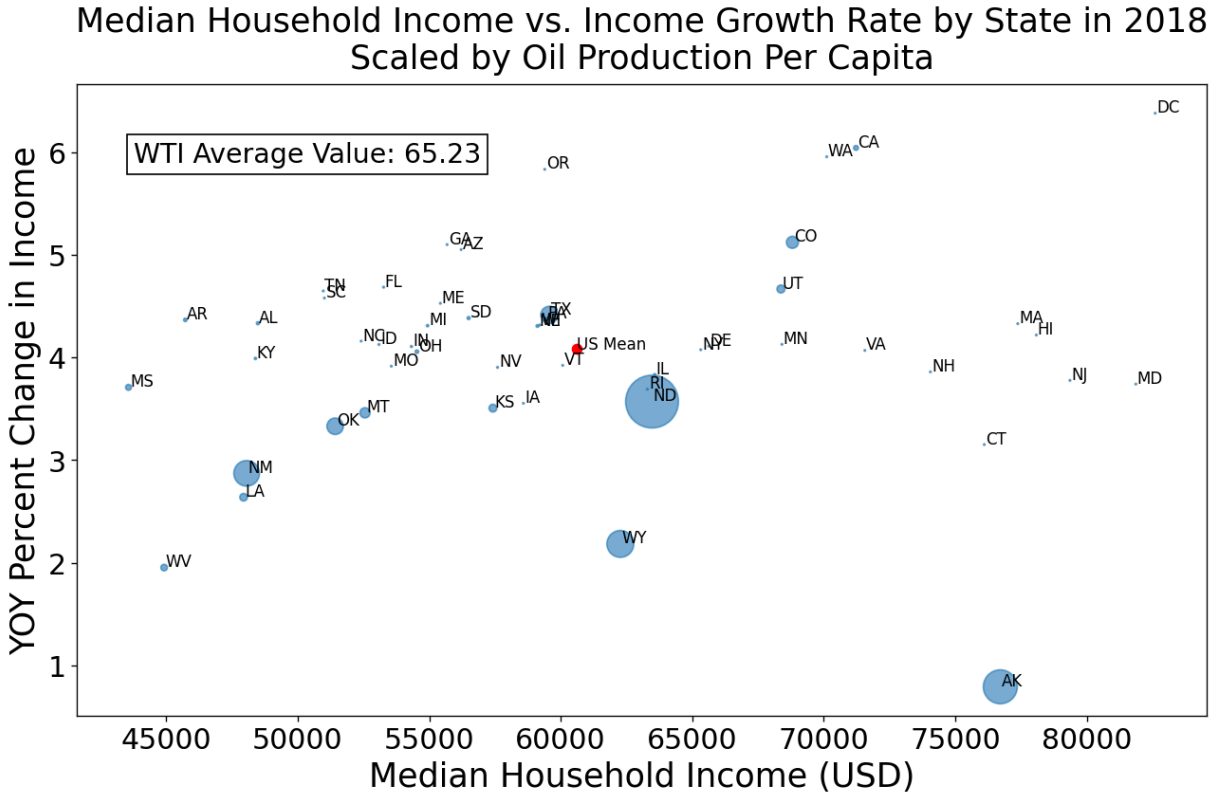

Median Household Income vs. Income Growth Rate by State in 2017
Scaled by Oil Production Per Capita
WTI Average Value: 50.8
YOY Percent Change in Income
Median Household Income (USD)
US Mean
DC
OR
WA
CA
MT
CO
TN
RI
UT
MA
NV
NC
ME
AZ
NE
TX
NH
HI
SC
FL
MO
SD
WI
MN
VA
KY
AL
GA
PA
NJ
MD
MS
ID
MI
IA
ND
OK
KS
AR
IN
OH
IL
WV
NY
DE
VT
WY
CT
LA
NM
AK
45000
50000
55000
60000
65000
70000
75000
80000
3
4
5
6


Median Household Income vs. Income Growth Rate by State in 2018
Scaled by Oil Production Per Capita
WTI Average Value: 65.23
YOY Percent Change in Income
Median Household Income (USD)
US Mean
DC
WA
CA
OR
CO
GA
AZ
UT
TN
SC
FL
ME
AR
AL
SD
MI
TX
MA
HI
NC
ID
IN
OH
DE
MN
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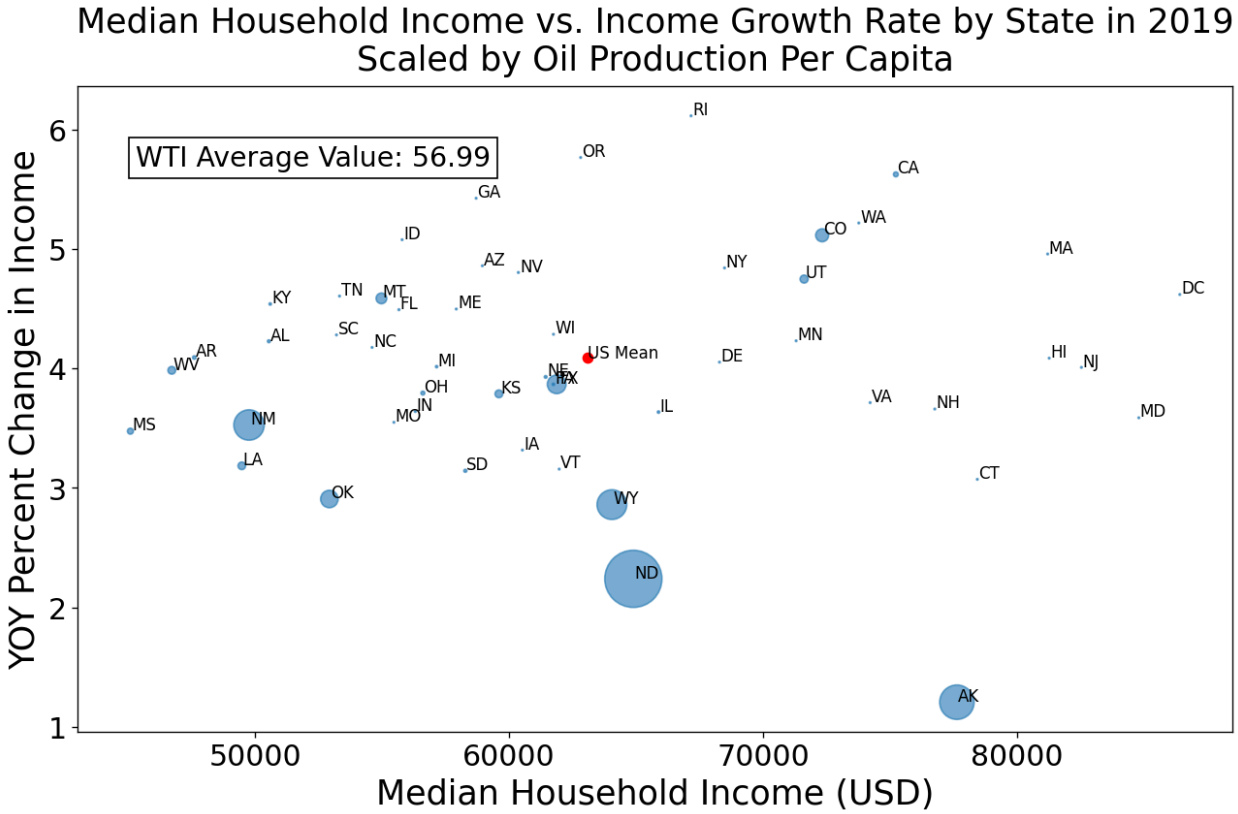
