HOW DOES OIL PRICE SHOCKS AFFECT WEALTH INEQUALITY

XIAOWEN LEI AND XIAOHAN MA

Abstract. This paper studies the effect of oil price changes on income and wealth inequality. Using data on macroeconomic aggregates, oil prices, and inequality metrics, we employ a structural vector autoregressive model and find that an increase in oil prices leads to a persistent and large increase in wealth inequality. To understand these dynamics, we solve an incomplete market model with aggregate oil price risks, and calibrate the model to the US data. When oil serves as both consumption goods and production input, positive oil shocks affect consumption savings decisions and change the relative price between labor and capital. Our numerical results demonstrate that a one standard deviation shock to oil prices raises both income and wealth inequality, peaking at 0.93% and 0.8% respectively from their baseline levels. The effect persists even after millennia. While initial inequality growth is primarily explained by wage reductions, the gradual recovery of capital returns and capital stock explains why inequality remains high.

Keywords: oil price shocks, inequality, heterogeneous agent, structual var

JEL Classification Numbers: D31, E10, Q43

1. Introduction

We live in an age of volatile oil prices. We also live in an age of growing inequality. This paper asks the question of whether these two phenomena might be connected. It attempts to study the dynamic responses of income and wealth inequality to oil price changes since the Great Moderation period.

Even though this might seem like a straightforward task, it is in fact quite challenging due to two main reasons. First, even in a static world, the effects of oil price shocks on income and wealth distribution vary across different markets and may counteract one another. Second, in a dynamic world with heterogeneous agents, characterizing and computing the aggregate variables is challenging because the wealth distribution becomes a state variable which is an infinite-dimensional object. The curse of dimensionality makes it difficult to solve such models with reasonable computational efficiency.

To address these challenges, we adopt a continuous time heterogeneous agent model (HACT) framework. This enables us to explore the dynamic nonlinear impact of oil price shocks across the entire spectrum of income and wealth distribution through the

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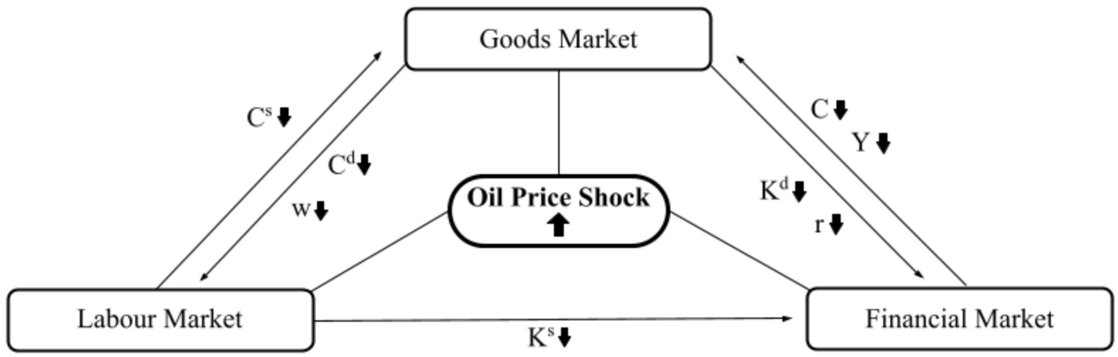

FIGURE 1. Flow chart of oil price shock transmission mechanism

interaction of the goods market, labor market, and financial market channels. In an *a la* Aiyagari 1994 type of idiosyncratic labor income risk model with aggregate oil price shocks, we solve for an equilibrium economy where oil functions as both a consumption good and a production input. We then ask the question: how do the dynamics of aggregate and distributional variables evolve in response to a one-time temporary oil price shock? The solutions are characterized analytically using coupled Hamilton-Jacobi-Bellman equations and Kolmogorov-Fokker-Planck (HJB-KFP) equations and the market clearing conditions and are then fully solved numerically.

Figure 1 illustrates the way oil price shocks spread across these three markets and affect the distribution. Two main paths explain this: the relative price path and the saving and spending path. The first path increases inequality, while the second one reduces it. First, upon a positive oil price shock, energy input demand is dampened, which leads to firms demanding less capital and labor. This puts downward pressure on wages and interest rates ((Olovsson 2019, Kocaarslan, M. A. Soytas, and U. Soytas 2020)). Since wealthier households tend to earn more capital income (e.g., interest rate) while poorer households rely more on labor income, changes in inequality then become a horse race between capital and labor income. Our numerical shows that the reduction of capital income and much less than the reduction of labor income, which constitutes the dominating forces that both explains the magnitude as well as the persistence of the rise in income and wealth inequality.

On the other hand, an increase in oil prices affects households' consumption and savings decisions. A positive oil price shock can translate into a higher general price level (e.g.: transportation cost, manufacturing input cost, etc.), and is then passed on to consumers. This in turn reduces aggregate demand for consumption. Since poorer households have a higher marginal propensity for consumption, this results in a rise in consumption inequality. However, this also incentivize them to do more precautionary savings, which can potentially have an equalizing effect on wealth distribution. Quantitatively, this effect is much less significant than the relative price channel in affecting income and wealth inequality.

The model is then calibrated to the U.S. annual data on aggregate and distributional variables between 1985 and 2019. Based on the calibrated model, we simulate the economy with a one-time positive and persistent MIT shock, which raises oil prices by one standard deviation in the initial period and gradually returns to its steady state. The results suggest that aggregate economic activities, such as output, consumption, and investment, are reduced in response to the shock, whereas the general price level rises. This is consistent with the literature where oil price shocks are typically viewed as negative supply-side shocks. On the other hand, both income and wealth inequality rise, peaking at 0.8% and 0.93% respectively. We then conduct several counterfactual analyses based on the baseline model. By reducing oil intensity used in production, lowering the share of oil consumption among households, and increasing the elasticity of substitution between consumption of oil goods and final goods, we find that the aggregate economy is much less affected under these scenarios compared to the baseline results. Furthermore, the adverse impact of oil price shocks on both income and wealth inequality is mitigated. Finally, to complement the theoretical exploration, we estimate a structural VAR model with U.S. data on oil prices, macroeconomic variables, and inequality measures. The impulse responses suggest consistent aggregate and distributional responses implied by the theoretical results.

