Crude oil price shocks and state tax implications

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Abstract

How do state taxes respond to changes in oil prices? For the United States, the answer remains inconclusive. We use a consumer optimization model to derive an optimal tax function, whose parameters are estimated from a structural model and a reduced-form model. Firstly, this study departs from the existing literature in the sense that it does not assume or predict a linear effect of oil prices on state taxes. Instead, we find a nonlinear concave relationship between state taxes and oil prices, which implies that higher oil prices lead to diminishing marginal returns in state taxes. Secondly, our findings corroborate the notable hypothesis of Kilian's (2008) study, which states that oil price shocks are not all created equal. Here, we find a negative average response of state taxes to changes in oil prices for periods led by negative oil supply shocks (for example, the Arab Spring). Alternatively, we find the opposite effect, for periods led by positive oil demand shocks and positive oil supply shocks (for example, the oil price boom of the early 2000s and the 2014 oil glut). Lastly, we find strong distributional effects of oil price shocks on state taxes: oil-dependent states (Alaska, Oklahoma, Wyoming, Texas, New Mexico, North Dakota, and Louisiana) face a more elastic and volatile response of state taxes to changes in oil prices compared to other states. For tax policy implications, our model predicts that motor fuel consumption is overtaxed relative to its importance in the consumer price index.

Keywords: State taxes, crude oil price shocks, threshold regression, simultaneous equations models.

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1. Introduction

The United States is the largest producer of petroleum in the world, yet it remains a price taker on the global market for crude oil. Consequently, fluctuations in crude oil prices affect the US economy in various ways (Qureshi and Ahmad, 2025). While the bulk of the literature focuses extensively on the inflationary consequences of oil price shocks, this paper explores the state tax implications of oil price shocks, which is one area that has not been thoroughly analyzed in context of the United States. Crude oil-related expenditure (for example, gasoline, fertilizers, kerosene, rubber tire, etc.) respond significantly to fluctuations in crude oil prices (Alsalman and Karaki, 2019; Wang, 2013). This implies that changes in oil prices are likely to have important implications for state tax revenue. Particularly, because the latter depends significantly on personal consumption expenditure; especially at the state level.

After performing a thorough examination of the literature, this study finds that there are only a handful of studies that examine the relationship between crude oil prices and state taxes. Kaczmarski and Baek's (2018) study is the only study that focuses explicitly on estimating the oil price elasticity of state taxes for Alaska. For the United States, it is evident that the current literature lacks conclusive findings on the tax implications of oil price shocks. Consequently, this study exploits this gap found in the literature by estimating the oil price elasticity of state taxes, which is useful to predict the response of state taxes to changes in oil prices, conditional on the full distribution of oil prices. Given the relative importance of oil expenditure in the consumer price index, having a reliable estimate of the oil price elasticity of state taxes is essential for state budget preparations and tax policy; hence the relative importance of this study.

This paper relies on a consumer optimization model with a constant elasticity of substitution (CES) to better understand the economic factors that are likely to influence the oil price elasticity of state taxes. Focusing on the notable proposition of Kilian (2008), this study introduces a macroeconomic parameter referred to as the "ambivalent oil effect" into the CES optimal consumption function. This structural parameter captures the weighted average response of state income to changes in crude oil prices. More importantly, unlike the standard CES model, the "ambivalent oil effect" influences nominal state expenditure. Moreover, the sign and the magnitude of the "ambivalent oil effect" smooths out or amplifies the substitution effect of an oil price shock on consumption expenditure. The theoretical model emphasizes two key features: it reflects distributional effects of oil price shocks on state taxes and a nonlinear relationship between oil prices and state taxes, which is influenced by the elasticity of substitution and the “ambivalent oil effect”. Here, the empirical objective is to test the theoretical assumptions. To achieve the latter, the main empirical framework relies on two key models: a structural model and a reduced-form model.

For the structural model, this study relies on the panel two stage least squares (2SLS) estimator to estimate the oil price elasticity of state taxes by addressing the simultaneous relationship between personal consumption expenditure and state taxes. For the reduced-form model, this study uses a panel threshold regression model to estimate a reduced-form tax function derived from the theoretical model. The threshold model tests the consistency of the main parameter estimates and examines the relevance of the “ambivalent oil effect” hypothesis. Overall, the two empirical models yield consistent estimates that are in line with the theoretical assumptions. The main empirical results can be summarized in three key points. Firstly, this study finds that personal consumption expenditure is highly significant in transmitting the effect of oil price shocks on state taxes. Moreover, higher oil prices lead to diminishing marginal consumption expenditure, suggesting that fluctuations in crude oil prices affect consumer welfare.

Secondly, this study departs from the existing literature in the sense that it does not assume or predict a linear effect of oil prices on state taxes. Instead, this paper finds a significant nonlinear concave relationship between state taxes and oil prices, indicating that higher oil prices lead to diminishing marginal returns in state taxes. Lastly, this study finds strong distributional effects of oil prices on state taxes: oil-dependent states (for example, Alaska, Oklahoma, Wyoming, Texas, New Mexico, North Dakota, and Louisiana) face a more elastic and volatile tax response to changes in oil prices in contrast to other states. According to the “ambivalent oil effect” hypothesis, the latter finding is due to strong differences in the average response of state income to changes in oil prices.

This study performs multiple robustness checks to ensure that the main empirical estimates are consistent and robust. This study relies on alternative proxies for state taxes and oil prices to test the consistency of the main parameter estimates. Overall, the robustness checks suggest that the main empirical estimates are robust and consistent. The rest of this paper is organized as follows. Section 2 provides a brief review of the literature. Section 3 introduces the conceptual framework. Section 4 presents the main empirical framework and discusses the key results. The last section discusses several policy implications. Appendix A conducts a series of additional robustness checks to test the consistency of the main empirical results.

2. Literature review

The literature on oil shocks focuses extensively on the inflationary consequences of oil price shocks. There are only a handful of studies that examine the tax implications of oil price shocks in the United States. Nonetheless, this section focuses on those studies that are relevant for estimating the oil price elasticity of state taxes. For oil exporters, studies show that oil prices are statistically significant in explaining tax revenue (Jabri et al., 2022; Spatafora and Samake, 2012). According to the literature, most studies find a linear effect of oil prices on tax revenue. A few studies find a linear asymmetric effect of oil prices on tax revenue (Kaczmarski and Baek, 2018). This study departs from the existing literature in the sense that it does not assume or predict a linear effect of oil prices on state taxes. Here, both the theoretical model and the empirical results depict a nonlinear concave relationship between oil prices and state taxes, which means that higher oil prices lead to diminishing marginal returns in state tax revenue. For the United States, there is no study found in the literature that provides this latter conclusion.

Abubakar et al. (2023) show that Nigeria's fiscal balance responds positively to negative oil price shocks in the short run. Similarly, using the same approach, Table 3 in Appendix A shows that state taxes respond positively to negative oil price shocks in the short run. A few studies provide empirical evidence of distributional effects of oil price shocks on macroeconomic activities (Potts and Yerger, 2024). For the United States, this is the first study in the literature to provide evidence of distributional effects of oil price shocks on state taxes. This study uses the size of the oil sector as the main threshold variable to estimate the effect of oil prices on state taxes; hence another contribution to the literature.

3. Conceptional framework

The section relies heavily on standard microeconomics theory. A minor contribution emanates from introducing a parameter referred to as the "ambivalent oil effect" into the CES consumption function. The standard CES model assumes that nominal expenditure is constant. Given the United States' dependence on crude oil, this section argues that fluctuations in crude oil prices are likely to affect nominal expenditure. The"ambivalent oil effect" hypothesis captures the latter idea. Following the literature, the representative household consumes different heterogenous goods (i), including oil-related consumer goods. Following Yilmazkuday (2021), the consumer derives utility from an ordinal utility function that exhibits properties of constant elasticity of substitution (CES).

The CES functional form offers a realistic way to model the oil price elasticity of state taxes. Particularly, because it does not force the elasticity of substitution to be equal to 1. Which is useful, because oil-related consumer goods are expected to be relatively inelastic. Following the literature, preferences are assumed to be homothetic. Which means that the aggregate consumption index can be defined as follows

$$C = \left[\left(\sum_{i=1}^{n} \gamma_i c_i^{\frac{\sigma-1}{\sigma}} \right) \right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

$$\sigma > 0, \; \sum_{i=1}^{n} \gamma_i = 1$$

where C denotes the aggregate consumption index. i stands for an index of differentiated consumer goods (for example, i can take on the notion of oil-related goods, which is the main focus of the study). σ denotes the elasticity of substitution which is a positive parameter. γ denotes the preference parameter. In a standard CES model, income is determined exogenously. Here, this section assumes that part of aggregate state income emanates from the production of good (i), which depends on the sectoral price (P_i). While the latter idea is highly simplified, it does offer unique theoretical properties that are useful to estimate the oil price elasticity of state taxes. Moreover, sectoral prices tend to be important in understanding consumer behavior (Carvalho et al., 2021). Consider the following budget constraint:

$$y = \sum_{i=1}^{n} P_i c_i$$

$$\varphi \in \mathbb{R}$$

where y denotes aggregate income, which is a function of two components: exogenous income (w_0) and endogenous income ($P_i^{\varphi_i}$), which depends on the sector price (i). Treating income as partially endogenous is the simplest way to incorporate the weighted average response of state income to changes in crude oil prices. Here, the objective is to derive the optimal demand function and use the latter to estimate an optimal tax function based on the household optimization problem. Following the literature, the standard consumer optimization problem can be expressed as follows

$$\max_{\{c_i\}} C : \left[\left(\sum_{i=1}^{n} \gamma_i c_i^{\frac{\sigma-1}{\sigma}} \right) \right]^{\frac{\sigma}{\sigma-1}} - \lambda \left(w_o P_i^{\varphi_i} - \sum_{i=1}^{n} P_i c_i \right)$$

where the first-order condition yields the optimal demand function as follows

$$c_i^* = \frac{\gamma_i^\sigma P_i^{\varphi_i - \sigma}}{\sum_{j=1}^n \gamma_j^\sigma (P_j)^{1-\sigma}} \cdot w_0 \tag{2}$$

which is slightly different than the standard CES Marhsallian demand function derived as follows:

$$c_i^* = \frac{\gamma_i^\sigma P_i^{-\sigma}}{\sum_{j=1}^n \gamma_j^\sigma (P_j)^{1-\sigma}} \cdot w_0$$

In Equation (2), the optimal demand for good (i) depends positively on initial wealth and ambiguously on the relative price (P_i/P_j). Here, the "ambivalent oil effect" (φ_i) is a structural economic parameter that captures the weighted average response of state income to changes in the given sector price (i). For theoretical purposes, the size of sector (i) in aggregate state income is determined exogenously. However, a larger exogenous (i) sector implies a stronger weighted average response of state income to changes in the given sector price. This is the key assumption that introduces distributional effects of oil price shocks in the model, which is useful to understand the pass-through of oil prices on state taxes in the United States. Moreover, the source of the oil shock and its effect on aggregate state income is also captured by the "ambivalent oil effect", which is estimated by using the full distribution of oil price shocks within a given interval of time.