Median Household Income vs. Income Growth Rate by State in 2019
Scaled by Oil Production Per Capita
WTI Average Value: 56.99
YOY Percent Change in Income
Median Household Income (USD)
US Mean
RI
OR
CA
GA
WA
CO
ID
MA
AZ
NV
NY
UT
DC
KY
TN
MT
FL
ME
AL
SC
WI
MN
AR
WV
NC
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DE
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NJ
NE
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KS
IN
VA
NH
MS
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MO
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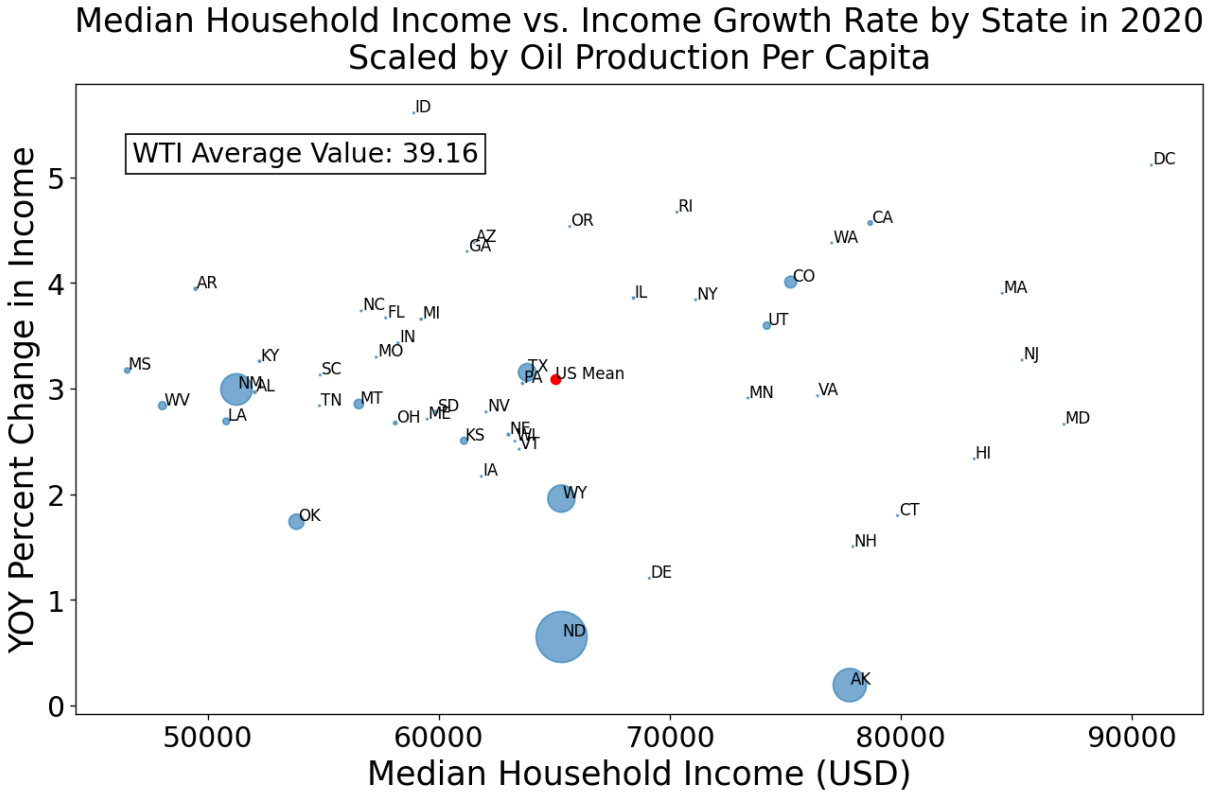
Median Household Income vs. Income Growth Rate by State in 2020
Scaled by Oil Production Per Capita
WTI Average Value: 39.16
YOY Percent Change in Income