The subsequent sections of this paper are structured as follows: Section 2 delves into the background and motivation behind the study. Relevant literature is outlined in Section 3. Section 4 presents an incomplete market model featuring oil price shocks, and characterizes the steady state of the economy and its transition dynamics. Section 6 solves the model numerically using finite difference methods. It offers a counterfactual analysis that examines how the extent of oil's contribution influences the way inequality responds to shifts in oil prices. In section 7, a structural vector autoregressive analysis is conducted to examine the oil price shocks on aggregate and distributional variables empirically. The paper concludes and outlines future avenues of research in Section 8. Additionally, the appendix provides a description of the data employed in the SVAR analysis and includes a robustness check using quarterly data.

2. Motivation

According to the US Energy Information Administration, energy is an important factor that fuels U.S. economic activities. For example, transportation and industrial production respectively account for 67.2% and 26.9% of total U.S. oil consumption in 2021. Thus, fluctuations in oil prices can play a crucial role in influencing aggregate economic dynamics. However, less is known on the distributional impact of oil price shocks.

Figures 2 and 3 plot the lagged relationship between real oil prices and income and wealth using U.S. data from 1985 to 2019. The x-axis shows the percentage difference in income and wealth share of the top 1% and the bottom 50% group using data from Saez and Zucman 2016. The y-axis denotes the real oil price level in the US using 1982 as

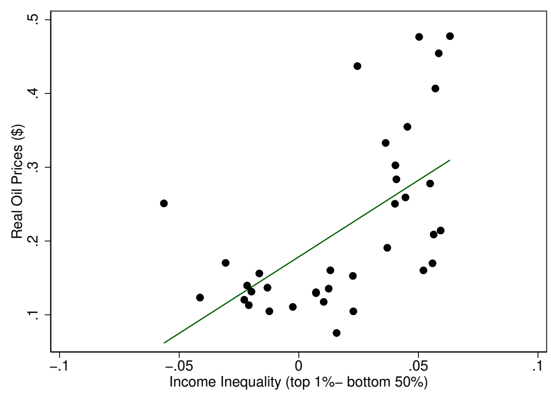

FIGURE 2. Correlation between Real Oil Prices and Income Inequality (1985-2019)

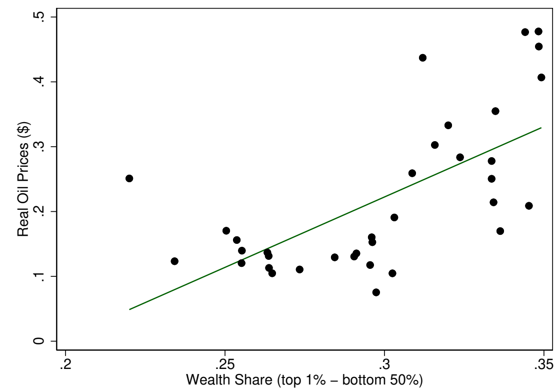

FIGURE 3. Correlation between Real Oil Prices and Wealth Inequality (1985-2019)

the CPI base year. We focus on this period when the U.S. macroeconomy is more stable compared to the Great Inflation period (1965-1982).In addition, the conduct of monetary policy has dramatically changed since the mid-1980s.[1] Excluding the pre-1984 sample allows us to focus on the dynamics of oil prices and inequality during the period with relatively less volatile economic and policy regimes. They describe the correlation between real oil prices in the preceding period and the level of inequality in the contemporaneous year respectively. As shown, there is a significant positive relationship between oil prices and both income and wealth inequality. Although the evidence demonstrated only captures unconditional correlation, it motivates us to conduct more rigorous analyses to investigate the possible causal relationship between oil prices and inequality, both theoretically and empirically.

3. Literature review

The paper attempts to bridge the gap between two seemingly unrelated pieces of literature. It systematically studies the dynamic responses of both income and wealth distribution in response to oil price shocks. The first is recent literature that focuses on the macroeconomic dynamics of income and wealth inequality. It is widely acknowledged that both income and wealth inequality has been rising significantly worldwide since the 1980s (Piketty 2014). While the topic of wealth inequality was primarily studied within the field of development economics, it has recently gained attention among macroeconomists (Ahn et al. 2018). Some focuses on taxes and technology (Kaymak and Poschke 2016), globalization (Azzimonti, De Francisco, and Quadrini 2014), entrepreneurship (Jones and J. Kim 2018), automation (Moll, Rachel, and Restrepo 2022), some focus on monetary

[1]This economic episode has been documented by many scholars and policymakers, including Stock and Watson 2003 and Bernanke 2004, among others.

policy (Kaplan, Moll, and Violante 2018), others examine the heterogeneous return to wealth (Fagereng et al. 2020), etc.

The second literature it relates to is the macroeconomics of energy. It has been documented in the literature that oil price changes serve as one of the most important supply-side disturbances that can generate fluctuations in the aggregate economy. The aggregate economic effect of oil price shocks on the macro-economy has been well-researched and well-understood (Hamilton 1983, Rotemberg and Woodford 1996, Hamilton 2003, Barsky and L. Kilian 2004, Lutz Kilian 2008). Traditional macroeconomic theory suggests that oil price shocks lead to stagflation, characterized by higher inflation and lower aggregate consumption, investment, and output (Herrera, Karaki, and Rangaraju 2019, Edelstein and Lutz Kilian 2009, Koirala and Ma 2020).

Few studies have focused on the distributional impact of oil prices. Most existing work focuses on empirical analysis. They either examines the natural resource curse (Sebri and Dachraoui 2021, Parcero and Papyrakis 2016, Brunnschweiler and Bulte 2008), as well as how oil price shocks affect *income inequality* (Edmond et al. 2021, D.-H. Kim and Lin 2018. Parcero and Papyrakis 2016). Bettarelli et al. 2023 recently explores how energy price inflation affects consumption inequality. The theoretical framework that features a heterogeneous response of common oil price shocks is lacking. Perhaps the most related work to ours on this front is Pieroni 2023 and Auclert et al. 2023. They both study an oil-importing open economy heterogeneous agent model with nominal rigidity. However, their focus lies on the aggregate variables, income inequality, and the optimal fiscal and monetary policy response to an energy price shock. Our paper differs in that we include capital in production, which as shown later serves as a non-negligible channel through which oil prices affect inequality. Furthermore, we provide empirical evidence in addition to our theoretical prediction.