When i takes on the category of oil-related consumer goods, φ_i represents the weighted average response of state income to changes in oil prices. For oil-dependent states, on average, the "ambivalent oil effect" is expected to be positive and relatively stronger. Particularly, because the elasticity of substitution is low and the size of the oil sector weights higher in the state's GDP (Kaczmarski and Baek, 2018). Moreover, on average, φ_i is likely to be positive, because positive demand-led oil price shocks tend to be more frequent (Archanskaïa et al., 2012; De et al., 2022).

For non-oil dependent states, on average, the "ambivalent oil effect" is expected to be positive, but relatively weaker and closer to zero for the following reason: a lot of states do not extract crude oil, but they act as export corridors, or large international processing facilities that reexport oil-related consumer goods. As a result, positive demand-led oil price shocks are expected to increase state income, as the demand for labor rises due to stronger global demand for crude oil. Alternatively, negative oil supply shocks are expected to cause minor setbacks or no major changes in state income. Particularly, because the size of the oil sector is expected to be relatively smaller for non-oil dependent states.

More importantly, studies show that positive demand-led oil price shocks are increasingly becoming more frequent and larger. Therefore, on average, for the non-oil dependent states, this study also expects the "ambivalent oil effect" to be positive, but relatively weaker in contrast to the oil-dependent states. The data support the "ambivalent oil effect" hypothesis very well. Table (10) in appendix A shows that the average response of state income to changes in real oil prices is positive, but relatively higher for the oil-dependent states compared to the non-oil dependent states. Therefore, this study expects strong distributional effects of oil price shocks on state taxes.

In conclusion, mathematically, the main idea is that a positive "ambivalent oil effect" smooths out the impact of the oil price shock on aggregate consumption expenditure ($\sum_{i=1}^{n} P_i c_i^*$). Alternatively, the opposite holds true, when the "ambivalent oil effect" is insignificant or negative. Instead, in the latter scenario, the "ambivalent oil effect" amplifies the substitution effect of the shock on aggregate consumption expenditure. Following standard macroeconomic theory, taxes are modeled as a fraction of aggregate consumption expenditure. Therefore, this section assumes a stable structural relationship between state taxes and aggregate consumption expenditure. Consider the optimal tax function of interest

$$T = \sum_{i=1}^{n} \theta_i P_i c_i^* \tag{3}$$

where θ_i denotes the tax rate for each specific good (i). T denotes state tax collections from all consumer purchases, which includes general sales taxes, excise taxes, motor fuel taxes, consumer energy taxes, and other sources of personal consumption expenditure. Here, this study identifies household consumption expenditure as a key channel for transmitting the effect of oil price shocks on state taxes. The latter assumption is a widely acceptable principle in the literature (Yilmazkuday, 2021).

For the United States, T is extremely relevant in the tax structure of every state. According to the literature, it accounts for 30% to 70% of total state taxes, depending on whether the state collects income taxes and severance taxes. Here, any missing tax components (for example, income taxes or the level of severance taxes) are held constant for theoretical simplicity.[1] Particularly, because the shape of the relationship between state taxes and crude oil prices depends mainly on the

[1]Severance taxes depend on income from oil extraction and the latter is influenced by oil prices, which means that the response of severance taxes to changes in oil prices can be indirectly captured by the "ambivalent oil effect". A strong positive response of state income to changes in oil prices means higher severance taxes.

"ambivalent oil effect" and the elasticity of substitution. Based on the model, the latter conclusion holds, regardless of whether income taxes or severance taxes are included as exogenous variables in Equation (3).

Therefore, this section argues that T is a good approximation of total state taxes, especially when the objective is to examine the curvature of the relationship between total state taxes and crude oil prices. Nonetheless, the empirical model uses total state taxes in order to properly estimate the magnitude of the oil price elasticity of state taxes. Inserting c_i^* into Equation (3) produces a reduced-form tax function defined as follows

$$T(P, w_0) = \frac{\sum_{i=1}^{n} \theta_i \gamma_i^{\sigma} P_i^{(1+\varphi_i-\sigma)}}{\sum_{j=1}^{n} \gamma_j^{\sigma} P_j^{1-\sigma}} \cdot w_o \tag{4}$$

where optimal state tax revenue depends on relative prices, tax rates, consumer preference, and exogenous income. Here, the main objective is to estimate the oil price elasticity of state taxes. Therefore, to achieve the latter objective, this section follows the literature and transforms Equation (4) in logarithm to compute the tax elasticity as follows

$$\frac{\partial \tau}{\partial p_c} = \left[\left(\frac{\partial X}{\partial P_c} \times \frac{P_c}{X} \right) - \left(\frac{\partial Z}{\partial P_c} \times \frac{P_c}{Z} \right) \right]$$

where $X = \sum_{j=1}^{n} \theta_j \gamma_j^{\sigma} P_j^{(1+\varphi_j-\sigma)}$ and $Z = \sum_{j=1}^{n} \gamma_j^{\sigma} P_j^{1-\sigma}$. Using the notations above, the derivative of the natural log of state taxes (τ) with respect to the natural log of crude oil prices (p_c) is computed as follows

$$\frac{\partial \tau}{\partial p_c} = \left[(1+\varphi_c-\sigma) \frac{\theta_c \gamma_c^{\sigma} P_c^{(1-\sigma+\varphi_c)}}{\sum_{j=1}^{n} \theta_j \gamma_j^{\sigma} P_j^{(1-\sigma+\varphi_j)}} - (1-\sigma) \frac{\gamma_c^{\sigma} P_c^{1-\sigma}}{\sum_{j=1}^{n} \gamma_j^{\sigma} P_j^{1-\sigma}} \right] \tag{5}$$

where the change in state taxes is ambiguous. Equation (5) depends on the "ambivalent oil effect", the elasticity of substitution, and the weight of oil-related consumption taxes $\left\{ \frac{\theta_c \gamma_c^{\sigma} P_c^{(1-\sigma+\varphi_c)}}{\sum_{j=1}^{n} \theta_j \gamma_j^{\sigma} P_j^{(1-\sigma+\varphi_j)}} \right\}$ relative to the weight of oil-related expenditure in the consumer price index $\left\{ \frac{\gamma_c^{\sigma} P_c^{1-\sigma}}{\sum_{j=1}^{n} \gamma_j^{\sigma} P_j^{(1-\sigma)}} \right\}$. For oil-related consumer goods (for example, motor fuel), according to the literature, the elasticity of substitution is expected to be relatively low ($.3 < \sigma < .8$). Here, using a Bayesian regression model, this study uses a noninformative uniform prior distribution to calibrate the "ambivalent oil effect" as follows

$$E(\varphi_c | y = .27)$$

The marginal posterior distribution for different estimates of φ_c are reported in Figure 2 in appendix A. Nonetheless, even with these latter calibrations, the response of state taxes to changes in real oil prices remains highly ambiguous. Particularly, because one must account for the weight of oil-related consumption taxes and the relative importance of oil-related expenditure in the consumer price index. For theoretical purposes, this study relies on motor fuel as a proxy for the oil-related consumption goods in order to predict the response of state taxes to an increase in crude oil prices. The average weight of motor fuel tax revenue in the tax structure of states is close to 6 %. Whereas the Bureau of Labor Statistics states that the weight of motor fuel expenditure in the CPI is approximately 3%.

Therefore, given these latter parameters, *ceteris paribus*, one can argue that motor fuel is significantly overtaxed at the state level; hence a key tax policy implication that policymakers can exploit. Nonetheless, given all the calibrated parameters, Equation (5) states that the response of state taxes to an increase in the relative price of oil is likely to be positive, but nonlinear in the relative price. Overall, based on the second derivative ($\frac{\partial^2 T}{\partial P_c^2} < 0$), the model predicts a nonlinear concave relationship between state taxes and oil prices. Particularly, because the elasticity of substitution is low and the "ambivalent oil effect" is positive and less than one.

Moreover, the theoretical results show that a higher φ_c implies a stronger response of state taxes to changes in oil prices. This shows that the states that are highly dependent on oil production with a larger oil sector are likely to be more sensitive to changes in oil prices compared to states that are less dependent on oil extraction; hence another key tax policy implication found in this section. Overall, this section contributes to literature by showing that the "ambivalent oil effect" offsets the substitution effect of an increase in oil prices, which provides the basis for a concave downward relationship between state taxes and oil prices. The latter assumption is highly supported by the data (for example, see Figure 5 in Appendix A).

The theoretical model uses a few simplifying assumptions, but the benefit is that the model is not overparameterized, and the assumptions are well justified by the economic literature. Nonetheless, the optimal tax function derived here is essential to understand tax policy and how fluctuations in oil prices influence state taxes. This section emphasizes that oil prices affect state taxes from two angles: production and consumption. The "ambivalent oil effect" emanates from the production side: an increase in oil prices leads to an increase in aggregate state income, which positively influences aggregate consumption expenditure and state taxes.

On the other hand, the substitution effect stems directly from consumption: as oil prices rise, oil-related consumption falls as households relocate part of spending to other goods. Therefore, the "ambivalent oil effect" truly offsets the substitution effect of an increase in oil prices, which strengthens aggregate consumption expenditure and state taxes. Particularly, because consumption expenditure is proportional to state taxes. The next section tests the concavity assumption and the "ambivalent oil effect" hypothesis.

4. Empirical methodology

4.1. Data

This section relies on longitudinal annual data. The range of the data is from 1994 to 2025. The latter period provides the full available data for total state tax collections. The data includes all 50 states. This study focuses on consumer behavior and the welfare implications of oil prices. Therefore, the main dependent variable is measured as follows

$$\tau = ln\left(\frac{total\ state\ tax\ collections}{state\ resident\ population}\right)$$

For additional robustness, this section considers the log of motor fuel state tax per capita (τ^f) to further examine the relevance of the theoretical framework. States taxes are collected from the Federal Reserve Bank of Saint Louis. This section relies on the WTI Cushing oil price index as the main indicator of crude oil prices. For the price deflator, this study relies on the consumer price index (CPI). The main proxy for real oil prices is computed by taking the log ratio of crude oil prices to the consumer price index (p_c/p_j).

Most studies do not consider different proxies of oil prices. For empirical robustness, one should question the empirical estimates when the latter are highly sensitive to different proxies of oil prices. Here, this study relies on the US regular gasoline price index as an alternative indicator of crude oil prices. The gasoline price data are collected from Federal Reserve Bank of Saint Louis. The alternative proxy for real oil prices is computed by taking the log ratio of gasoline prices to the consumer price index (p_g/p_j). It is important to recognize that the Bureau of Labor Statistics computes the consumer price index by relying on selected metro areas. This implies that the CPI dataset is not purely available at the state level.

Moreover, the implicit price deflator for personal consumption expenditure is not useful for this study, because the latter is only available from 2008. As a result, this study relies on the national CPI index as the main deflator for computing the real price of crude oil. While the latter approach is common in the literature, this study recognizes that the national CPI index omits the relevant structural differences in prices that exist across the states. Notably, following the literature, if one assumes that these structural differences are unobservable time-invariant factors, then the unobserved heterogeneity can be addressed by relying on state-specific fixed effects.

In order to test the consistency of the main parameter estimates, this study considers a price deflator that is available at the state level. This strategy allows one to examine the consequences of utilizing different price deflators in estimating the oil price elasticity of state taxes. This study chooses the FHFA house price index as the alternative price deflator to the CPI. Consequently, an additional proxy for real oil prices is computed by taking the log ratio of WTI to the house price index (p_c/p_h). Figure 1 plots the three proxies for real oil prices.