Median Household Income (USD)
US Mean
ID
DC
RI
OR
CA
AZ
GA
WA
AR
CO
IL
NY
MA
NC
FL
MI
UT
IN
MO
MS
KY
SC
TX
PA
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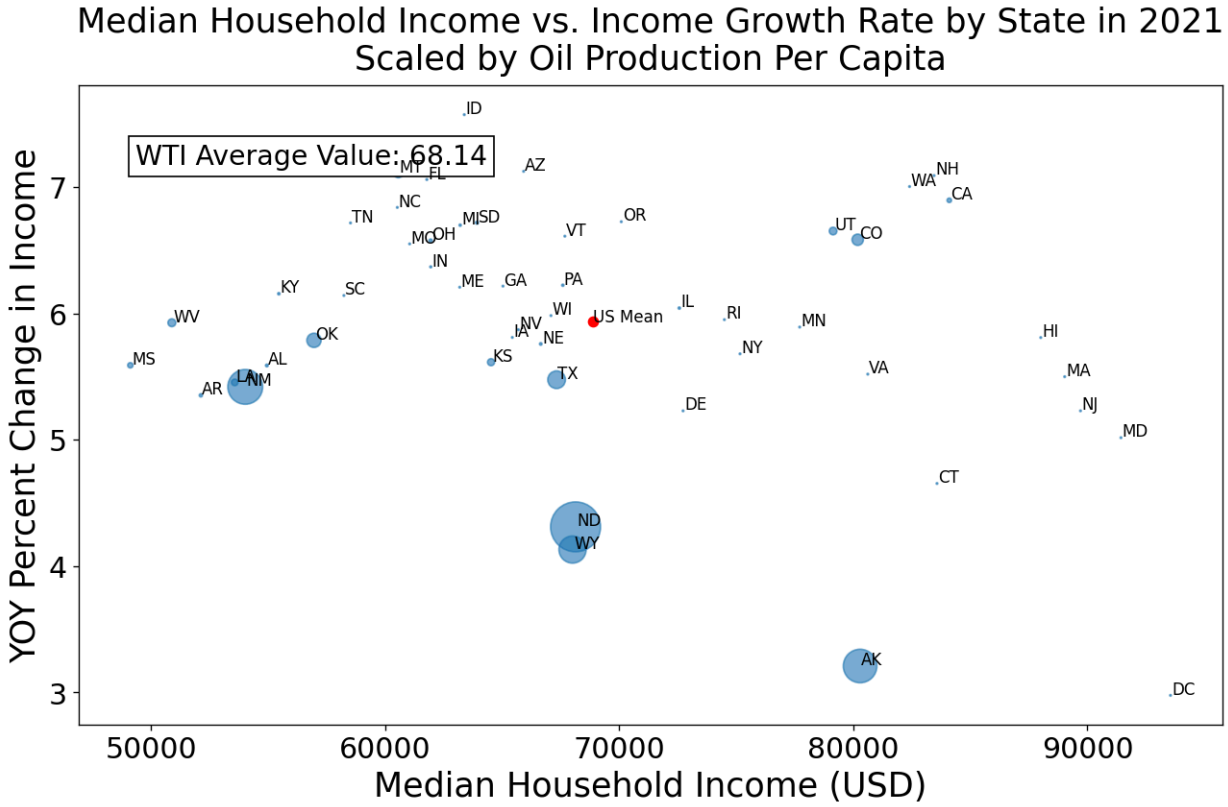
Median Household Income vs. Income Growth Rate by State in 2021
Scaled by Oil Production Per Capita
WTI Average Value: 68.14
YOY Percent Change in Income
Median Household Income (USD)
US Mean
ID
AZ
MT
FL
NC
TN
MI
SD
OR
VT
OH
MO
IN
ME
GA
PA
KY
SC
WV
OK
WI
IA
NV
NE
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RI
MN
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TX
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NM
DE
VA
HI
MA
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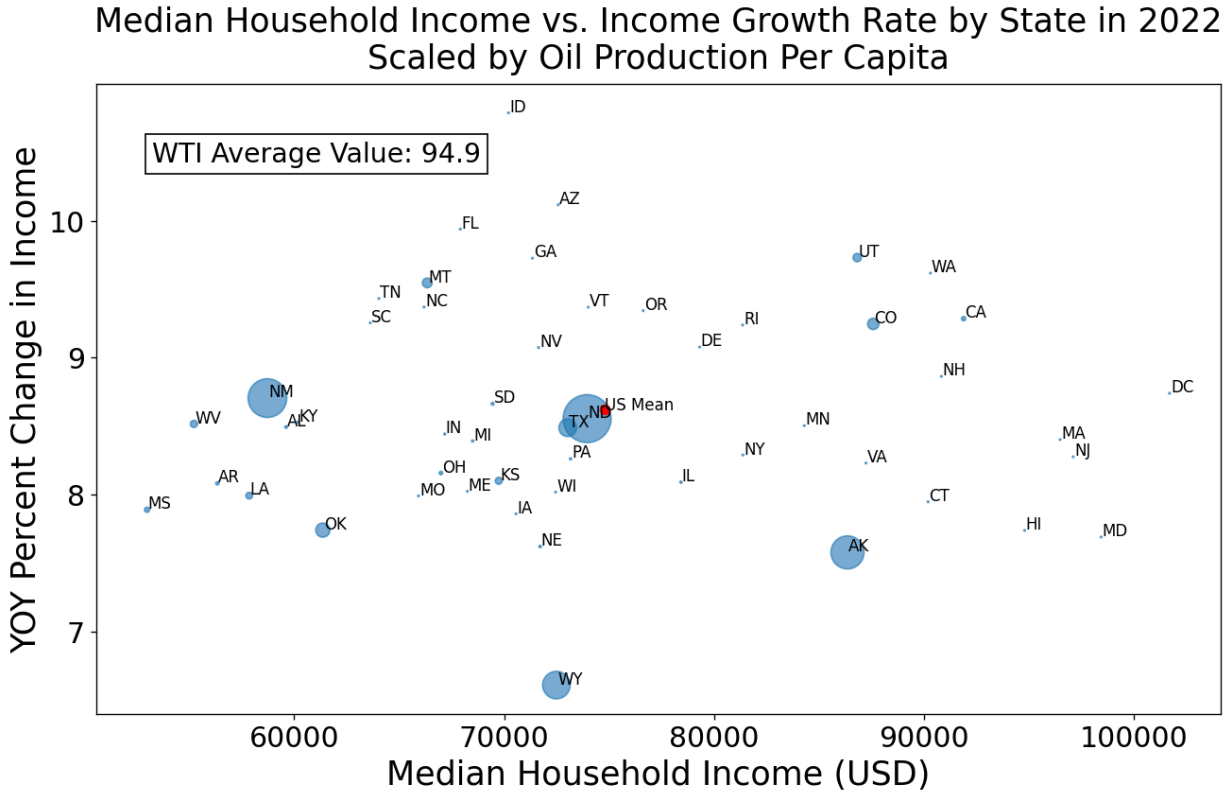
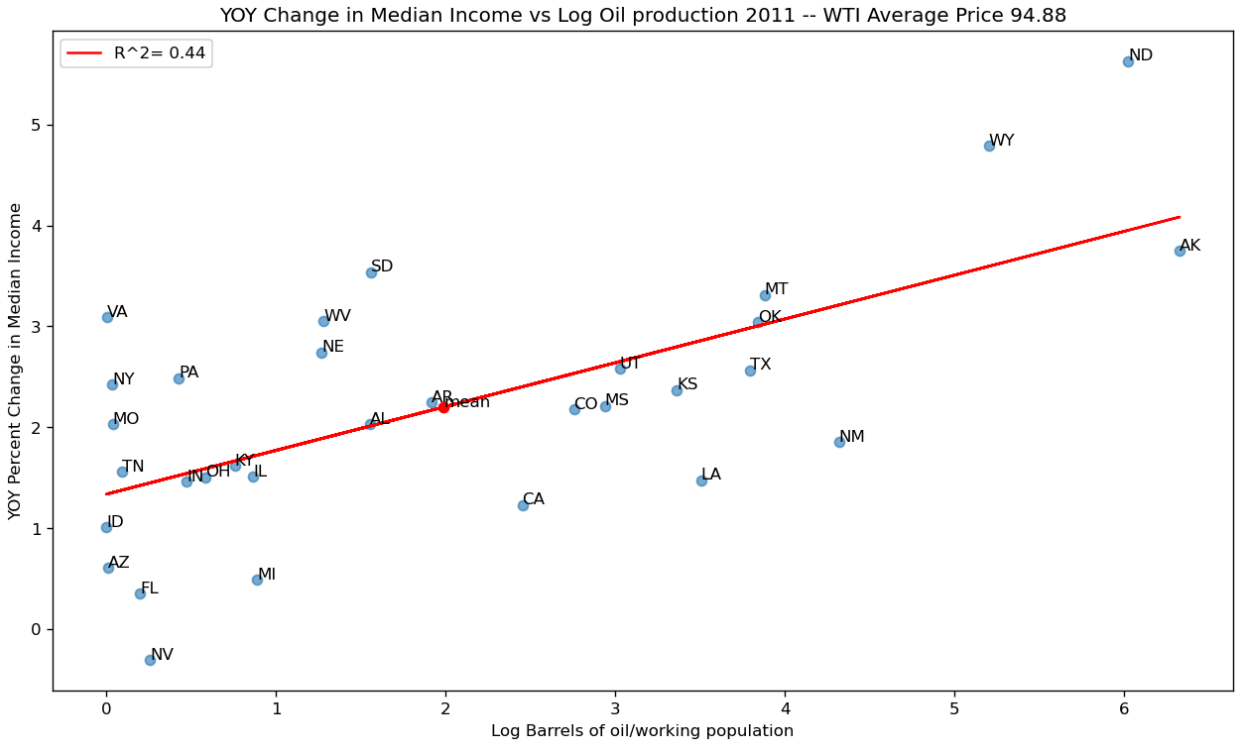