4. Model

The model combines two existing pieces of literature. The first features oil price shocks in the economy as in O. J. Blanchard and Marianna Riggi 2013. We consider an oil-importing closed economy where the oil supply is infinite and exogenous changes in oil prices drive changes in oil demand. The second features a Aiyagari 1994 type of incomplete market model of income and wealth inequality. This framework allows us to consider the heterogeneous effect of oil price shock on various distributions of the economy.

4.1. **Households.**

Time is continuous. The economy consists of a measure 1 continuum of infinitely lived households (i.e.:$\bar{N} = 1$). Each household i consumes, works, invests in capital and rents out to the firms. They receive labor income and rental payments. Idiosyncratic labor income shocks contribute to heterogeneity in household income and wealth. Households make consumption/savings decisions continuously to solve the following optimization problem

$$\max_{c,l} \mathbb{E} \int_0^\infty e^{-\rho t} \frac{c^{1-\phi}}{1-\phi} dt \tag{1}$$

where

$$c \equiv \left((1-\xi)^{1-\sigma} c_Y^{\sigma} + \xi^{1-\sigma} c_E^{\sigma}\right)^{\frac{1}{\sigma}} \tag{2}$$

Here, ρ denotes the time discount rate. Agents have CRRA preferences over consumption. ϕ is the risk aversion coefficient. c is a consumption bundle that consists of both final goods consumption c_Y and oil-related goods c_E. ξ represents the weight of oil-related goods in total consumption and $\sigma \in (0,1)$ captures the elasticity of substitution between oil and final goods. Let p denote the aggregate price, the implied relationship between the price of oil goods p_E, final goods p_Y, and the composite good p thus becomes

$$p \equiv \left((1-\xi) p_Y^{\frac{\sigma}{\sigma-1}} + \xi p_E^{\frac{\sigma}{\sigma-1}}\right)^{\frac{\sigma-1}{\sigma}} \tag{3}$$

To focus on the relative price between oil goods and final goods, we can normalize $p_Y = 1$ so that the aggregate price level is simplified to

$$p \equiv \left(1 + \xi p_E^{\theta}\right)^{\frac{1}{\theta}} \tag{4}$$

where $\theta = \frac{\sigma}{\sigma-1}$.

The agent's (real) labor income follows a two-state Poisson process. There is a low state z_1 and a high state z_2. The process jumps from the low state to the high state with a jump intensity λ_1, and from the high state to the low state with jump intensity λ_2. Households budget constraints read

$$da = (ra - c + wl(\mathbb{1}(z = z_1) + \mathbb{1}(z = z_2))dt \tag{5}$$

where a denotes real asset value, r and w are real rental rate and real wage. In addition, a borrowing constraint states that

$$a \geq a_{min} \tag{6}$$

which ensures the existence of a stationary distribution.

Let V^1, and V^2 denote the value function of the households currently in low and high income state respectively, the individual Hamilton-Jacobian-Bellman (HJB) equations become

$$\rho V^1 = \max_c \left[\frac{c^{1-\phi}}{1-\phi} + V_a^1(ra - c + z_1 w) + \lambda_1(V^2 - V^1)\right] \tag{7}$$

$$\rho V^2 = \max_c \left[\frac{c^{1-\phi}}{1-\phi} + V_a^2(ra - c + z_2 w) + \lambda_2(V^1 - V^2)\right] \tag{8}$$

The first order conditions of consumption thus reads

$$c_1^* = (V_a^1)^{-1/\phi}; \quad c_2^* = (V_a^2)^{-1/\phi} \tag{9}$$

4.2. **Final goods firm.** The final goods market is competitive. The final goods firm produces final goods Y_t by combining oil, capital, and labor, i.e.:

$$Y = ZE^{\alpha}K^{\beta}N^{\gamma} \tag{10}$$

Firms take input cost p_E, p, w, r as given, and optimize over real input demand (E_D^*, K_D^*, N_D^*) so as to maximize profit. Their problem can be stated as

$$\max_{E,K,N} p_Y Y - p_E E - rpK - wpN \tag{11}$$

Optimal input decision requires the firm to equalize the marginal cost for each input. The solution of the above problem reads

$$E_D^* = \left(\frac{p_E}{\alpha Z K^{\beta} N^{\gamma}}\right)^{\frac{1}{\alpha-1}} \tag{12}$$

$$K_D^* = \left(\frac{rp}{\beta Z E^{\alpha} N^{\gamma}}\right)^{\frac{1}{\beta-1}} \tag{13}$$

$$N_D^* = \left(\frac{wp}{\gamma Z E^{\alpha} K^{\beta}}\right)^{\frac{1}{\gamma-1}} \tag{14}$$

Since $0 < \beta < 1$, $\frac{\partial p}{\partial p_E} > 0$ and $\alpha + \beta + \gamma < 1$, we know that

$$\frac{\partial E^*}{\partial p_E} < 0 \quad and \quad \frac{\partial K^*}{\partial p_E} < 0 \quad and \quad \frac{\partial N^*}{\partial p_E} < 0 \tag{15}$$

Notice that the above comparative statics describes only the partial equilibrium effect of oil price shock on production input by fixing other equilibrium variables at their benchmark level. As we can see, increases in oil price has a contractionary effect on production by increasing input cost. The general equilibrium response will be provided in section 6.

4.3. **Aggregation.** To close the model, we impose market-clearing conditions for oil goods, labor as well as capital. First, since the oil supply $\bar{E}$ is infinite, exogenous changes in oil prices determine the oil demand for both consumption and production, i.e.:

$$E^* = E_D^* + \int c_{E,i} di = \bar{E} \tag{16}$$

Next, labor market clearing requires that labor demand equals the inelastic labor supply $\bar{N}$, i.e.:

$$N^* = N_D^* = \frac{\lambda_1}{\lambda_1 + \lambda_2}\bar{N} = \frac{\lambda_1}{\lambda_1 + \lambda_2} \tag{17}$$

Finally, the capital market clearing condition states that total households' savings are equal to total productive capital.

$$K^* = K_D^* = \int_0^1 a_i di \tag{18}$$

Equations (16), (17) and (18), along with equations (12), (13), (14) jointly determine the wage rate, rental rate and equilibrium oil, capital and labor input.