Figure 1: Real Oil Prices

The house price index does not measure aggregate consumer prices, but it does capture some structural differences in costs between the states. Moreover, relying on the house price index is useful to introduce variations in real oil prices between the states. Therefore, one can argue that the house price index is a good alternative for the CPI. Particularly because it is strongly correlated to the consumer price index.

More importantly, each price deflator adds something that the other lacks. The house price index emanates from the U.S Federal housing database. This section chooses 1994 as the base year for all price indexes.

For consumption expenditure, this section relies on the log of personal consumption expenditure per capita (c). Personal consumption expenditure data are available from 1997 to 2024 and the data emanate from the Bureau of Economic Analysis. This section relies on the log of air passenger traffic per capita (airTraffic) as an external instrument for personal consumption expenditure. Air traffic data are collected from the Bureau of Transportation Statistics. Air traveling exhibits characteristics of consumer confidence. It contributes to additional consumer spending that influences state taxes (for example, transportation, dining, gifts, etc.). Therefore, air traveling is likely to be a valid external instrument for personal consumption expenditure, because it affects personal consumption expenditure directly and state taxes indirectly through personal consumption expenditure.

This section relies on the log of petroleum export per capita (crudeExport) as an exogenous proxy for income. Petroleum export revenue is determined exogenously, which means that it can be a valid exogenous proxy for domestic income. Export data are collected from the Census Bureau. Additionally, this section relies on stock performance (returns) as an alternative proxy for exogenous income. Stock performance is derived from annual stock returns. The latter are computed by using the Dow Jones Industrial index, which is collected from Yahoo Finance. Lastly, this section uses the share of oil and gas production in GDP (oilSector) as the main threshold variable in the panel threshold regression model. The oil and gas production data are collected from the Bureau of Economic Analysis. The summary statistics for the main dataset are reported in Appendix A in Table 7. The data are publicly available and for replication purposes, the codes and the data are released on the authors' website.

4.2. Panel two-stage least squares estimator

This section tests the key theoretical assumptions derived in Section 3. In the theoretical model, state taxes and consumption expenditure are endogenous and simultaneously determined. Furthermore, the theoretical model predicts a nonlinear relationship between crude oil prices and state taxes. Consequently, the empirical framework must account for nonlinearities and endogeneity in order to properly estimate the oil price elasticity of state taxes. Consider the following regression model

$$\tau_{s,t} = b_1 t_{s,t-2} + b_2 c_{s,t} + b_3 (p_c/p_j)_{s,t} + b_4 (p_c/p_j)^2_{s,t} + \eta_s + u_{s,t} \tag{6}$$

where all the variables are expressed in logarithm. s is a subscript for states and t denotes time. η_s is a vector of state-specific fixed effects.[2] u is a serially uncorrelated vector of idiosyncratic errors. c denotes the log of personal consumption expenditure per capita. This section proposes the following moment condition

$$E\left(\tau_{s,t-2} \cdot u_{s,t}\right) = 0$$

which implies that the two-year lagged dependent variable is uncorrelated with the error term at time (t). Here, the main objective is to estimate the direct nonlinear elasticity

$$\frac{\partial \tau}{\partial (p_c/p_j)} = b_3 + 2b_4(p_c/p_j)$$

According to the literature, crude oil prices are determined exogenously. Therefore, the relative price of crude oil is naturally uncorrelated with the error term at time (t). However, this latter assumption is likely to be violated, because consumption is endogenous and correlated to (p_c/p_j), which implies the following

$$cov(p_c/p_j, u) \neq 0$$

Therefore, using Equation (6) directly to estimate the oil price elasticity of state taxes leads to a bias estimate. Consequently, this section considers a two-step estimation approach. The first step consists of estimating c conditional on a given matrix of instruments (W). Consider the first-stage regression

$$c = W\psi + \varepsilon \tag{7}$$

where c denotes an $N \times 1$ column vector of consumption observations. W denotes an $N \times 5$ matrix of two instruments, including the three exogenous variables: $tax_{s,t-2}$, $(p_c/p_j)^2$, and (p_c/p_j). Following Schaffer (2005), all the variables in equation (7) are demeaned. The instrumental variable approach consists of using one internal instrument and one external instrument. $c_{s,t-1}$ is likely to be correlated with the error term at time (t). Therefore, this section relies on deeper lags of consumption (for example, $c_{s,t-2}$ or $c_{s,t-3}$). For the external instrument, this paper relies on the

[2]Crude oil prices are determined exogenously, and oil price shocks are common macroeconomic shocks for all the states. Moreover, the variations in the oil price data are purely driven by time. Therefore, including time fixed effects in Equation (6) would capture most of the variations in oil prices, making it more difficult to properly identify the oil price elasticity of state taxes. Therefore, for econometric purposes, time fixed effects are not considered in Equation (6).

log of air passenger traffic per capita (airTraffic). ψ is a 5×1 column vector of coefficients to be estimated (for example, these coefficients are reported in Appendix A in Table 9). ε is an $N \times 1$ column vector of demeaned errors. The objective is to find a vector ($\hat{\psi}$) that minimizes the sum of the residuals squared:[3]

$$\min_{\hat{\psi}} \Phi = c'c - 2\hat{\psi}'W'c + \hat{\psi}'W'W\hat{\psi} \tag{8}$$

taking the first-order condition provides the normal equations

$$(W'W)\hat{\psi} = W'c$$

from which, we can solve for the optimal vector ($\hat{\psi}$) as follows

$$\hat{\psi} = (W'W)^{-1}W'c \tag{9}$$

Furthermore, inserting Equation (9) into equation (7) and taking the expectation produces the predicted vector as follows

$$\hat{c} = W(W'W)^{-1}W'c$$

where the projection matrix (P) is defined by $W(W'W)^{-1}W'$. The second step consists of using the projected regressor matrix to estimate the structural parameters as follows

$$\tau = \hat{X}\beta + u$$

where τ denotes an $N \times 1$ column vector of demeaned tax observations. $\hat{X} = PX$ denotes the projected regressor matrix, which is an $N \times 4$ matrix of demeaned regressors that include: $tax_{s,t-2}$, (p_c/p_j), $(p_c/p_j)^2_{s,t}$, and Pc. u is an $N \times 1$ column vector of demeaned idiosyncratic errors, which are assumed to be serially uncorrelated. The panel two-stage least square estimator can be derived as follows

$$\min_{\hat{\beta}} \Phi : \tau'\tau - 2\hat{\beta}'\hat{X}'\tau + \hat{\beta}'\hat{X}'\hat{X}\hat{\beta}$$

taking the first-order condition yields

$$\hat{\beta} = \left[(PX)'(PX)\right]^{-1}(PX)'\tau$$

[3]The sum of the residuals squared can be approximated as follows: $(c - W\hat{\psi})'(c - W\hat{\psi})$.

simplifying the above and using the fact that $P = W(W'W)^{-1}W'$, the final panel 2SLS estimator can be derived as follows

$$\hat{\beta} = \left[X'W(W'W)^{-1}W'X\right]^{-1} X'W(W'W)^{-1}W'\tau \tag{10}$$

where $\hat{\beta}$ denotes a (4×1) column vector of structural parameters to be estimated. Following Schaffer (2005), this section addresses concerns of serial correlation and heteroskedasticity by relying on clustered robust standard errors, which are clustered at the state level. The additional moment conditions imposed in the main empirical framework must be evaluated to ensure that the empirical estimates are valid. Therefore, this study relies on the Sargan-Hansen test of overidentification to ensure that the data does not reject the additional moment conditions imposed here.[4] The next section reports the main empirical estimates.

4.3. Main empirical results

Table 1 reports the main empirical results with the p-values associated with the Sargan-Hansen test of overidentification and the Kleibergen-Paap test of underidentification. The diagnostic tests suggest that the empirical results are largely robust across all different specifications. The overidentification test suggests that the additional moment conditions imposed in Section 4.2 are not rejected by the data. On the other hand, the Kleibergen-Paap test of underidentification shows that the instruments are relevant and useful to identify the key structural parameters. The regressors explain a high percentage of variation in state taxes. This reinforces confidence in the theoretical model and the econometric framework. Table 9 in Appendix A reports the F-statistics for the first-stage results.

The strength of the F-statistics suggests that the set of instruments is relatively strong. From a statistical perspective, the diagnostics tests reiterate that the instruments are both valid and relevant. Table 1 shows that personal consumption expenditure is statistically significant in transmitting the effect of oil price shocks on state taxes. Here, a 10 % increase in personal consumption expenditure per capita increases state tax revenue per capita by 4 to 6 %. In line with the theoretical assumptions, Table 9 in Appendix A shows that the relationship between personal consumption expenditure and oil prices is nonlinear and concave. This implies that an increase in oil prices has negative welfare consequences for households.

[4] This section relies on Schaffer's (2005) xtivreg2 estimator to estimate Equations (9) and (10).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	τ	τ	τ	τ	τ	τ	τ	τ	τ
$c_{s,t}$	0.479***	0.510***	0.580***	0.530***	0.550***	0.620***	0.547***	0.558***	0.667***
	[0.425,0.532]	[0.460,0.560]	[0.524,0.636]	[0.473,0.588]	[0.492,0.609]	[0.561,0.679]	[0.484,0.610]	[0.498,0.618]	[0.597,0.738]
$\tau_{s,t-2}$	0.504***	0.496***		0.478***	0.473***		0.475***	0.476***	
	[0.434,0.573]	[0.437,0.555]		[0.431,0.525]	[0.431,0.516]		[0.428,0.523]	[0.435,0.518]	
$\tau_{s,t-3}$			0.410***			0.394***			0.376***
			[0.330,0.490]			[0.330,0.458]			[0.330,0.421]
(p_c/p_j)	0.165***			0.126***			0.215***		
	[0.101,0.229]			[0.060,0.191]			[0.140,0.291]		
$(p_c/p_j)^2$	-0.077***			-0.051**			-0.096***		
	[-0.124,-0.031]			[-0.098,-0.004]			[-0.141,-0.051]		
(p_c/p_h)		0.123**			0.118**			0.146**	
		[0.029,0.218]			[0.021,0.215]			[0.034,0.258]	
$(p_c/p_h)^2$		-0.083***			-0.076***			-0.092***	
		[-0.129,-0.036]			[-0.124,-0.028]			[-0.146,-0.037]	
(p_g/p_j)			0.213***			0.185***			0.402***
			[0.109,0.318]			[0.078,0.292]			[0.253,0.550]
$(p_g/p_j)^2$			-0.163***			-0.122**			-0.316***
			[-0.288,-0.039]			[-0.242,-0.001]			[-0.440,-0.193]
N	1249	1249	1249	1200	1200	1200	1100	1100	1100
Instruments	5	5	5	5	5	5	5	5	5
R^2	0.8079	0.8088	0.7887	0.7982	0.7983	0.7789	0.7656	0.7646	0.7461
Hansen J statistic (p-value)	0.4958	0.3347	0.2971	0.2011	0.5563	0.1713	0.1143	0.0702	0.2549
Kleibergen-Paap statistic (p-value)	0.0043	0.0220	0.0357	0.0003	0.0016	0.0000	0.0194	0.0201	0.0171

95 % confidence interval in brackets
$p < 0.10^{*}$,$p < 0.05^{**}$,$p < .01^{***}$

Table 1: Panel 2SLS (Second Stage)

Lastly, as expected from Section 3, Table 1 finds a nonlinear concave relationship between state taxes and crude oil prices. In other words, higher oil prices lead to diminishing marginal returns in state tax revenue per capita. More importantly, the initial oil price level and the magnitude of the oil shock are two important factors that are useful to forecast the effect of oil prices on state taxes. For instance, at lower oil prices, an increase in real oil prices is expected to cause an increase in state taxes; as long as the "ambivalent oil effect" is positive and the elasticity of substitution is low. In 2021, real oil prices increased by 50%, but average state tax revenue per capita also increased simultaneously by 16%. This increase in state taxes was partially caused by a lower oil price level prior to the shock. The price of oil dropped from $65 to $40 dollars per barrel in 2020 prior to the shock.