B. YEAR-OVER-YEAR CHANGE IN MEDIUM INCOME VS LOG OIL PRODUCTION FROM 2011-2022


YOY Change in Median Income vs Log Oil production 2011 -- WTI Average Price 94.88
R^2= 0.44
YOY Percent Change in Median Income
Log Barrels of oil/working population
ND
WY
AK
SD
MT
OK
VA
WV
NE
UT
TX
NY
PA
KS
AR
mean
CO
MS
MO
AL
NM
TN
IN
OH
KY
IL
LA
CA
ID
AZ
MI
FL
NV

YOY Change in Median Income vs Log Oil production 2012 -- WTI Average Price 94.05
R^2= 0.25
YOY Percent Change in Median Income
Log Barrels of oil/working population
ND
WV
SD
NY
NE
KS
LA
OK
TX
AK
PA
KY
AR
CO
VA
IL
AL
mean
UT
NM
TN
OH
MS
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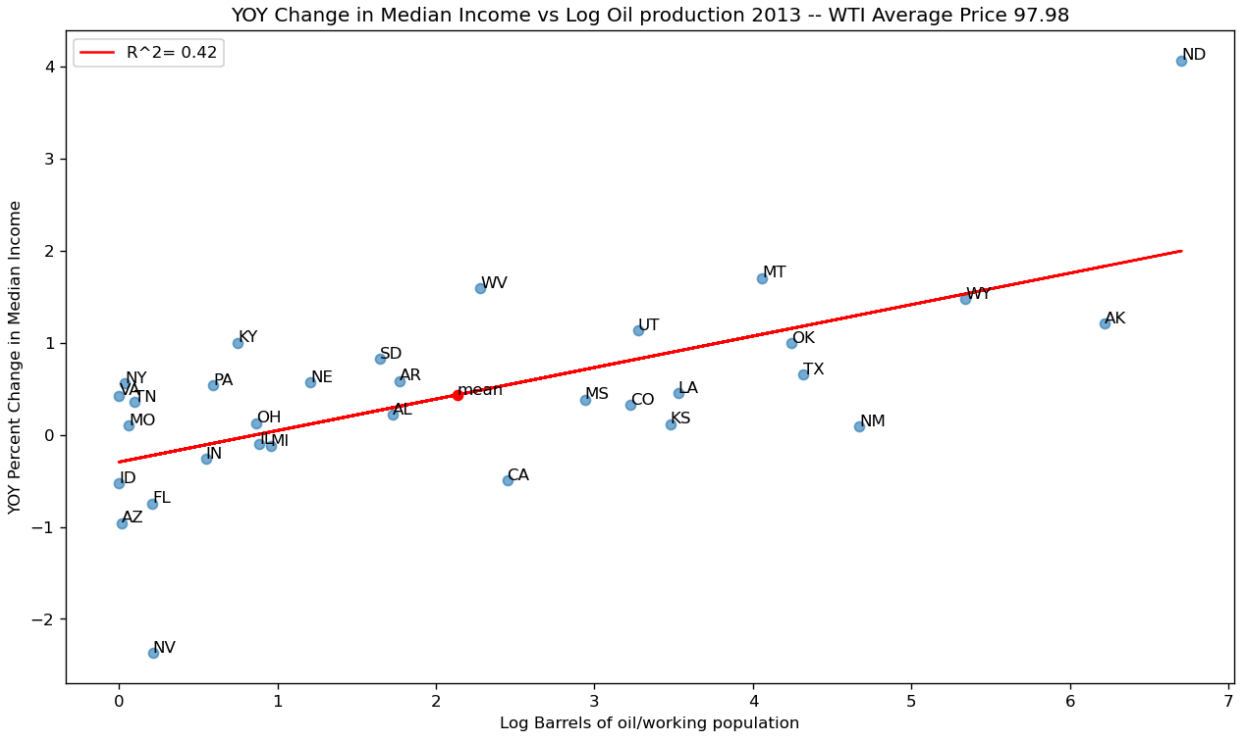
YOY Change in Median Income vs Log Oil production 2013 -- WTI Average Price 97.98
R^2= 0.42
YOY Percent Change in Median Income