5. Stationary distribution

We start by characterizing the stationary distribution of this economy for any given oil price p_E. The system of equations that characterizes the equilibrium requires coupled Hamilton-Jacobian-Bellman equations and the Kolmogorov-Fokker-Plank equations (HJB-KFP), along with the aggregation conditions. Formally, we have

$$\rho V^1 = \max_{c,l}\left[\frac{c^{1-\phi}}{1-\phi} + b\frac{l^{1-\psi}}{1-\psi} + V_a^1(ra - c + z_1 w) + \lambda_1(V^2 - V^1)\right] \tag{19}$$

$$\rho V^2 = \max_{c,l}\left[\frac{c^{1-\phi}}{1-\phi} + b\frac{l^{1-\psi}}{1-\psi} + V_a^2(ra - c + z_2 w) + \lambda_2(V^1 - V^2)\right] \tag{20}$$

$$\frac{\partial f^1}{\partial t} = -\frac{\partial}{\partial a}(f^1(ra - c + z_1 w)) - \lambda_1 f^1 + \lambda_2 f^2 \tag{21}$$

$$\frac{\partial f^2}{\partial t} = -\frac{\partial}{\partial a}(f^2(ra - c + z_2 w)) - \lambda_2 f^2 + \lambda_1 f^1 \tag{22}$$

$$K^* = \left(\frac{rp}{\beta E^\alpha N^\gamma}\right)^{\frac{1}{\beta-1}} = \int\int af^1 da + \int\int af^2 da \tag{23}$$

$$E^* = \left(\frac{p_E^{1-\beta}(\alpha rp)^\beta}{\alpha\beta^\beta}\right)^{\frac{1}{\alpha+\beta-1}} \tag{24}$$

$$N^* = \left(\frac{wp}{\gamma E^\alpha K^\beta}\right)^{\frac{1}{\gamma-1}} \tag{25}$$

$$a \geq a_{min} \tag{26}$$

The above system of equations holds both in the steady state (when $f_t^1 = f_t^2 = 0$) as well as in the transition dynamics. Due to the additive labor income shocks, numerical methods are needed to compute the solution of the model.

6. Numerical Results

6.1. **Benchmark parameters.** In this section, we begin by presenting the policy functions using calibrated parameters. We discretize the continuous time model above into annual frequency. We then present the impulse response functions of the economy in response to a one-time positive MIT shock of oil price p_t^E.

Table 1 presents the benchmark parameters used for the simulation exercise. These parameters are calibrated to match the historical average in our sample period (1985-2019) in the US economy. Risk aversion ϕ is set to 2. Discount rate ρ equals 0.05, which implies an annual interest rate of 4.9%. For the labor income process, we first normalize the low-income state z_1 to one and then calibrate z_2 to match the US unemployment insurance replacement ratio. According to the US Department of Labor, the annual average UI replacement ratio from 1997 (the earliest time where data is available) to 2019 amounts to 0.464, which then implies that $z_2 = 1/0.464 = 2.155$. Next, we calibrate the switching rate λ_1 and λ_2. The average duration of unemployment is 20.3 weeks using the BLS data from 1985 to 2019. This gives an annualized job finding rate of 0.928, which then implies a continuous time job finding rate of $\lambda_1 = -log(0.928) = 0.0747$. We then use this value to calibrate the average unemployment rate $\frac{e^{-\lambda_2}}{e^{-\lambda_1}+e^{-\lambda_2}}$ [2] to match the average unemployment rate from 1985 to 2019 from BLS data of 5.9%. The implied $\lambda_2 = 2.84$. Following O. Blanchard and M. Riggi 2013, we use 1.7% for the share of oil consumption out of total consumption composite, ξ, and 0.51 for the elasticity of substitution between oil and final goods consumption, σ. On the production side, we set the income share of oil out of total output, α, at 1.7%. Assuming a constant return to scale and the labor income share γ is about 67% out of the output, the income share of capital β is thus 31%. Finally, the persistence parameter of the oil price shocks is set at 0.81, which implies that a half-life of 3.3 years is estimated from the data on real crude oil prices from 1985 to 2019.

Table 1. Benchmark Parameter Values

Parameters	Value	Data Source
ϕ	2	Risk aversion
ρ	0.05	Discount rate
α	0.017	oil share out of output
β	0.31	capital share out of output
γ	0.67	labor share out of output
λ_1	0.0747	Calibrate to match the average duration of unemployment (BLS, 1985-2022)
λ_2	2.84	Calibrate to match the average unemployment rate (BLS, 1985-2019)
z_1	1	Normalized to 1
z_2	2.155	Calibrated to match UI replacement ratio (1997-2019)
σ	0.49	elasticity of substitution between oil and final goods consumption
ξ	0.017	oil share out of total consumption
ρ_E	0.81	persistence of oil price shocks

6.2. **Simulation.** Based on the calibrated model, we simulate the economy with a positive oil price shock whose magnitude is one standard deviation. Figure 4 and 5 plot the impulse response functions up to 100 years, with the vertical axis representing percentage deviation from steady states. On impact, the interest rate and the wage rate immediately decrease by 2.35% and 2.30% respectively, due to that higher oil prices lead to higher production costs and thus lower demand for energy, labor and capital inputs. Interestingly, the interest rate gradually increases above the steady state whereas the wage rate stays below, which imply that low-wealth households whose main income source is through working are more negatively affected by the higher oil prices relative to high-wealth households who own a relatively higher amount of capital. Both income and wealth inequality increase, with the peak effects of 0.80% and 0.93% deviation from their steady states,

[2] Here, $e^{-\lambda_1}$ is the annualized job finding rate, and $e^{-\lambda_2}$ is the annaulized job seperation rate.

roughly occurring 16 years after the shocks hit the economy.