Here, the main empirical estimates are highly consistent, irrespective of the different oil proxies used to estimate the oil price elasticity of state taxes. The 2SLS model predicts a positive average response of state taxes to changes in oil prices during periods led by positive oil demand shocks. During the oil price boom of the early 2000s, when oil prices rose significantly due to rising global demand, the model predicts a positive and stronger average response of state taxes to changes in crude oil prices. On the other hand, the 2SLS model predicts the opposite effect during periods led by negative oil supply shocks. During the Arab Spring, when oil prices surged from $80 to $98 per barrel, the model predicts a negative average response of state taxes to changes in oil prices.

For periods led by negative oil demand shocks or positive oil supply shocks, the 2SLS model predicts a positive average response of state taxes to changes in oil prices. For instance, between 2014 and 2016, when oil prices collapsed significantly due to the oil glut and deteriorating oil demand, the 2SLS model predicts an increasingly positive response of state taxes to changes in oil prices. Lastly, Table 12 in Appendix A estimates the 2SLS model by using motor fuel state taxes (τ^f) as the alternative dependent variable. This approach allows one to test the consistency of the main empirical estimates. The 2SLS regressions for τ^f are reported in Columns 1, 2, and 3 in Table 12. These latter regressions corroborate the main empirical results found here: higher oil prices lead to diminishing marginal returns in motor fuel state tax revenue per capita.

4.4. Reduced-form model

According to the theoretical model, the size of the state's oil sector is important for understanding the effect of oil prices on state taxes. Particularly, because a larger oil sector implies a stronger "ambivalent oil effect", which influences both consumption expenditure and state taxes. Consequently, as shown in the theoretical framework, understanding the relationship between state taxes and crude oil prices requires testing for distributional effects; hence another contribution to the literature. This section relies on a panel threshold regression model to test for distributional effects of oil price shocks on state taxes. Following Hansen (1999), consider the following model

$$\tau_{s,t} = \eta_s + Z'_{s,t}\delta + X'_{s,t}\Gamma(oilSector_{s,t} \leq \phi) + X'_{s,t}\Gamma(oilSector_{s,t} \geq \phi) + u_{s,t} \qquad (11)$$

where oilSector denotes the main threshold variable. ϕ is the threshold parameter. η is a vector of state-specific fixed effects. Z is a vector of non-state covariates (this section uses stock performance as the only non-state variable). X contains the state variables: $tax_{s,t-2}$, $(p_c/p_j)_{s,t}$, $(p_c/p_j)^2_{s,t}$, crudeExport$_{s,t}$, and $\triangle c_{s,t-1}$. Note that because $c_{s,t}$ is $I(1)$ and endogenous, this section uses the lagged difference of consumption expenditure to address concerns of endogeneity and nonstationary. Following Hansen's (1999) recommendations, all covariates are expected to be exogenous and $I(0)$. Therefore, it is empirically convenient to rely on the reduced-form model, as long as the instruments are strictly exogenous or weakly exogenous.

Table 2 reports different specifications of Equation (11) as a means to test for consistency in the parameter estimates. All estimates of ϕ are statistically significant. This implies that the size of the state's oil sector is statistically significant in explaining the pass-through of oil shocks on state taxes. The latter finding reinforces the "ambivalent oil effect" hypothesis. The oil-dependent states and the non-oil dependent states are identified by the threshold regression model. The oil-dependent states include: Alaska, Louisiana, Oklahoma, North Dakota, Texas, Wyoming, and New Mexico. Table 2 shows that the oil price elasticity of state taxes is relatively more elastic for the oil-dependent states compared to the other states, which are referred to as the non-oil dependent states.

According to the "ambivalent of effect" hypothesis, the latter finding is due to differences in the average response of state income to changes in oil prices. The "ambivalent oil effect" is estimated for both groups in Table 10 in Appendix A. Table 10 shows that the "ambivalent oil effect" is positive and relatively higher for the oil-dependent states compared to the non-oil dependent states. More importantly, Table 2 reiterates that the relationship between state taxes and real oil prices is nonlinear and concave. This strengthens the "ambivalent oil effect" hypothesis even further. Lastly, Table 2 shows that the effect of personal consumption expenditure on state taxes is more elastic for the oil-dependent states compared to the non-oil dependent states. The latter finding is consistent with the theoretical assumptions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	τ	τ	τ	τ	τ	τ	τ	τ	τ
$\text{returns}_{s,t-1}$				0.006***	0.006***	0.006***			
				[0.005,0.007]	[0.005,0.007]	[0.005,0.007]			
constant	1.440*	1.498*	1.484*	1.684**	1.680**	1.748**	1.059**	0.790*	1.148**
	[-0.117,2.997]	[-0.142,3.137]	[-0.242,3.209]	[0.141,3.227]	[0.199,3.161]	[0.105,3.392]	[0.113,2.005]	[-0.045,1.625]	[0.123,2.172]
$\tau_{s,t-2}$									
(oilSector$\leq \phi$)	0.791***	0.802***	0.795***	0.761***	0.783***	0.763***	0.852***	0.898***	0.843***
	[0.577,1.006]	[0.584,1.021]	[0.560,1.031]	[0.547,0.975]	[0.586,0.980]	[0.538,0.987]	[0.723,0.981]	[0.790,1.005]	[0.705,0.981]
(oilSector$\geq \phi$)	0.517***	0.544***	0.609***	0.330**	0.554***	0.435***	0.802***	0.854***	0.806***
	[0.189,0.845]	[0.142,0.945]	[0.242,0.977]	[0.070,0.590]	[0.186,0.921]	[0.114,0.755]	[0.649,0.955]	[0.715,0.992]	[0.652,0.961]
$(p_c/p_j)_{s,t}$									
(oilSector$\leq \phi$)	0.508***			0.554***			0.245***		
	[0.318,0.697]			[0.321,0.788]			[0.095,0.394]		
(oilSector$\geq \phi$)	3.265***			4.032***			1.156***		
	[2.806,3.724]			[2.520,5.544]			[0.564,1.747]		
$(p_c/p_j)^2_{s,t}$									
(oilSector$\leq \phi$)	-0.297***			-0.358***			-0.125***		
	[-0.425,-0.168]			[-0.514,-0.202]			[-0.214,-0.036]		
(oilSector$\geq \phi$)	-1.450***			-1.681***			-0.557***		
	[-1.963,-0.938]			[-2.813,-0.549]			[-0.794,-0.320]		
$(p_c/p_h)_{s,t}$									
(oilSector$\leq \phi$)		0.134***			0.095**			0.085***	
		[0.045,0.223]			[0.008,0.182]			[0.034,0.137]	
(oilSector$\geq \phi$)		3.700***			3.314***			0.753**	
		[2.016,5.385]			[1.679,4.948]			[0.150,1.356]	
$(p_c/p_h)^2_{s,t}$									
(oilSector$\leq \phi$)		-0.119***			-0.124***			-0.045**	
		[-0.176,-0.063]			[-0.179,-0.069]			[-0.083,-0.008]	
(oilSector$\geq \phi$)		-2.133***			-1.967***			-0.413***	
		[-3.044,-1.222]			[-2.862,-1.073]			[-0.718,-0.108]	
$(p_g/p_j)_{s,t})$									
(oilSector$\leq \phi$)			0.573***			0.649***			0.344***
			[0.275,0.871]			[0.317,0.981]			[0.108,0.581]
(oilSector$\geq \phi$)			3.053***			4.675***			1.521***
			[2.397,3.709]			[3.246,6.104]			[0.764,2.279]
$(p_g/p_j)^2_{s,t}$									
(oilSector$\leq \phi$)			-0.542***			-0.759***			-0.277**
			[-0.917,-0.167]			[-1.171,-0.346]			[-0.529,-0.024]
(oilSector$\geq \phi$)			-2.054***			-3.444***			-1.226***
			[-3.478,-0.631]			[-5.979,-0.910]			[-1.704,-0.749]
$\triangle c_{s,t-1}$									
(oilSector$\leq \phi$)							1.668***	1.512***	1.689***
							[1.442,1.895]	[1.315,1.710]	[1.458,1.920]
(oilSector$\geq \phi$)							5.671***	4.332***	5.694***
							[2.765,8.577]	[2.620,6.043]	[2.920,8.467]
$\text{crudeExport}_{s,t}$									
(oilSector$\leq \phi$)	0.023*	0.029**	0.018	0.014	0.019	0.012			
	[-0.001,0.046]	[0.002,0.057]	[-0.007,0.043]	[-0.008,0.036]	[-0.004,0.041]	[-0.010,0.034]			
(oilSector$\geq \phi$)	0.185	0.199*	0.169	0.326***	0.175	0.307***			
	[-0.039,0.409]	[-0.028,0.426]	[-0.067,0.404]	[0.144,0.508]	[-0.036,0.386]	[0.111,0.502]			
ϕ	10.35***	10.35***	10.35***	12.79***	10.35***	12.79***	9.32***	3.98***	9.32***
R^2	0.81	0.79	0.82	0.84	0.84	0.84	0.87	0.88	0.87
N	1150	1150	1150	1150	1150	1150	1300	1300	1300

95 % confidence interval in brackets

$p < 0.10^{*}$,$p < 0.05^{**}$,$p < .01^{***}$

Table 2: Panel Threshold Model (Oil Sector)

Overall, the empirical results derived here are highly consistent with both the theoretical underpinnings and the main empirical results derived in Section 4.3. Figure 2 plots the predicted response of state taxes to changes in historical oil prices. For periods led by positive oil demand shocks or deteriorating oil demand, Equation (11) predicts a positive and stronger average response of state taxes to changes in oil prices (for example, see the oil price elasticity of state taxes during the oil price boom of the early 2000s and the 2014 oil price crash). On the other hand, for periods led by negative oil supply shocks (for example, see the Arab Spring on Figure 2), Equation (11) predicts a negative average response of state taxes to changes in oil prices. For the oil-dependent states, Figure 2 shows that the response of state taxes to changes in oil prices is historically more elastic and volatile compared to the non-oil dependent states.