Log Barrels of oil/working population
ND
MT
WV
WY
AK
UT
KY
OK
SD
TX
NY
VA
TN
PA
NE
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mean
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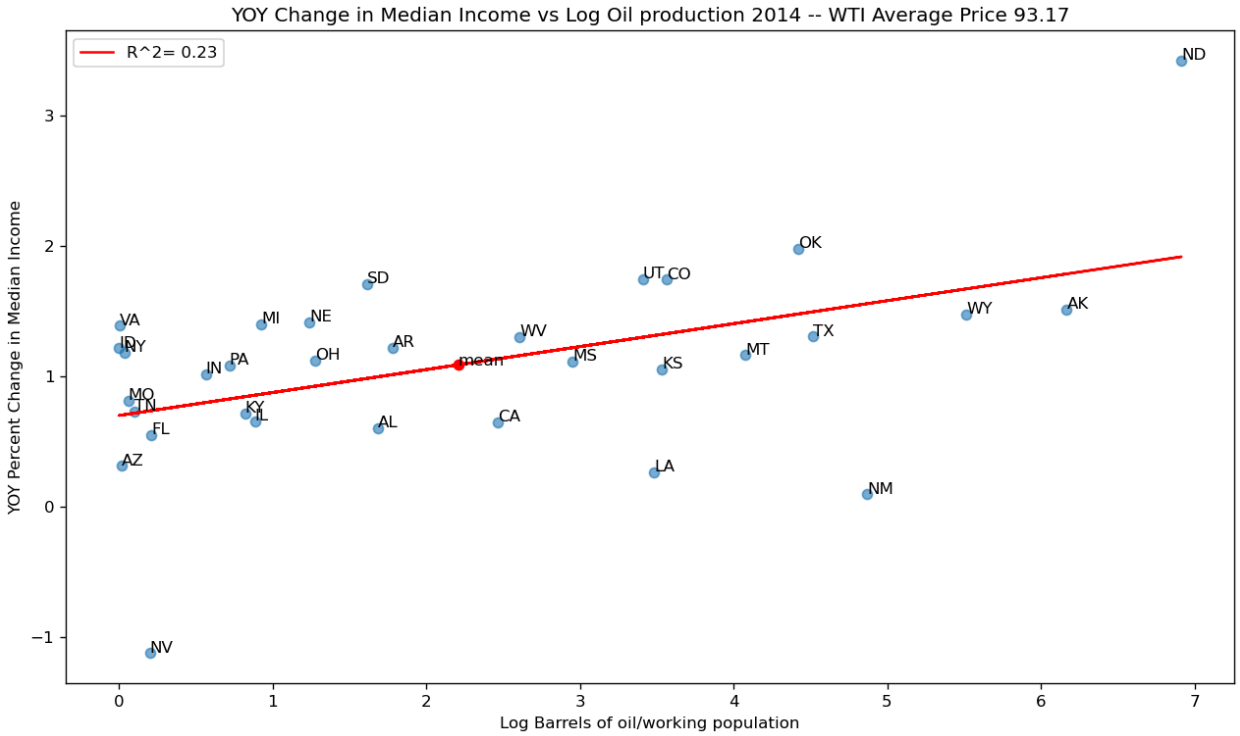
YOY Change in Median Income vs Log Oil production 2014 -- WTI Average Price 93.17
R^2= 0.23
YOY Percent Change in Median Income
Log Barrels of oil/working population
ND
OK
SD
UT
CO
VA
MI
NE
WY
AK
WV
TX
ID
NY
AR
IN
PA
OH
mean
MS
MT
KS
MO
TN
KY
IL
FL
AL
CA
AZ
LA
NM
NV

YOY Change in Median Income vs Log Oil production 2015 -- WTI Average Price 48.66
R^2= 0.14
YOY Percent Change in Median Income
Log Barrels of oil/working population
ND
CO
UT
OK
TX
TN
SD
OH
NE
IN
MI
NY
PA
KY
MO
mean
MT
WY