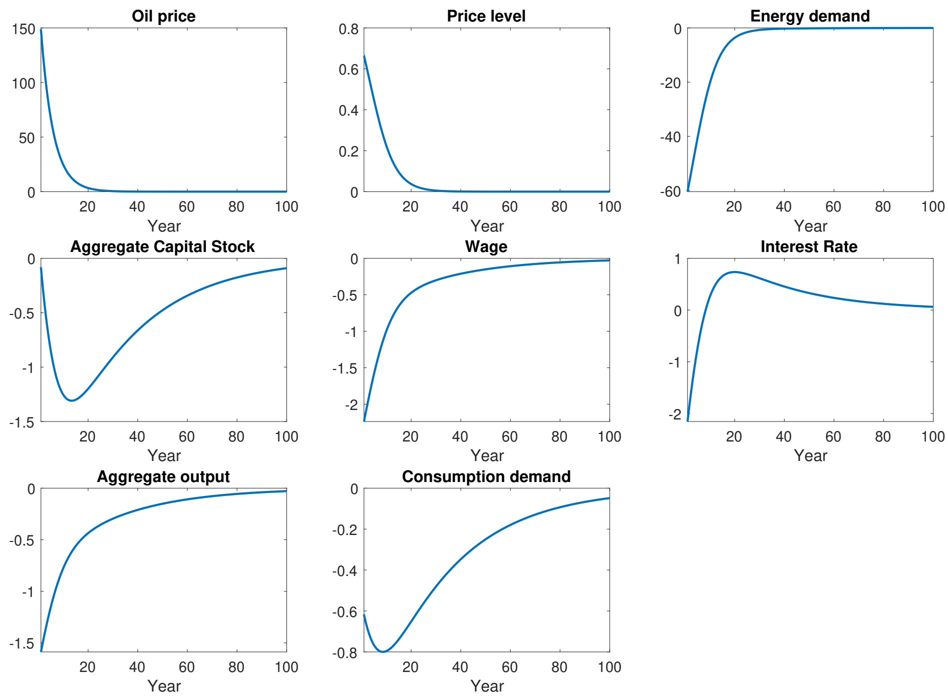

FIGURE 4. Impulse response functions (Unit: Δ% from steady state)

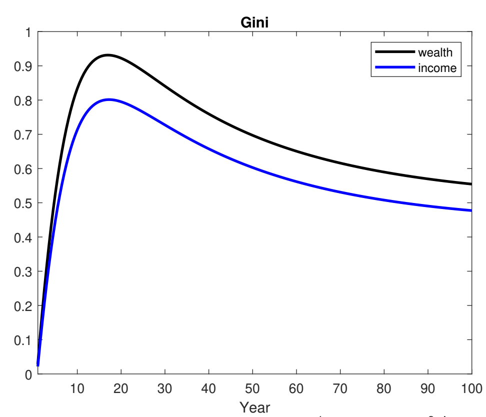

FIGURE 5. Impulse response functions (Unit: Δ% from steady state)

To understand the short-run and medium-run effects on the inequality responses, we can decompose the effect of oil price shock into the following transmission mechanisms.

In the short run, a positive oil price shock reduces wages by 2.24% on impact. This is because firms simultaneously reduce the demand for labor as well as oil in order to equalize the marginal product of both inputs. Notice that the interest rate reduces too by 2.15% due to a reduction in capital demand. Notice also that even though aggregate capital stock gradually decreases, it actually helps to raise the marginal product of capital, which then raises the interest rate right after the shock. Because capital income is the product of capital stock and interest rate, the total reduction of capital income is therefore not as significant as the reduction of labor income. Since income inequality is essentially the horse race between labor and capital income, our results suggest that the decreases in labor dominate the decreases in capital income in the short run, and lead to the initial substantial increase in income and wealth inequality. To understand the persistence of the inequality response in the medium run, notice that capital stock gradually increases while the interest rate stays at a persistently high level even after the peak. This is likely due to the fact that the demand of capital has recovered after the initial shock. In the medium run, the higher level of capital and interest rate dominates the recovered wage level, which then leads to persistent increases in income and wealth inequality.

One thing to note here is that the above transmission mechanism focuses on the relative price channel, while we have been silent about the consumption savings channel so far. As a matter of fact, inequality is actually reduced in response to positive oil price shocks through the consumption savings channel. As can be seen from Figure 4, increases in general price level reduce aggregate consumption decreased by 0.6% on impact and reaches the bottom to around 0.8% reduction in year 8. However, this effect is stronger for poorer households since they have a higher marginal propensity for consumption. Therefore, for any given income, poorer households reduces more consumption, and increase savings. [3] This dampens inequality. However, quantitatively, the relative price channel dominates the consumption savings channel. This explains why we still witness a large and persistent response of income and wealth inequality.

6.3. **Counterfactual analysis.** We first examine the counterfactual scenario where the amount of energy used in production is reduced by 50%, i.e., we change α to 0.85% from the baseline 1.7% while keeping other parameters remain at their baseline levels. Figures 6 and 7 respectively plot the impulse responses of aggregate variables and Gini coefficients under this scenario and under the baseline assumption. As shown, the impact of the same oil price shocks on aggregate variables, such as capital, output and consumption, is mitigated. This is not surprising, because firms are less negatively affected by elevated oil prices when there is lower oil intensity in production. As the reactions of both the wage rate and the interest rate are attenuated, the effects on wealth and income inequality are weakened.

[3] Notice that the reduction in aggregate consumption does not imply a simultaneous reduction in both oil goods and final goods consumption. In fact, oil goods consumption unambiguously decreases while the change in final goods consumption is ambiguous. On one hand, an increase in oil prices increases the overall price, which then reduces both consumptions directly (income effect). On the other hand, the relative oil price reduction might shift oil goods consumption towards final goods consumption (substitution effect).