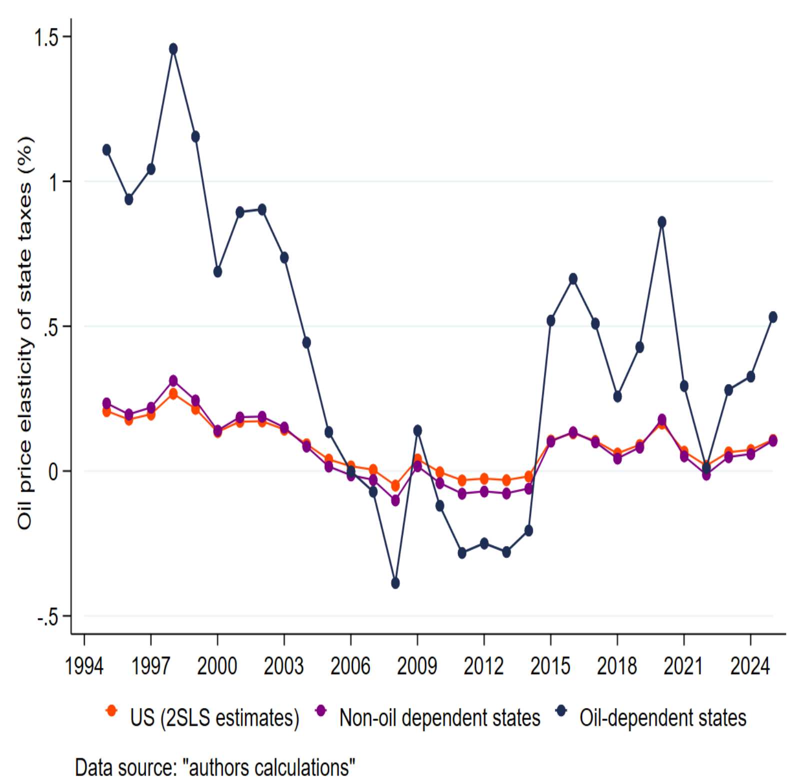

Figure 2: Historical Predictions (Oil Price Elasticity of State Taxes)

For additional robustness, Table 11 in Appendix A uses petroleum export per capita (crudeExport) as an alternative threshold variable. Table 11 corroborates the results found here. States that are highly dependent on oil production or petroleum export face a relatively more elastic response of states taxes to changes in oil prices.

5. Conclusion

How do state taxes respond to oil price shocks? This study shows that the answer to this question is not unequivocal. The response of state taxes to changes in oil prices depends on several factors: the tax weight oil taxes in the tax structure of the state, the "ambivalent oil effect", the weight of oil expenditure in the consumer price index, and the elasticity of substitution of oil for other consumer goods. Overall, this study finds that state taxes increase with oil prices, but at a decreasing rate. At lower oil prices, the average response of state taxes to an increase in oil prices is likely to be positive. At higher oil prices, there is strong diminishing marginal returns in state tax revenue per capita.

The empirical findings emphasize three key policy implications. Firstly, this study stresses the importance of taxing oil-related consumption in function to its relative importance in the consumer price index. Particularly, because the elasticity of substitution is low and nominal expenditure responds positively to rising oil prices. This policy would minimize pressure on state taxes following a sharp increase in oil expenditure caused by a drastic increase in oil prices. Secondly, we find strong distributional effects of oil price shocks on state taxes: oil-dependent states (Alaska, Oklahoma, Wyoming, Texas, New Mexico, North Dakota, and Louisiana) face an elastic and more volatile response of state taxes to changes in oil prices.

Lastly, this study finds that the source of the oil shock is useful in understanding the oil price elasticity of state taxes. For periods led by negative oil supply shocks, this study finds a negative average response of state taxes to changes in oil prices. Alternatively, for periods led by positive oil demand shocks or positive oil supply shocks, this paper finds the opposite effect. Hence the following question: how can the state mitigate the burden of negative oil supply shocks on the state taxes and consumer welfare? Normally, tax cuts, lifting oil supply restrictions, and oil subsidies are common policies that states use to alleviate the burden of negative oil supply shocks on the state budget and households. However, this study argues that a countercyclical oil tax policy would be useful to generate the funds needed to build strong petroleum reserves and sustain the cost of energy assistance programs that states rely on to minimize the burden of negative oil supply shocks on the state budget and households.

Moreover, the revenue derived from this tax program would be reinvested into a sovereign wealth fund to generate more interest revenue for the state, which can be used as emergency funds during periods of negative oil supply shocks. For instance, the leading oil-dependent states such as Texas, New Mexico, Louisiana, Wyoming, North Dakota, and Alaska are already using sovereign wealth funds that are funded from oil revenue. Nonetheless, this study argues that adopting a countercyclical oil tax policy could further strengthen these sovereign wealth funds.

In conclusion, this study performs multiple robustness checks to ensure that the main empirical estimates are consistent and robust (for example, see Appendix A for additional robustness checks). Different proxies of oil prices are used to examine the consistency of the main parameter estimates. This study relies on different samples to test the strength of the key theoretical assumptions. Furthermore, Appendix A uses additional empirical models to ensure that the main empirical results are not spurious. Ultimately, this study reconciles the literature by testing for asymmetric effects, threshold effects, and nonlinearities in estimating the effect of oil prices on state taxes.

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Appendix A

Conceptional framework

Consumer choice problem

$$\max_{\{c_i\}} C : \left[\left(\sum_{i=1}^{n} \gamma_i c_i^{\frac{\sigma-1}{\sigma}}\right)\right]^{\frac{\sigma}{\sigma-1}} - \lambda\left(w_o P_i^{\varphi_i} - \sum_{i=1}^{n} P_i c_i\right)$$

where the first-order condition can be solved as follows

$$\frac{\sigma}{\sigma-1} \cdot \frac{\sigma-1}{\sigma} \cdot \left[\left(\gamma_j \sum_{i=1}^{n} c_j^{\frac{\sigma-1}{\sigma}}\right)\right]^{\frac{1}{1-\sigma}} \cdot \gamma_i c_i^{(-1/\sigma)} = \lambda P_i$$

simplifying the above allows one to solve for the consumption index as follows

$$c_i = \lambda^{-\sigma}\left[\left(\gamma_j \sum_{i=1}^{n} c_j^{\frac{\sigma-1}{\sigma}}\right)\right]^{\frac{\sigma}{1-\sigma}} \cdot \gamma_i^{\sigma} \cdot (P_i)^{-\sigma}$$

inserting c_i into the budget constraint and taking the sum across all goods yields

$$w_o P_i^{\varphi_i} = \lambda^{-\sigma}\left[\left(\gamma_j \sum_{i=1}^{n} c_j^{\frac{\sigma-1}{\sigma}}\right)\right]^{\frac{\sigma}{1-\sigma}} \cdot \gamma_j^{\sigma} \cdot \sum_{j=1}^{n} (P_j)^{1-\sigma}$$

rearranging terms further yields

$$\lambda^{-\sigma}\left[\left(\gamma_j \sum_{i=1}^{n} c_j^{\frac{\sigma-1}{\sigma}}\right)\right]^{\frac{\sigma}{1-\sigma}} = \frac{w_o P_i^{\varphi_i}}{\sum_{j=1}^{n} \gamma_j^{\sigma} (P_j)^{1-\sigma}}$$

plugging the above into c_i yields the optimal demand function as follows

$$c_i^* = \frac{\gamma_i^{\sigma} P_i^{(\varphi_i-\sigma)}}{\sum_{j=1}^{n} \gamma_j^{\sigma} P_j^{(1-\sigma)}} \cdot w_0$$

Oil price elasticity of tax revenue

$$\frac{\partial \tau}{\partial p_c} = \left[\left(\frac{\partial X}{\partial P_c} \times \frac{P_c}{X} \right) - \left(\frac{\partial Z}{\partial P_c} \times \frac{P_c}{Z} \right) \right]$$

where $X = \sum_{j=1}^{n} \theta_j \gamma_j^{\sigma} P_j^{(1+\varphi_j-\sigma)}$ and $Z = \sum_{j=1}^{n} \gamma_j^{\sigma} P_j^{1-\sigma}$. Using the above notations, the derivative of the natural log of aggregate taxes (τ) with respect to the natural log of crude oil prices (p_c) can be derived as follows

$$\frac{\partial \tau}{\partial p_c} \dashrightarrow \left([1-\sigma+\varphi_c]\theta_c \gamma_c^{\sigma} P_c^{\varphi_c-\sigma} \times \frac{P_c}{\sum_{j=1}^{n} \theta_j \gamma_j^{\sigma} P_j^{(1-\sigma+\varphi_j)}} \right) - \left((1-\sigma)\gamma_c^{\sigma} P_c^{-\sigma} \times \frac{P_c}{\sum_{i=1}^{n} \gamma_j P_j^{1-\sigma}} \right)$$

simplifying the above yields the final solution as follows

$$\frac{\partial \tau}{\partial p_c} = \left[(1+\varphi_c-\sigma) \frac{\theta_c \gamma_c^{\sigma} P_c^{(1-\sigma+\varphi_c)}}{\sum_{j=1}^{n} \theta_j \gamma_j^{\sigma} P_j^{(1-\sigma+\varphi_j)}} - (1-\sigma) \frac{\gamma_c^{\sigma} P_c^{(1-\sigma)}}{\sum_{j=1}^{n} \gamma_j^{\sigma} P_j^{(1-\sigma)}} \right]$$

Panel error correction model

The theoretical model predicts a stable structural relationship between state taxes and consumption expenditure. This implies that state taxes and consumption could be cointegrated. However, the unit root tests reported in Table 8 suggest that cointegration may be irrelevant. Particularly, because τ is $I(0)$ in levels. Nonetheless, for the sake of additional robustness, this section considers the plausibility of misleading unit root tests, which are highly common in the literature. Therefore, this section tests for cointegration to complement the main empirical results found in Section 4.

Following the Engle-Granger cointegration approach, this section estimates a long-run relationship between τ and c by using a simple panel regression model with time and state-specific fixed effects. The unit root test of the residuals of the long-run regression are reported in Table 8. ξ is $I(0)$, which suggests that state taxes and personal consumption expenditure could be cointegrated over time. Therefore, this section relies on a panel error correction model to test for symmetric and asymmetric effects of oil price shocks on state taxes in the short run and the long run. For the period considered here, Table 3 does not find robust evidence of a long-run asymmetric effect of oil prices on state taxes.

	(Pool mean group)	(Mean group)	(Fixed effects)
	τ	τ	τ
Long-run estimates			
$(pc/pj)^{+}$	-0.022	0.159	0.076
	[-0.061,0.017]	[-0.098,0.416]	[-0.037,0.189]
$(pc/pj)^{-}$	-0.046***	0.059	-0.004
	[-0.070,-0.022]	[-0.075,0.192]	[-0.098,0.091]
$c_{s,t}$	1.118***	0.724***	0.889***
	[0.949,1.287]	[0.249,1.199]	[0.428,1.351]
	$\triangle\tau$	$\triangle\tau$	$\triangle\tau$
Short-run estimates			
$\xi_{s,t-1}$	-0.363***	-0.670***	-0.266***
	[-0.429,-0.296]	[-0.732,-0.607]	[-0.295,-0.237]
$\triangle(pc/pj)^{+}$	0.192***	0.150***	0.186***
	[0.148,0.236]	[0.128,0.171]	[0.147,0.225]
$\triangle(pc/pj)^{-}$	0.097***	0.044*	0.094***
	[0.024,0.170]	[-0.003,0.091]	[0.034,0.154]
$\triangle c_{s,t-1}$	0.473***	0.629***	0.405***
	[0.295,0.651]	[0.407,0.850]	[0.198,0.612]
constant	-1.383***	-1.799*	-0.420
	[-1.633,-1.133]	[-3.642,0.044]	[-1.635,0.794]
N	1300	1300	1300

Table 3: Panel Error Correction Model (Asymmetric Effects)

On the other hand, Table 3 provides strong evidence of a short-run asymmetric effect, but only in the magnitude of the shock.[5] In the short run, both negative and positive oil price shocks have a positive effect on state tax revenue growth.