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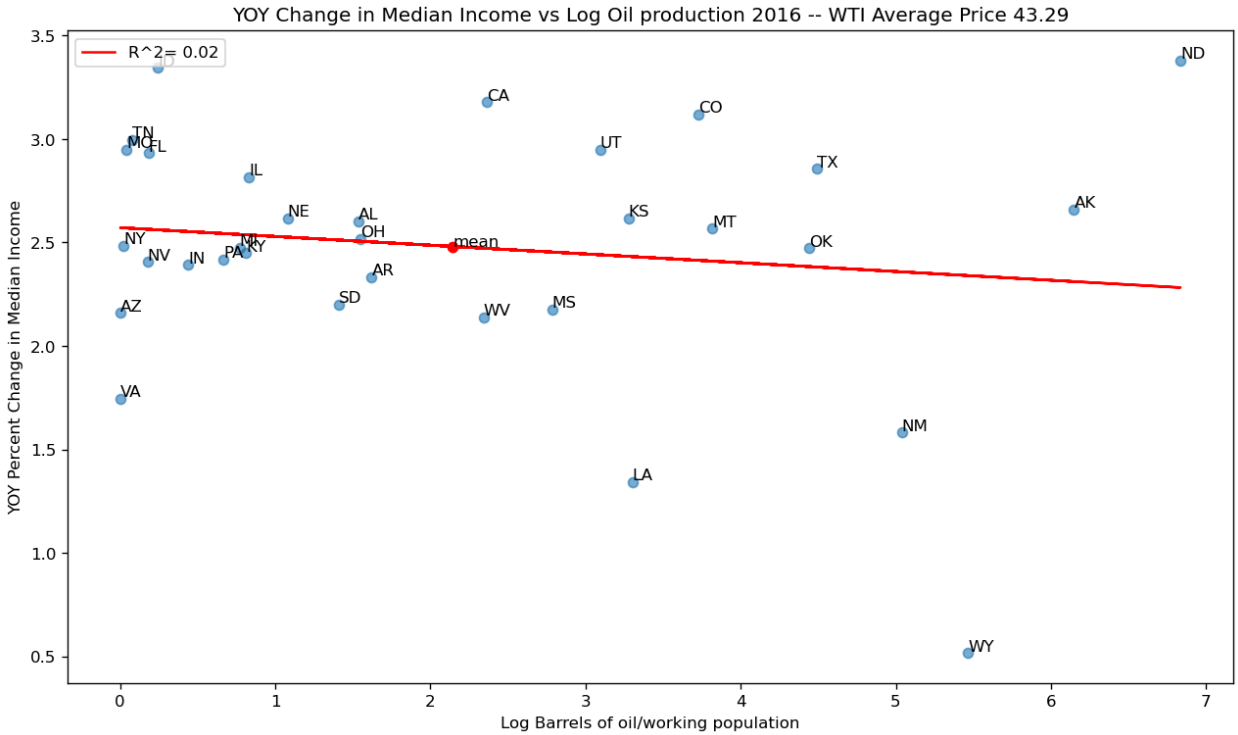
YOY Change in Median Income vs Log Oil production 2016 -- WTI Average Price 43.29
R^2= 0.02
YOY Percent Change in Median Income
Log Barrels of oil/working population
ND
CA
CO
TN
MO
FL
UT
TX
IL
NE
AL
KS
MT
AK
NY
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mean
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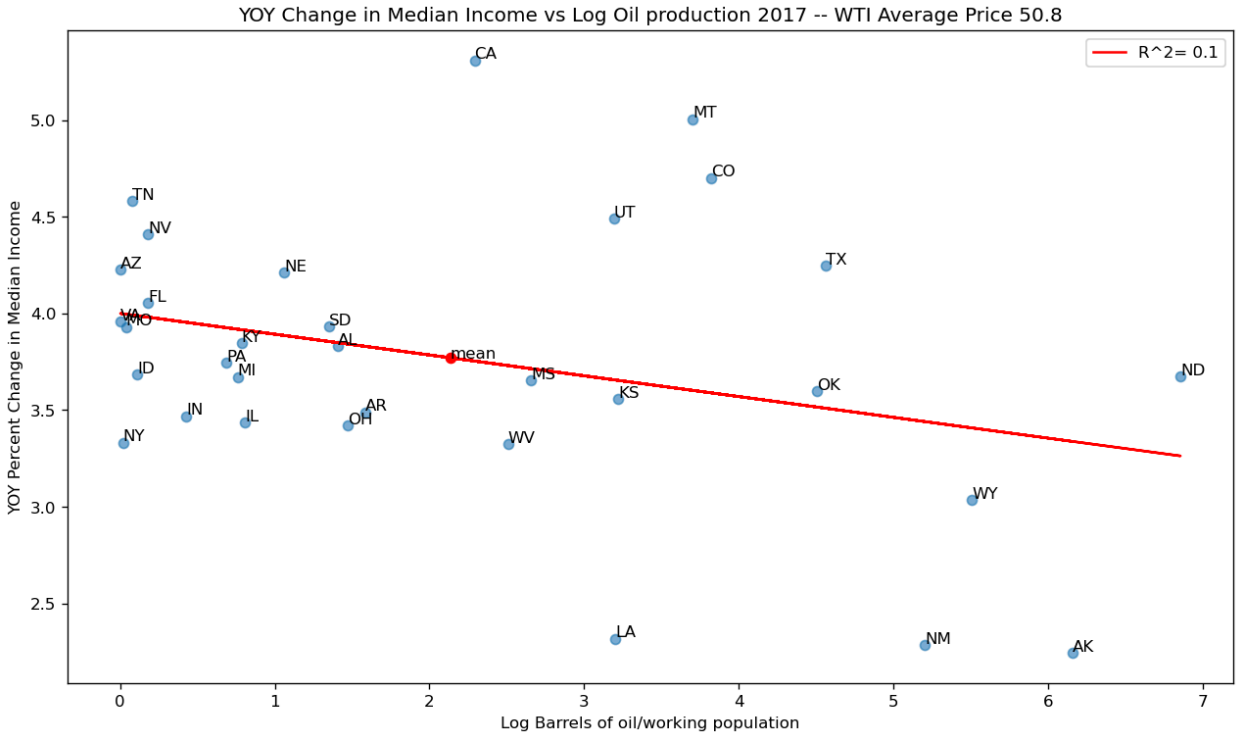
YOY Change in Median Income vs Log Oil production 2017 -- WTI Average Price 50.8
R^2= 0.1
YOY Percent Change in Median Income
Log Barrels of oil/working population
CA
MT
CO
TN
UT
NV
AZ
NE
TX
FL
SD
KY
AL
mean
PA
ID
MI
MS
ND
OK
KS
IN
AR
IL
OH
NY
WV
WY
LA
NM
AK

YOY Change in Median Income vs Log Oil production 2018 -- WTI Average Price 65.23
R^2= 0.28
YOY Percent Change in Median Income