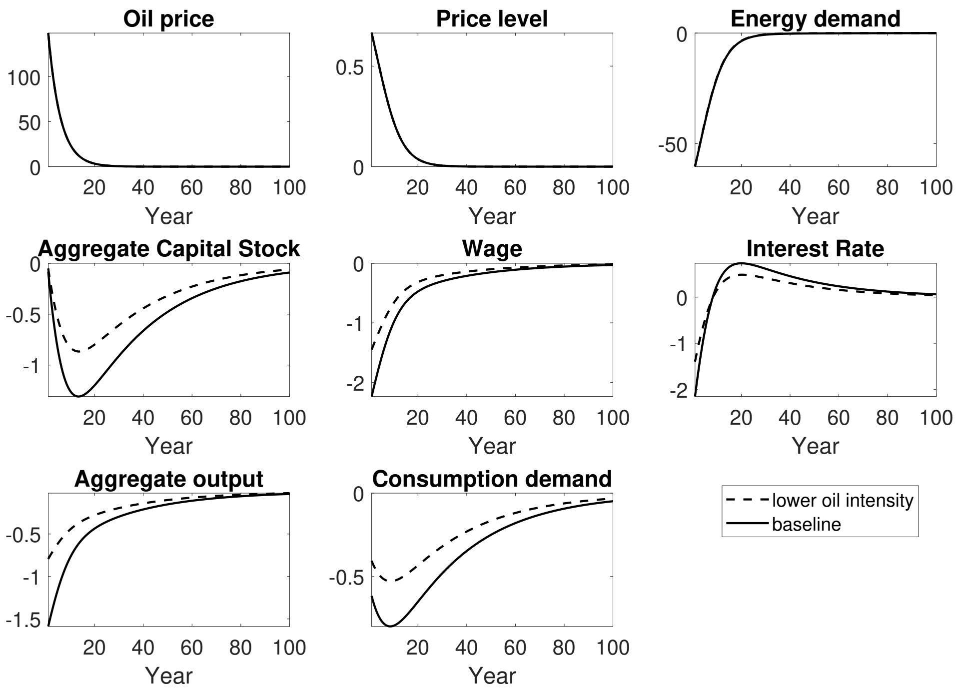

FIGURE 6. Impulse response functions (Unit: $\Delta\%$ from steady state)

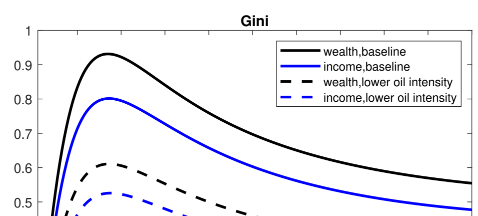

FIGURE 7. Impulse response functions (Unit: $\Delta\%$ from steady state)

We then examine the scenario where households do not consume oil, i.e., $\xi = 0$. The simulation results are shown in Figures 8 and 9. Since no oil is present in the composite good, the price level remains the same as the baseline. On the other hand, higher oil prices still affect the capital and labor returns, but at a smaller magnitude. Therefore, aggregate variables are less affected, so are income and wealth inequality.

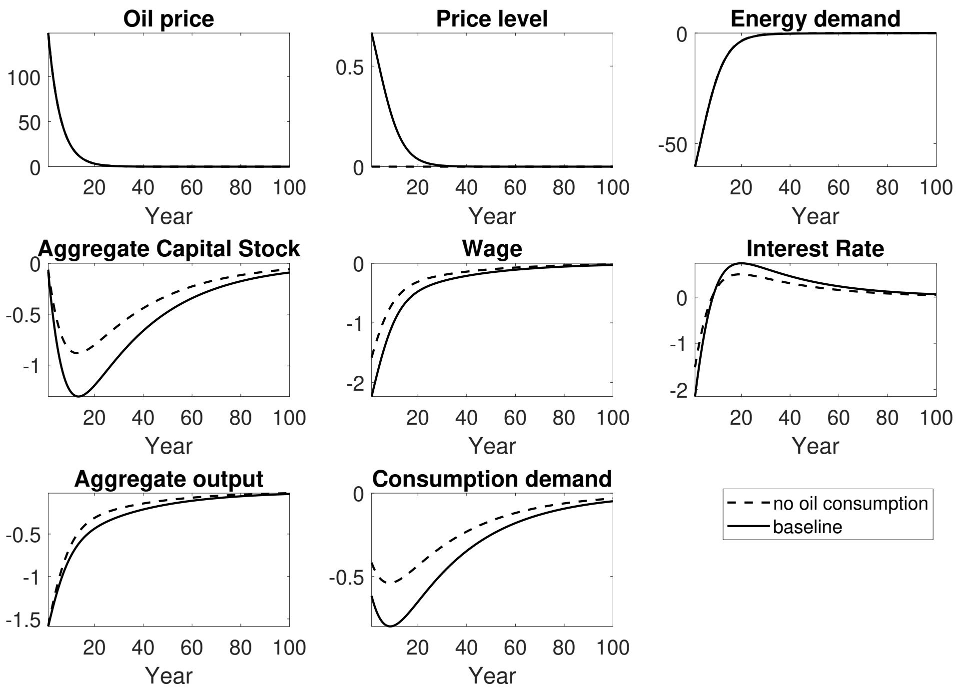

FIGURE 8. Impulse response functions (Unit: Δ% from steady state)

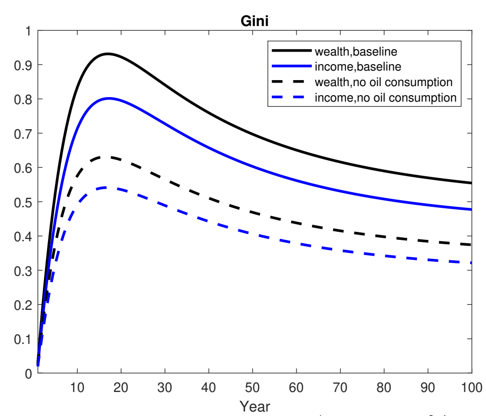

FIGURE 9. Impulse response functions (Unit: Δ% from steady state)

Finally, we conduct a simulation experiment where as increase the elasticity of substitution between oil and final goods by 50%, i.e., we change σ from 0.49 to 0.75. The results are displayed in Figures 10 and 11. Under a higher substitution elasticity, households can substitute away from oil to final goods when oil prices are higher, and thus are less significantly affected. The wealth and income inequality also respond less when the elasticity is higher, as the wage and interest rates experience smaller changes compared to the baseline.