[5]Following Shin et al. (2014), this section relies on STATA's pnardl estimator to test for asymmetric effects of oil prices on state taxes in Table 3.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\triangle\tau_t$	$\triangle\tau_t$	$\triangle\tau_t$	$\triangle\tau_t$	$\triangle\tau_t$	$\triangle\tau_t$	$\triangle\tau_t$	$\triangle\tau_t$	$\triangle\tau_t$
$\triangle\tau_{t-2}$	-0.195***		-0.190***	-0.151***	-0.152***	-0.150***	-0.172***		-0.171***
	[-0.230,-0.161]		[-0.223,-0.157]	[-0.171,-0.131]	[-0.175,-0.129]	[-0.170,-0.129]	[-0.207,-0.136]		[-0.207,-0.134]
$\triangle\tau_{t-3}$		-0.033						-0.039*	
		[-0.079,0.014]						[-0.085,0.007]	
$\triangle(p_c/p_j)_{s,t-1}$	0.051***			0.051***			0.180***		
	[0.015,0.086]			[0.015,0.088]			[0.082,0.279]		
$\triangle(p_c/p_j)^2_{s,t-1}$	-0.038***			-0.045***			-0.097***		
	[-0.058,-0.019]			[-0.066,-0.025]			[-0.148,-0.045]		
$\triangle c_{s,t-1}$	0.282***	0.170**	0.203**						
	[0.108,0.456]	[0.010,0.331]	[0.029,0.377]						
$\xi_{s,t-1}$	-0.158***	-0.197***	-0.159***	-0.164***	-0.164***	-0.164***	-0.167***	-0.203***	-0.168***
	[-0.221,-0.096]	[-0.268,-0.127]	[-0.225,-0.094]	[-0.223,-0.105]	[-0.234,-0.094]	[-0.226,-0.103]	[-0.236,-0.099]	[-0.279,-0.127]	[-0.240,-0.096]
$\triangle(p_c/p_h)_{s,t-1}$		0.035*			0.029*			0.081**	
		[-0.000,0.070]			[-0.002,0.060]			[0.015,0.148]	
$\triangle(p_c/p_h)^2_{s,t-1}$		-0.034***			-0.023**			-0.055***	
		[-0.055,-0.013]			[-0.040,-0.006]			[-0.094,-0.016]	
$\triangle(p_g/p_j)_{s,t-1}$			0.087***			0.075**			0.258***
			[0.026,0.148]			[0.015,0.136]			[0.124,0.392]
$\triangle(p_g/p_j)^2_{s,t-1}$			-0.086***			-0.103***			-0.221***
			[-0.136,-0.036]			[-0.153,-0.053]			[-0.335,-0.106]
$\text{returns}_{s,t-1}$				0.002***		0.002***			
				[0.002,0.002]		[0.002,0.002]			
$\text{returns}_{s,t-2}$					-0.001**				
					[-0.002,-0.000]				
$\triangle$ $\text{crudeExport}_{s,t-1}$							-0.010**	-0.010**	-0.012***
							[-0.017,-0.002]	[-0.017,-0.002]	[-0.020,-0.004]
constant	0.030***	0.029***	0.033***	0.024***	0.048***	0.025***	0.042***	0.039***	0.042***
	[0.023,0.037]	[0.023,0.035]	[0.026,0.040]	[0.021,0.028]	[0.042,0.054]	[0.022,0.028]	[0.040,0.045]	[0.037,0.041]	[0.040,0.044]
N	1350	1350	1350	1400	1400	1400	1100	1100	1100

Table 4: Panel Error Correction Model (Symmetric)

In Section 4, the empirical framework relies on the full distribution of oil prices to predict the nonlinear effect of oil prices on state taxes. This approach is well justified, given the weak evidence of a long-run asymmetric effect of oil prices found here. In the short run, negative and positive oil price shocks move state taxes in the same direction. Therefore, Table 4 uses the Engle-Granger cointegration approach to estimate a symmetric panel error correction model. Table 4 reiterates that the relationship between crude oil prices and state taxes is unequivocally nonlinear and concave. The latter finding is consistent with the long-run estimates found in Section 4. In Tables 3 and 4, the error-correction term (ξ_{t-1}) is highly significant and negative. This implies that state taxes respond significantly to disequilibria from the long-run equilibrium.

Replication (different samples)

This study strives to achieve consistency in the parameter estimates. Therefore, it is important to ensure that the main empirical results are not vulnerable to a sample selection bias. Therefore, for the sake of empirical robustness, this paper replicates the main empirical framework for the top global oil exporters and importers. This approach allows one to test the consistency of the main parameter estimates. For the top global oil importers, this section relies on the top 10 oil importers in the world. However, note that tax data for China and Japan are not available. Moreover, the United States is not included in the sample of oil importers. Here, the top 10 global oil importers included in this section are: Germany, India, the Korean Republic, Netherlands, Spain, Thailand, the United Kingdom, France, Italy, and Singapore.

For the global oil exporters, this study relies on the top 10 oil exporters the world; including Iran and Qatar. There are lot of missing information for Kuwait and Nigeria. Therefore, Kuwait and Nigeria are replaced with Oman and Angola. The sample of oil exporters includes: Saudi Arabia, United Arab Emirates, Qatar, The United States, Russia, Canada, Iran, Brazil, Oman, Norway, Angola, and Iraq. Total tax revenue data are not available for several top oil exporters. Therefore, this section relies on the log of total government revenue per capita as a proxy for (τ). Total tax revenue has a significant weight in total government revenue, which means that total government revenue can be a good alternative for total tax revenue. Moreover, total government revenue includes all tax receipts, including other types of government revenue, excluding grants. For the top global oil importers, this section uses the log of total tax revenue per capita as a proxy for (τ.) For personal consumption expenditure, this section relies on households' final consumption expenditure per capita as a proxy for (c). For the exogenous income variable, this section relies on the log of world GDP per capita (worldGDP). For the crude oil indicator, this section relies on the global Brent oil price index, which is adjusted for the local currency. For the price deflator, the consumer price index remains the top choice. Oil price data emanate from the Federal Reserve Bank of Saint Louis. The data for all the other macroeconomic variables are collected from the World Development Indicators.

For the top oil exporters, the "ambivalent oil effect" is expected to be stronger and positive due to the larger oil sector. Therefore, if the "ambivalent oil effect" hypothesis holds, then the oil price elasticity of state taxes is expected to be relatively more elastic. For the top global oil importers, the "ambivalent oil effect" is expected to be low and positive for two reasons. Firstly, supply-led oil price shocks are rare and according to the literature, demand-led oil price shocks have become increasingly more frequent (Archanskaïa et al., 2012; De et al., 2022). Secondly, for the top global oil importers, studies show that supply-led oil price shocks have limited to no effects on real wages (Enders and Enders, 2017). Whereas demand-led oil price shocks tend to have stronger and positive effects on labor demand, export revenue, and real economic activities (Carstensen et al., 2013).

Figure 3 computes the oil price elasticity of fiscal revenue by relying on historical oil prices. The elasticity is derived from the panel 2SLS estimates reported in Column (1) in Tables 5 and 6. As suggested by the "ambivalent oil effect" hypothesis, the oil price elasticity of fiscal revenue is more elastic for the global oil exporters compared to the global oil importers. The variance of the elasticity is also higher for the global oil exporters compared to the global oil importers. More importantly, Figure 3 shows that the global oil importers experienced a negative average response of tax revenue to changes in oil prices during the Arab Spring, which is a period led by negative oil supply shocks. For both samples, the average response of fiscal revenue to changes in oil prices is stronger and positive during periods led by positive oil supply shocks or positive oil demand shocks. These latter results are consistent with the results found in Section 4; hence the importance of performing additional robustness checks.

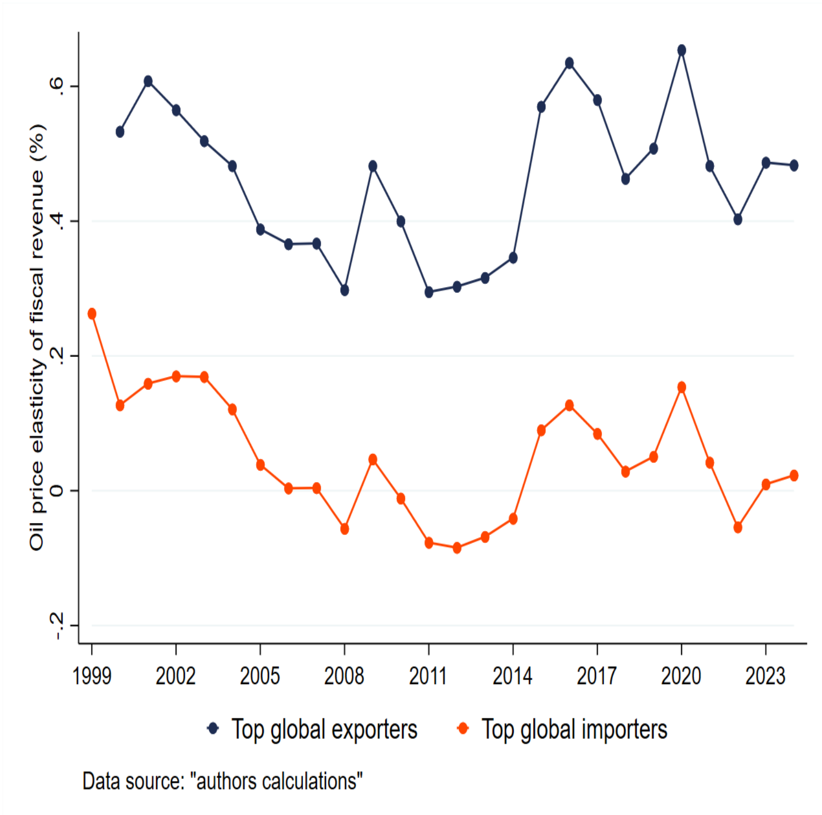

Figure 3: Historical Predictions (Oil Price Elasticity of Fiscal Revenue)

Here, for both samples, the empirical results are in line with the theoretical predictions: this study finds a nonlinear concave relationship between fiscal revenue and crude oil prices. The results found here are strongly in line with the main empirical results found in Section 4. Therefore, this paper argues that the theoretical underpinnings and the main empirical framework are well specified. Tables 5 and 6 report the empirical estimates for the three respective models: the panel 2SLS model, the reduced-form fixed effect model, and the panel fixed-effect error correction model.