Log Barrels of oil/working population
CA
CO
AZ
FL
UT
PA
MI
NE
SD
AL
AR
TX
ID
IN
KY
OH
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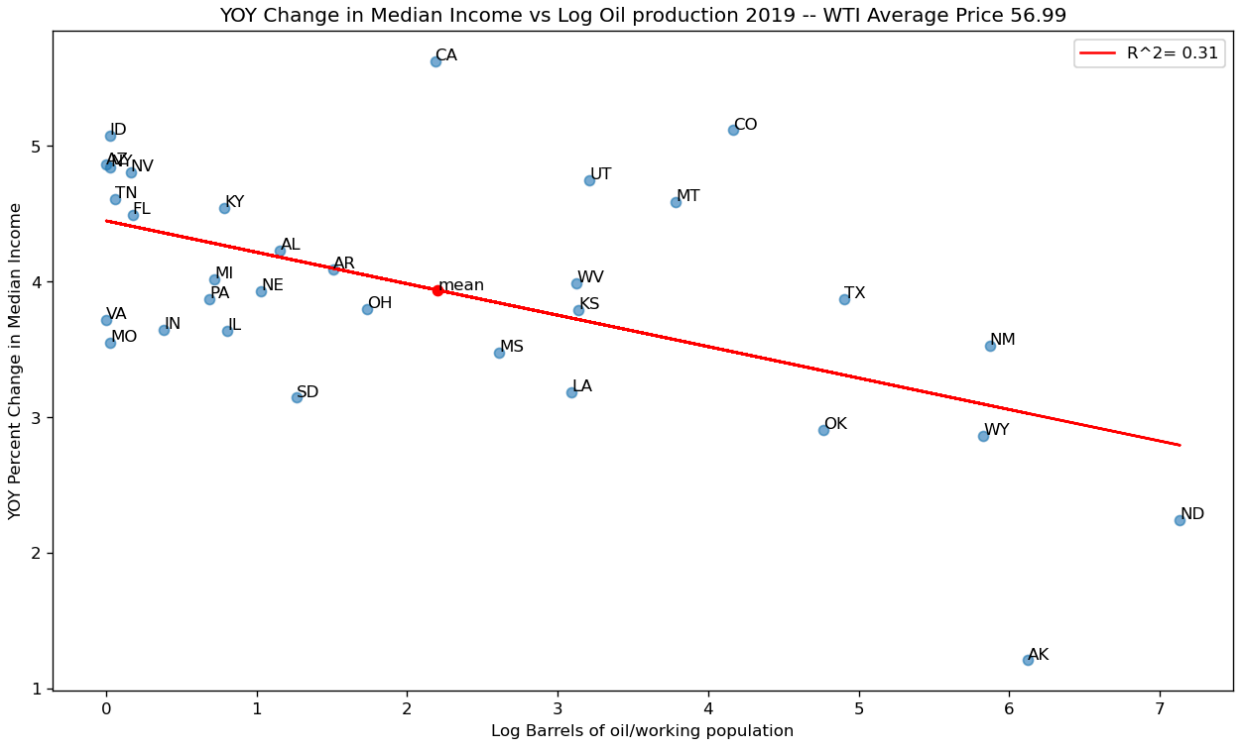
YOY Change in Median Income vs Log Oil production 2019 -- WTI Average Price 56.99
R^2= 0.31
YOY Percent Change in Median Income
Log Barrels of oil/working population
CA
CO
ID
NV
UT
MT
TN
FL
KY
AL
AR
MI
NE
mean
WV
PA
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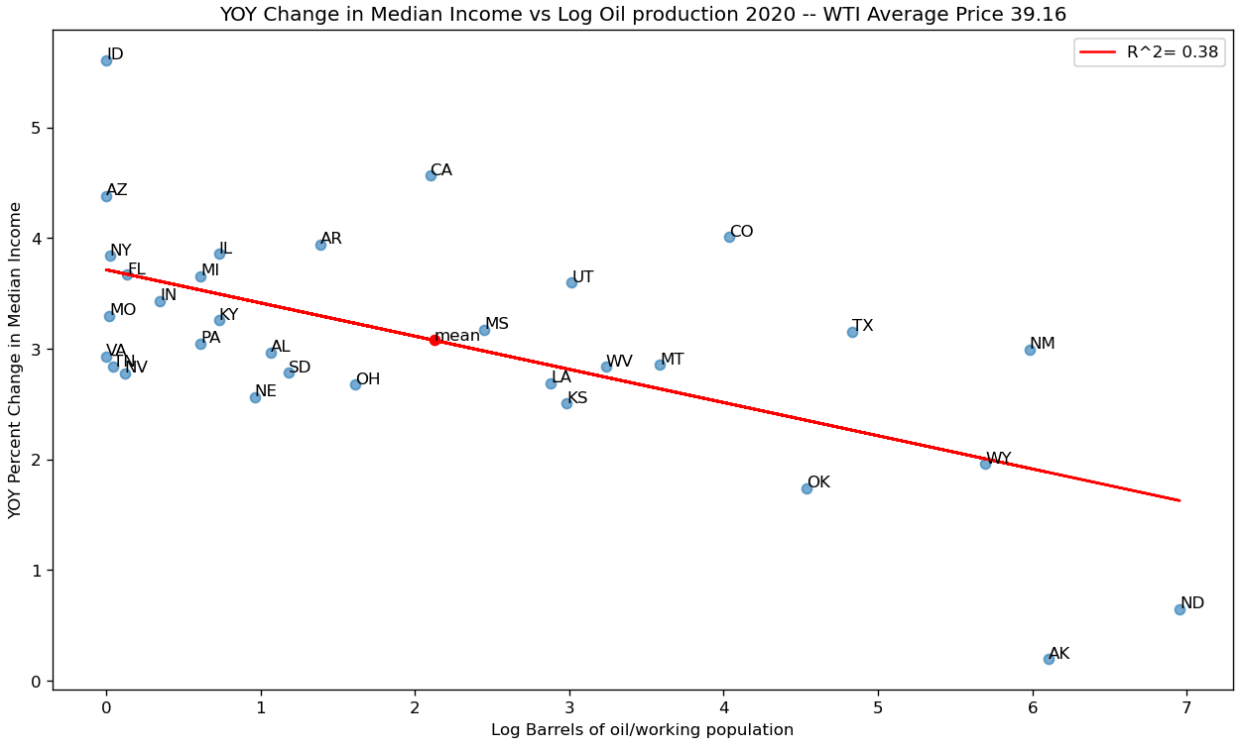
WY
ND
AK


YOY Change in Median Income vs Log Oil production 2020 -- WTI Average Price 39.16
R^2= 0.38
YOY Percent Change in Median Income
Log Barrels of oil/working population
ID
CA
AZ
CO
NY
IL
AR
FL
MI
UT
IN
MO
KY
MS
TX
PA
mean
NM
VA
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OH