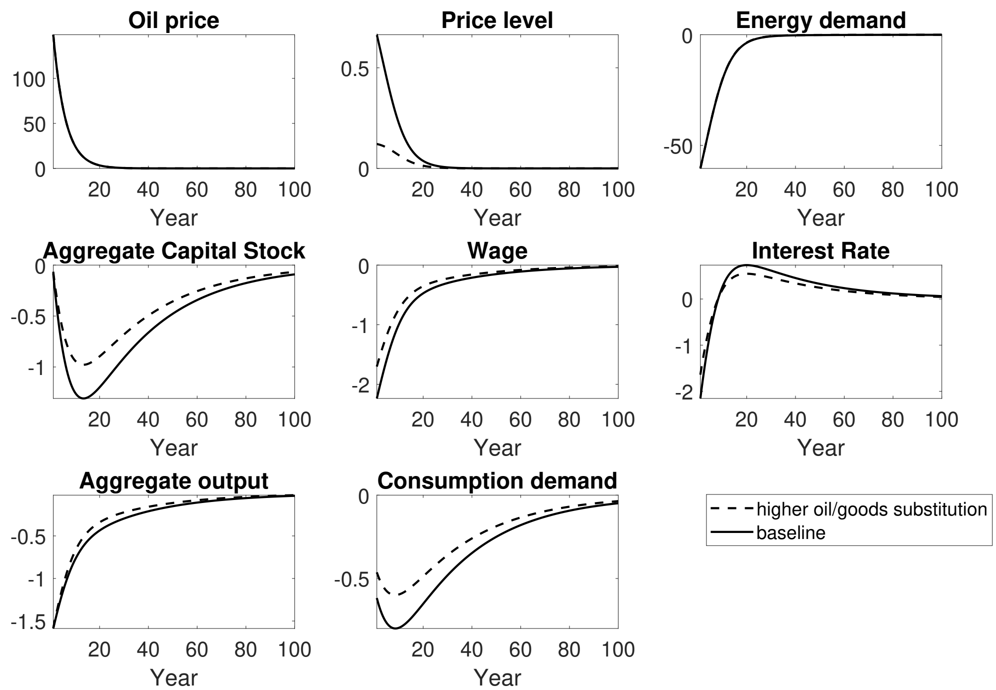

FIGURE 10. Impulse response functions (Unit: $\Delta\%$ from steady state)

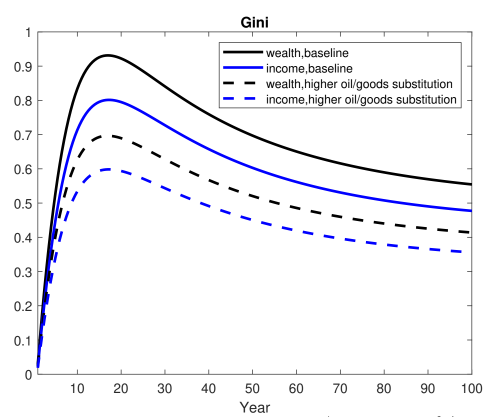

FIGURE 11. Impulse response functions (Unit: $\Delta\%$ from steady state)

7. Empirical Results

With regards to the empirical aspect of our study, we conduct several estimations using data on U.S. aggregate variables, inequality, and the energy market through the Structural Vector Auto-regressive (SVAR) analysis. In particular, we are interested in a baseline VAR model with the following variables:

$$\begin{bmatrix} \log(\textit{oil prices}) \\ \log(\textit{consumption}) \\ \log(\textit{real GDP}) \\ \log(\textit{employment}) \\ \textit{hourly wage rate} \\ \textit{federal funds rate} \\ \log(CPI) \\ \textit{saving rate} \\ \textit{inequality} \end{bmatrix}$$

We utilize the oil price data and the macroeconomic data from the FRED databases and the inequality data from the top income database Saez and Zucman 2016, the description of which are available in the appendix. The baseline model uses an annual frequency and the log differences of the non-stationary variables (oil prices, consumption, GDP, employment, wage rate, and CPI). We identify the model by Cholesky decomposition, i.e., we order oil prices as the first variable, which implies that oil price shocks can contemporaneously affect all the other variables, whereas other variables can only alter oil prices with a lag.

The estimation results are shown in Figure 12. An increase in oil prices results in declines in overall consumption and savings whereas slightly raises real GDP in the initial periods. The wage rate and employment are both lowered, but the price level raises. This is consistent with the literature that oil price shocks behave like negative aggregate supply shocks. The central bank responds by increasing the federal funds rate to control inflation on the impact of higher oil prices, but gradually lowers the policy rate to stimulate the economy, which falls in a recession years after the hit of oil price shocks. Finally, the impact on wealth inequality is significant and long-lasting, suggesting that even temporary oil price changes are able to have persistent distributional effects.

Figure 13 displays the impact of oil price changes estimated on a quarter-frequency dataset. The result suggests similar effects as shown by the baseline model: higher oil prices generally depress the economy and raise inequality.

8. Conclusion

This paper studies the effect of oil price changes on income and wealth inequality. Using data on macroeconomic aggregates, oil prices and inequality, we find in a structural vector autoregressive model that an increase in oil prices leads to a persistent increase in wealth inequality. To understand this change, we solve a continuous-time heterogeneous agent model with aggregate oil price shocks, and calibrate the model to the US data. Our result shows that a one standard deviation shock to the oil price leads to a 0.93% increase in wealth inequality and a 0.8% increase in income inequality When oil is being used as both consumption goods and production input.

Extensions of this model allow us to examine more economic scenarios. For example, by endogenizing oil production and oil hoarding activities, we would be able to draw a more complete picture on the impact of oil prices on inequality in an economy that has market power in the energy market. Additionally, assuming oil price shocks are stochastic (rather than deterministic) would change the behavior of producers and households It's interesting to explore the implications of such unexpectedness on inequality.

The understanding of how oil price shock transmits through the different income and wealth distribution of the economy can shed important light on various policies. For instance, the much-debated carbon tax has a direct effect on the ultimate oil prices that consumers encounter. Additionally, our framework can also be employed to evaluate the distributional effects of transitioning to cleaner technologies, as such a transition entails a higher fixed cost and is only within the means of the extremely affluent. Furthermore, monetary policymakers can also reap the benefits of such studies, as volatile headline inflation can be significantly driven by fluctuations in oil prices. The traditional singular core inflation targeting strategy may prove to be inadequate if the central bank is concerned about its distributional impact.