	(1) τ	(2) τ	(3) $\triangle\tau$
$c_{s,t}$	0.664***		
	[0.513,0.815]		
τ_{t-2}	0.176**		
	[0.024,0.328]		
τ_{t-3}		0.538***	
		[0.370,0.707]	
$\triangle\tau_{t-2}$			0.039
			[-0.090,0.168]
$(p_c/p_j)_{s,t}$	0.536***	0.401**	
	[0.345,0.727]	[0.009,0.793]	
$(p_c/p_j)^2_{s,t}$	-0.199***	-0.317**	
	[-0.333,-0.065]	[-0.561,-0.072]	
worldGDP$_{s,t}$		0.648**	
		[0.131,1.165]	
$\triangle(p_c/p_j)_{s,t-1}$			0.201***
			[0.073,0.329]
$\triangle(p_c/p_j)^2_{s,t-1}$			-0.063**
			[-0.118,-0.008]
$\triangle c_{s,t-3}$			0.559**
			[0.091,1.027]
$\xi_{s,t-1}$			-0.431***
			[-0.549,-0.313]
constant		0.522	0.032
		[-3.878,4.922]	[-0.013,0.077]
N	232	249	235

Table 5: Empirical Results (Top Global Oil Exporters)

	(1)	(2)	(3)
	τ	τ	$\triangle\tau$
$c_{s,t}$	0.758***		
	[0.456,1.061]		
τ_{t-3}	0.345***	0.783***	
	[0.109,0.581]	[0.547,1.019]	
$\triangle\tau_{t-3}$			-0.043
			[-0.203,0.117]
$(p_c/p_j)_{s,t}$	0.263***	0.219**	
	[0.101,0.425]	[0.045,0.393]	
$(p_c/p_j)^2_{s,t}$	-0.129***	-0.121***	
	[-0.212,-0.045]	[-0.189,-0.053]	
$\text{worldGDP}_{s,t}$		0.247**	
		[0.005,0.489]	
$\triangle(p_c/p_j)_{s,t-1}$			0.158***
			[0.084,0.233]
$\triangle(p_c/p_j)^2_{s,t-1}$			-0.091***
			[-0.132,-0.050]
$\triangle c_{s,t-1}$			-0.299*
			[-0.632,0.034]
$\xi_{s,t-1}$			-0.034
			[-0.200,0.133]
constant		-0.180	0.058***
		[-1.154,0.795]	[0.043,0.072]
N	207	223	213

Table 6: Empirical Results (Top Global Oil Importers)

Additional tables

		Mean	Std. Dev.	Min	Max	N/s/T
$\tau_{s,t}$	overall	7.814026	.4148358	6.589071	9.537588	1600
	between	.	.2336999	7.351617	8.292753	50
	within	.	.3442847	6.776462	9.378819	32
$\tau^f_{s,t}$	overall	-8.946232	.362757	-10.55457	-8.048864	1599
	between	.	.2993712	-9.977985	-8.438253	50
	within	.	.2098051	-9.956843	-8.285365	31.98
$c_{s,t}$	overall	10.41176	.2999244	9.639519	11.18334	1400
	between	.	.1186532	10.16179	10.66111	50
	within	.	.2759488	9.790257	11.02896	28
$\text{crudeExport}_{s,t}$	overall	3.477515	2.365464	-4.299506	9.671965	1150
	between	.	2.1342	-1.355665	7.976051	50
	within	.	1.061989	-4.397656	6.880113	23
$\text{airTraffic}_{s,t}$	overall	.2442406	1.210502	-8.214415	2.538785	1599
	between	.	1.184713	-5.496314	2.340219	50
	within	.	.3297423	-2.47386	3.693273	31.98
$\text{oilSector}_{s,t}$	overall	1.304826	3.397124	0	31.27028	1400
	between	.	3.045185	.0000322	15.36434	50
	within	.	1.564055	-8.768713	17.21077	28
$(p_c/p_j)_{s,t}$	overall	.6476211	.442668	-.2713612	1.383868	1600
	between	.	0	.6476211	.6476211	50
	within	.	.442668	-.2713612	1.383868	32
$(p_c/p_h)_{s,t}$	overall	.4563354	.4314833	-.4751985	1.623534	1600
	between	.	.0952814	.2840918	.6325392	50
	within	.	.4210407	-.5279742	1.584978	32
$(p_g/p_j)_{s,t}$	overall	.3398688	.2606012	-.1378298	.7760544	1600
	between	.	0	.3398688	.3398688	50
	within	.	.2606012	-.1378298	.7760544	32
$\text{returns}_{s,t}$	overall	8.900023	11.79696	-20.9747	29.74725	1600
	between	.	0	8.900023	8.900023	50
	within	.	11.79696	-20.9747	29.74725	32

Table 7: Summary Statistics (Main Data)

Variables	Inverse chi-squared	Inverse normal	T(5 % critical value)	Drift	Trend	lags
$\tau_{s,t}$	0.0007	0.0215		no	yes	1
$\tau^f_{s,t}$	0.0000	0.0000		yes	no	1
$c_{s,t}$	0.9930	0.9992		no	yes	1
$(p_c/p_j)_{s,t}$			0.0263	yes	no	1
$(p_c/p_h)_{s,t}$			0.0332	yes	no	1
$(p_g/p_j)_{s,t}$			0.0219	yes	no	1
$\text{returns}_{s,t}$			0.0004	yes	no	1
$\text{crudeExport}_{s,t}$	0.0000	0.0004		no	yes	1
$\text{airTraffic}_{s,t}$	0.0000	0.0000		no	yes	1
$\text{oilSector}_{s,t}$	0.0025	0.0004		no	no	1
$\xi_{s,t}$	0.0000	0.0001		no	yes	1
P-values are reported in this table						

Table 8: Unit Root Tests (Main Data)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$c_{s,t}$	$c_{s,t}$	$c_{s,t}$	$c_{s,t}$	$c_{s,t}$	$c_{s,t}$	$c_{s,t}$	$c_{s,t}$	$c_{s,t}$
$c_{s,t-3}$	0.9130752***	0.9592905***					.9487137***	.9662741***	.9643972***
airTraffic$_{s,t}$	0.0293216***	0.0410467***	0.037587***						
$\tau_{s,t-2}$	0.0658082	0.0464464	0.1200301*	.1346007**	.1162266**		0.0682684	0.0606612	
$\tau_{s,t-3}$						0.0513956			0.0418684
$(p_c/p_j)_{s,t}$	0.2365656***			.2975987***			0.413611***		
$(p_c/p_j)^2_{s,t}$	-0.156847***			-0.1910374***			-.2463768***		
$(p_c/p_h)_{s,t}$		0.0343095*			.070386 ***			.0751309***	
$(p_c/p_h)^2_{s,t}$		-0.0587364***			-.0845625***			-.0824689***	
$(p_g/p_j)_{s,t}$			0.246591***			.4128566***			0.7056942***
$(p_g/p_j)^2_{s,t}$			-0.3171304***			-.4656275***			-.7662845***
$c_{s,t-4}$			0.8552633***	0.8267044***	.8852765***	.9176641***			
returns$_{s,t-4}$				0.000242**					
returns$_{s,t-6}$					0.0003869***	.0011224***			
$\triangle$ crudeExport$_{s,t}$							0.0055647***	.0056888***	0.0075906***
Kleibergen-Paap F-Statistic	288.06***	506.22***	111.56***	265.41***	134.28***	444.08***	219.19***	248.97***	386.19***
$p < 0.10^*$,$p < 0.05^{**}$,$p < .01^{***}$									

Table 9: Panel 2SLS (First Stage)

	(Oil-dependent)	(Oil-dependent)	(Non-oil dependent)	(Non-oil dependent)
	y_t	$\triangle y_t$	y_t	$\triangle y_t$
$(p_c/p_j)_t$	0.418***		0.249***	
	[0.315,0.520]		[0.233,0.264]	
$\triangle(p_c/p_j)_t$		0.152***		0.039***
		[0.118,0.185]		[0.033,0.045]
constant	10.543***	0.035***	10.607***	0.036***
	[10.471,10.615]	[0.034,0.035]	[10.596,10.618]	[0.036,0.036]
N	203	196	1247	1204

95 % confidence interval in brackets
$p < 0.10^*$,$p < 0.05^{**}$,$p < .01^{***}$

Table 10: "Ambivalent Oil Effect" (Panel Regression Estimates)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	τ	τ	τ	τ	τ	τ	τ	τ	τ
$\text{returns}_{s,t-1}$				0.006***	0.006***	0.006***			
				[0.005,0.007]	[0.005,0.007]	[0.005,0.007]			
constant	0.983*	0.956	1.058*	1.230**	1.254**	1.327**	1.038**	0.973*	1.139**
	[-0.097,2.063]	[-0.269,2.182]	[-0.188,2.304]	[0.291,2.168]	[0.167,2.341]	[0.260,2.393]	[0.072,2.004]	[-0.112,2.059]	[0.062,2.216]
$\tau_{s,t-2}$									
(crudeExport$\leq \phi$)	0.863***	0.884***	0.859***	0.831***	0.846***	0.825***	0.853***	0.873***	0.843***
	[0.722,1.003]	[0.729,1.039]	[0.696,1.022]	[0.709,0.953]	[0.708,0.983]	[0.686,0.965]	[0.727,0.979]	[0.736,1.011]	[0.702,0.984]
(crudeExport$\geq \phi$)	0.779***	0.851***	0.791***	0.746***	0.810***	0.753***	0.778***	0.839***	0.780***
	[0.579,0.979]	[0.669,1.033]	[0.592,0.990]	[0.570,0.923]	[0.644,0.976]	[0.582,0.924]	[0.589,0.966]	[0.669,1.010]	[0.595,0.966]
$(p_c/p_j)_{s,t}$									
(crudeExport$\leq \phi$)	0.427***			0.437***			0.321***		
	[0.314,0.539]			[0.335,0.539]			[0.223,0.420]		
(crudeExport$\geq \phi$)	1.843***			1.803***			1.473**		
	[0.627,3.060]			[0.757,2.849]			[0.347,2.599]		
$(p_c/p_j)^2_{s,t}$									
(crudeExport$\leq \phi$)	-0.242***			-0.289***			-0.178***		
	[-0.315,-0.169]			[-0.359,-0.219]			[-0.241,-0.114]		
(crudeExport$\geq \phi$)	-0.895***			-0.908***			-0.695***		
	[-1.428,-0.362]			[-1.351,-0.465]			[-1.175,-0.214]		
$(p_c/p_h)_{s,t}$									
(crudeExport$\leq \phi$)		0.108***			0.062**			0.080***	
		[0.049,0.167]			[0.006,0.119]			[0.024,0.135]	
(crudeExport$\geq \phi$)		1.016**			0.971**			0.803**	
		[0.190,1.843]			[0.140,1.803]			[0.088,1.517]	
$(p_c/p_h)^2_{s,t}$									
(crudeExport$\leq \phi$)		-0.085***			-0.093***			-0.048***	
		[-0.119,-0.051]			[-0.126,-0.060]			[-0.081,-0.015]	
(crudeExport$\geq \phi$)		-0.619**			-0.624**			-0.454**	
		[-1.084,-0.153]			[-1.094,-0.155]			[-0.837,-0.072]	
$(p_g/p_j)_{s,t})$									
(crudeExport$\leq \phi$)			0.497***			0.527***			0.454***
			[0.268,0.725]			[0.325,0.729]			[0.256,0.653]
(crudeExport$\geq \phi$)			2.534***			2.624***			2.144***
			[1.109,3.959]			[1.462,3.786]			[0.722,3.566]
$(p_g/p_j)^2_{s,t}$									
(crudeExport$\leq \phi$)			-0.446***			-0.638***			-0.416***
			[-0.714,-0.179]			[-0.892,-0.383]			[-0.647,-0.185]
(crudeExport$\geq \phi$)			-2.064***			-2.310***			-1.743***
			[-3.101,-1.028]			[-3.130,-1.490]			[-2.762,-0.724]
$\triangle c_{s,t-1}$									
(crudeExport$\leq \phi$)							1.635***	1.733***	1.674***
							[1.343,1.926]	[1.423,2.042]	[1.377,1.972]
(crudeExport$\geq \phi$)							2.705***	2.903***	2.698***
							[1.246,4.165]	[1.275,4.531]	[1.260,4.137]
ϕ	5.89***	5.76***	5.89***	5.89***	5.89***	5.79***	5.89***	5.76***	5.89***
R^2	0.84	0.83	0.84	0.87	0.86	.86	.86	.85	.86
N	1150	1150	1150	1150	1150	1150	1150	1150	1150