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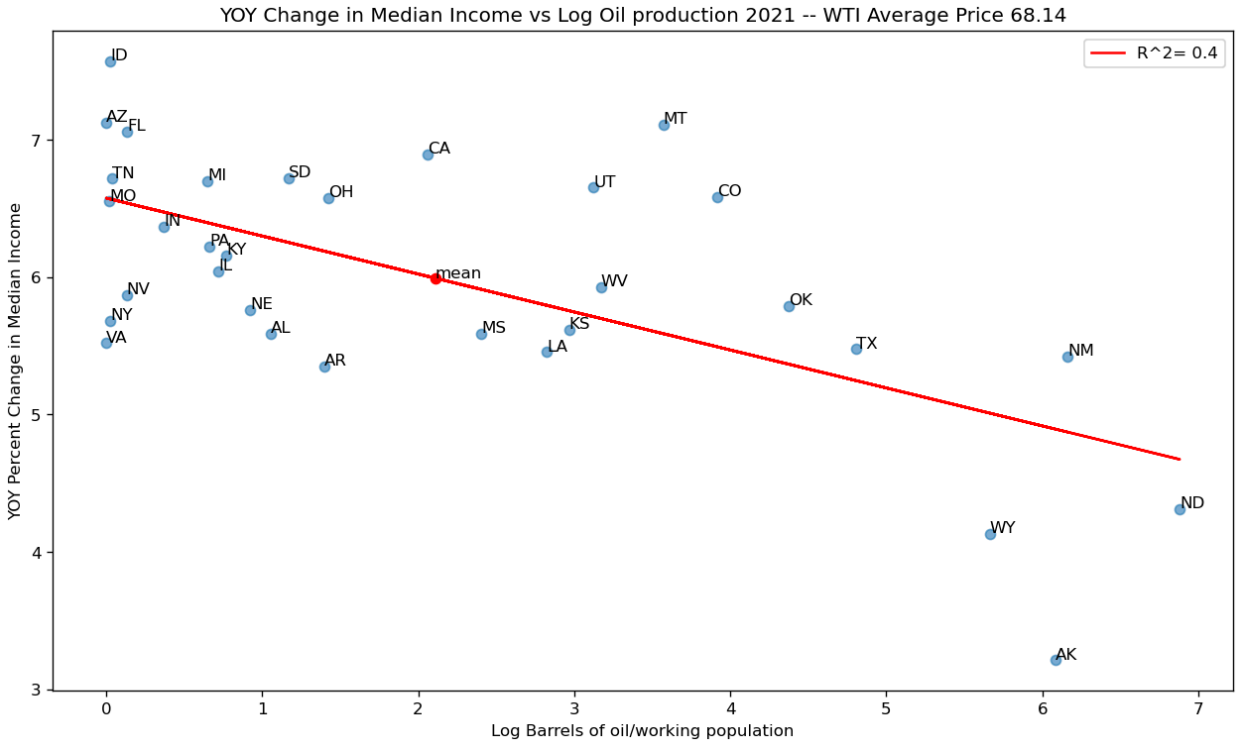
WY
OK
ND
AK


YOY Change in Median Income vs Log Oil production 2021 -- WTI Average Price 68.14
R^2= 0.4
YOY Percent Change in Median Income
Log Barrels of oil/working population
ID
AZ
FL
TN
MO
MI
SD
OH
CA
MT
UT
CO
IN
PA
KY
IL
mean
WV
NV
NE
NY
VA
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AR
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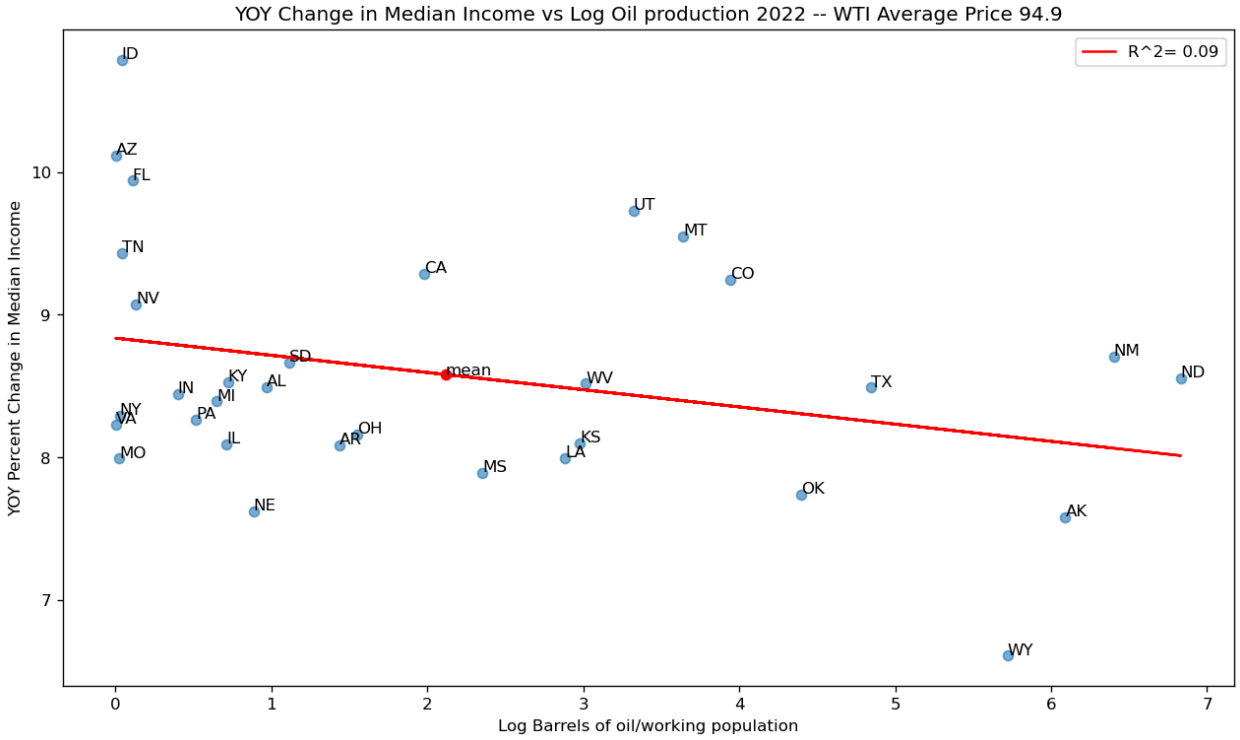
TX
NM
ND
WY
AK


YOY Change in Median Income vs Log Oil production 2022 -- WTI Average Price 94.9
R^2= 0.09
YOY Percent Change in Median Income
Log Barrels of oil/working population
ID
AZ
FL
UT
MT
TN
CA
CO
NV
SD
mean
WV
NM
ND
KY
AL
IN
MI
TX
NY
VA
PA
OH
AR
KS
IL
LA
MO
MS
OK
NE
AK
WY