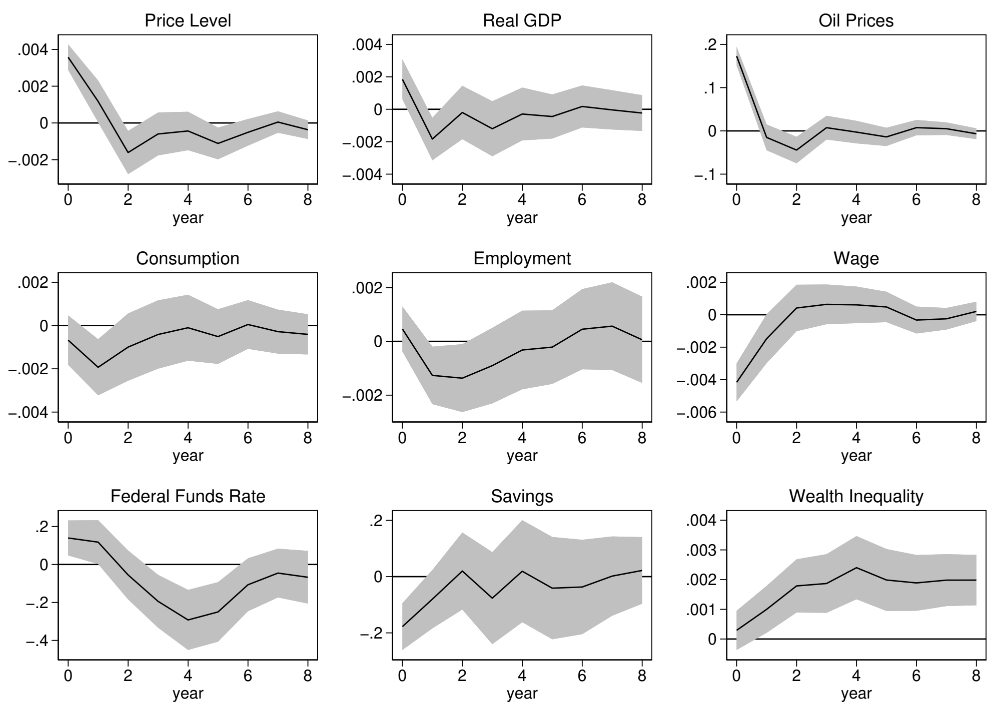

Figure 12. The Impact of Oil Price Changes

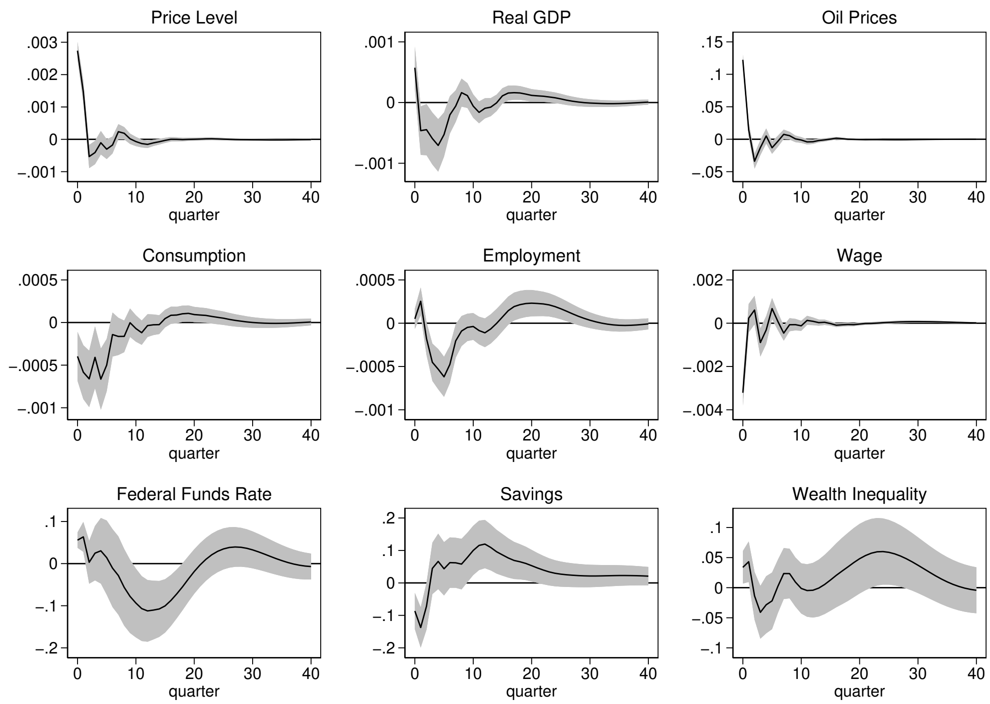

FIGURE 13. The Impact of Oil Price Changes

Appendix A. Data Description

Variable	Source	Definition
Real GDP	Bureau of Economic Analysis	The inflation adjusted value of the goods and services produced by labor and property located in the United States
CPI	Bureau of Labour Statistics	The price of a weighted average market basket of consumer goods and services purchased by households.
Hours Worked	Bureau of Labour Statistics	Hours worked for all workers in the Non-Farm Sector.
Federal Funds Rate	Federal Reserve Board	The nominal interest rate at which depository institutions lend reserve balances to other depository institutions overnight on an uncollateralized basis.
Crude Oil Prices	Energy Information Administration	Crude oil spot prices (dollars per barrel) deflated by CPI
T. Employment	Bureau of Labour Statistics	The number of U.S. workers in the economy that excludes proprietors, private household employees, unpaid volunteers, farm employees, and the unincorporated self-employed.
Real Pers. Expend.	Bureau of Economic Analysis	The nominal change in goods and services consumed by all households, and nonprofit institutions serving households, deflated by CPI
Investments	Bureau of Economic Analysis	Measure of the amount of money that domestic businesses invest within the U.S.
Wages	Bureau of Labour Statistics	Median usual weekly real earnings for full time workers 16 years and older.
Savings	Bureau of Economic Analysis	Calculated as the ratio of personal saving to disposable income.
Top 1% Wealth	Federal Reserve Board	Percentage of wealth held by the top 1% of U.S. households
Bottom 50% Wealth	Federal Reserve Board	Percentage of wealth held by the top 50% of U.S. households

Table 2. Data definition: all variables (1985 - 2019)

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