95 % confidence interval in brackets

$p < 0.10^*$,$p < 0.05^{**}$,$p < .01^{***}$

Table 11: Panel Threshold Model (Petroleum Export)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\tau^f_{s,t}$	$\tau^f_{s,t}$	$\tau^f_{s,t}$	$\tau^f_{s,t}$	$\tau^f_{s,t}$	$\tau^f_{s,t}$	$\tau^f_{s,t}$	$\tau^f_{s,t}$	$\tau^f_{s,t}$
$c_{s,t}$	0.146***	0.173***	0.170***						
	[0.076,0.215]	[0.102,0.244]	[0.095,0.245]						
$\tau^f_{s,t-2}$	0.626***	0.617***	0.619***	0.787***	0.806***	0.785***	0.689***	0.697***	0.696***
	[0.520,0.733]	[0.497,0.736]	[0.503,0.736]	[0.727,0.847]	[0.752,0.861]	[0.722,0.847]	[0.585,0.792]	[0.590,0.803]	[0.590,0.802]
$(p_c/p_j)_{s,t}$	0.151***			0.132***			0.288***		
	[0.058,0.245]			[0.076,0.189]			[0.194,0.381]		
$(p_c/p_j)^2_{s,t}$	-0.109***			-0.092***			-0.198***		
	[-0.168,-0.050]			[-0.136,-0.048]			[-0.262,-0.135]		
$(p_c/p_h)_{s,t}$		0.105***			0.089***			0.106***	
		[0.053,0.158]			[0.050,0.129]			[0.052,0.161]	
$(p_c/p_h)^2_{s,t}$		-0.097***			-0.082***			-0.115***	
		[-0.134,-0.059]			[-0.115,-0.049]			[-0.150,-0.079]	
$(p_g/p_j)_{s,t}$			0.074			0.206***			0.275***
			[-0.054,0.201]			[0.105,0.306]			[0.143,0.407]
$(p_g/p_j)^2_{s,t}$			-0.125			-0.249***			-0.363***
			[-0.283,0.034]			[-0.391,-0.108]			[-0.536,-0.190]
$\text{crudeExport}_{s,t}$							0.015***	0.018***	0.014***
							[0.006,0.024]	[0.009,0.027]	[0.006,0.023]
constant				-1.908***	-1.716***	-1.924***	-2.879***	-2.746***	-2.767***
				[-2.452,-1.364]	[-2.203,-1.228]	[-2.491,-1.357]	[-3.816,-1.942]	[-3.694,-1.798]	[-3.726,-1.807]
N	1247	1148	1148	1498	1498	1498	1148	1148	1148

95 % confidence interval in brackets
$p < 0.10^{*}$,$p < 0.05^{**}$,$p < .01^{***}$

Table 12: Oil Price Elasticity of State Taxes (Theoretical Case)

Figures

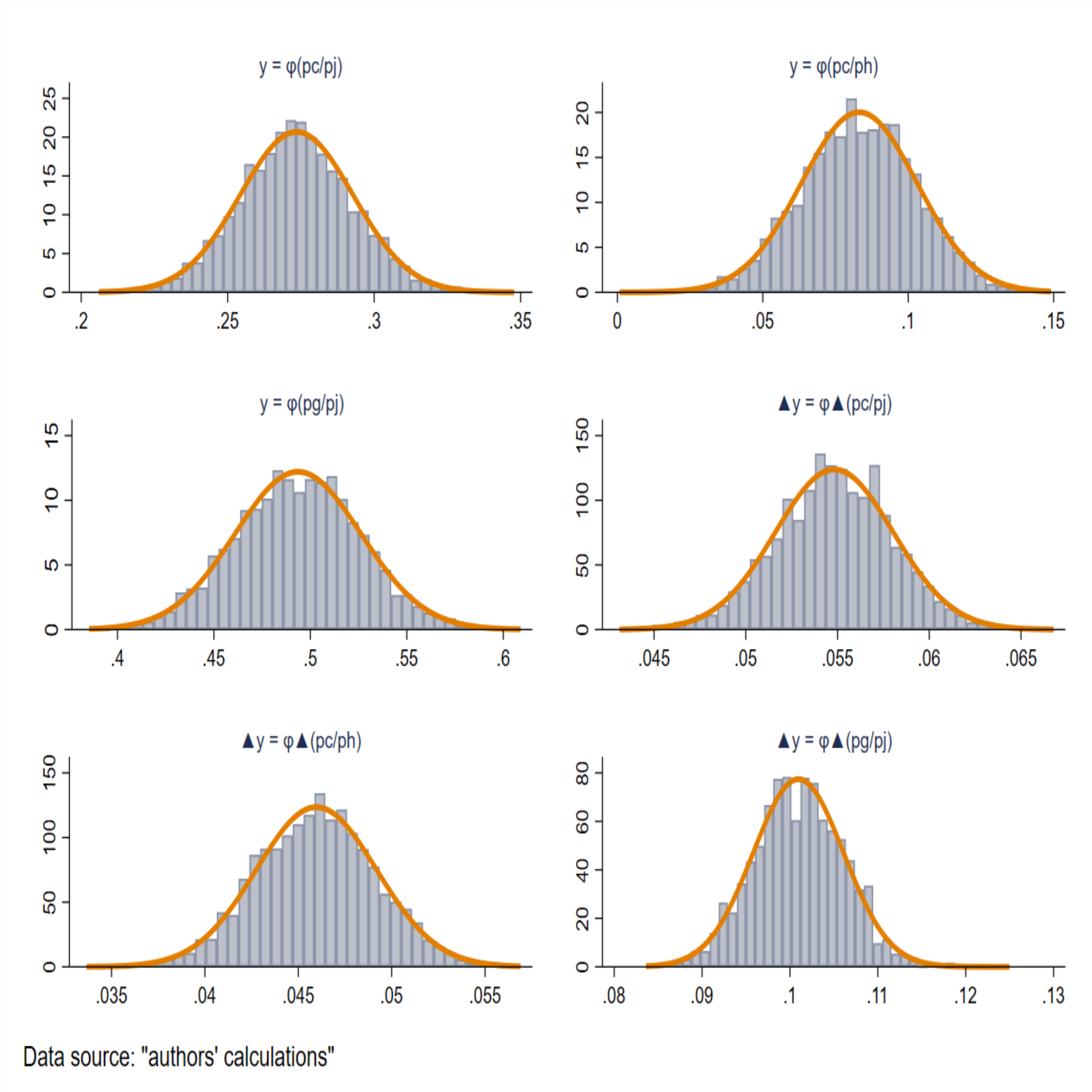

Figure 4: "Ambivalent Oil Effect" (Marginal Posterior Distributions)

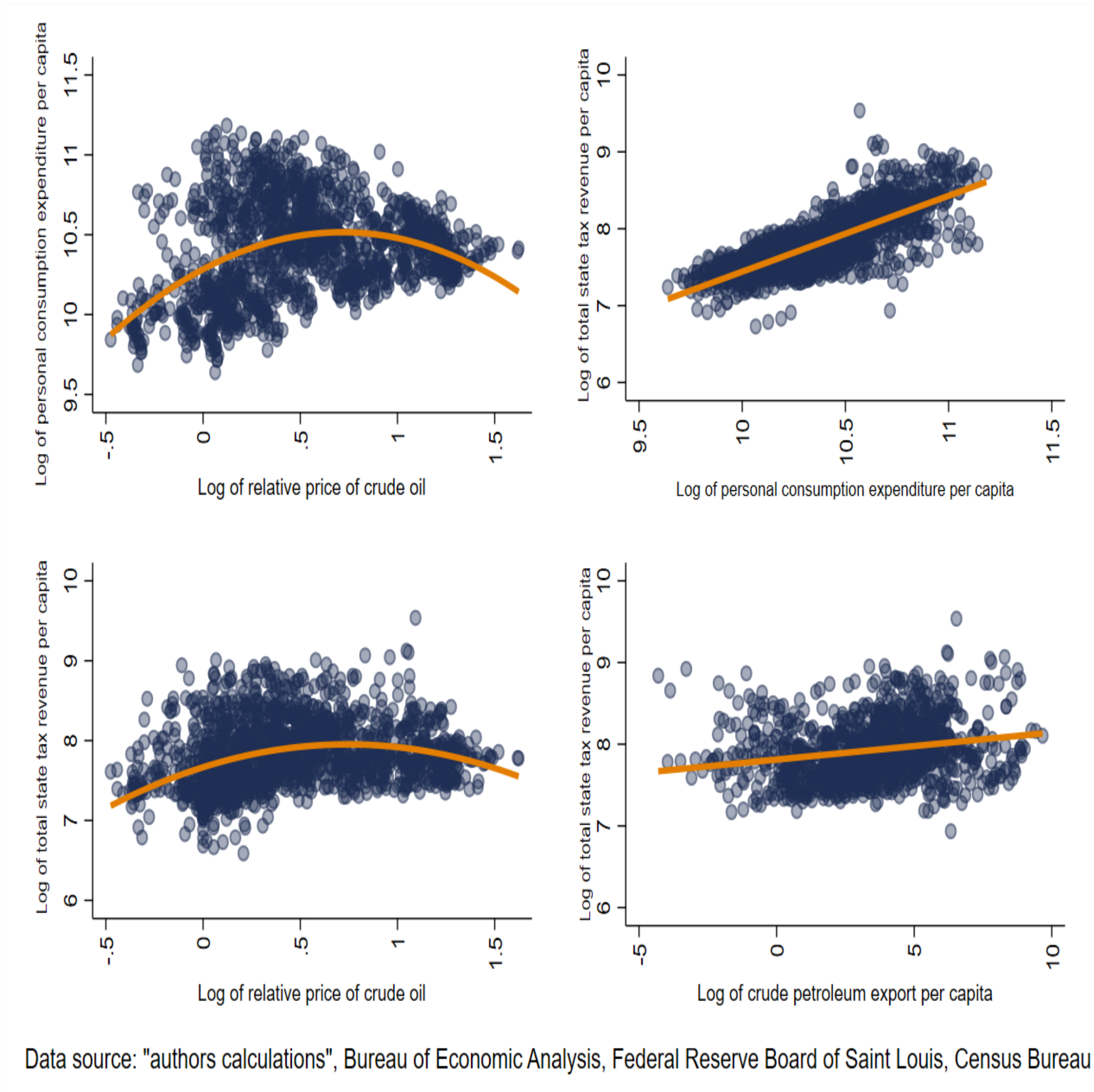

Figure 5: Meaningful Covariances