The Value of Fiscal Discipline for Oil-Exporting Countries*

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Abstract

I analyze how oil price shocks affect macroeconomic activity in an oil-exporting small open economy using a dynamic stochastic general equilibrium model. I show that fiscal policy is a key transmission channel that affects the degree of exposure to oil shocks. I assess the relevance of fiscal policy as a propagation mechanism by analyzing data for Mexico and Norway, two oil-exporting countries with different fiscal frameworks. Taking fiscal policy as given by the data, the model can successfully explain the responses of output, consumption and the relative price of nontradable goods for each country. Furthermore, the model is unable to explain these responses under counterfactual fiscal frameworks. Variance decomposition analysis shows that fiscal policy not only seems to work as a transmission mechanism, it also seems to be capable of regulating the size of pass-through. Finally, conducting welfare analysis, I find that fiscal policies that insulate the country from exogenous oil price shocks seem to be welfare improving over those that are procyclical.

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Introduction

A commonly held view—first introduced by the Dutch Disease literature—is that oil price increases and oil discoveries lead to higher government spending, an increase in the relative price of nontradable goods and a loss of competitiveness in the non-oil tradable sector. The economic literature, however, has not provided thorough quantitative empirical evidence on these views, nor it has explored the theoretical predictions of dynamic stochastic general equilibrium (DSGE) models. This paper shows that in a small oil-exporting economy, fiscal policy affects the extent to which GDP, private consumption and the relative price of nontradable goods react to a typical positive shock to world oil prices. Furthermore, fiscal discipline seems to be a valuable tool to regulate the impact of oil price shocks. Fiscal policies that insulate the economy from oil price shocks seem to be welfare improving over procyclical ones.

In order to understand the transmission mechanism of an oil price shock, I model a small open economy with production of tradable and nontradable goods and an oil endowment. The model contains five key features. First, an oil price shock generates a wealth effect. Both households and government want to consume more tradable and nontradable goods as their income rises due to higher oil prices. Second, there is a scarcity effect. The increased private and public willingness to consume—brought about by the wealth effect—generates in the short-run a scarcity of nontradable goods that drives up the relative price of nontradables. This scarcity is exacerbated by the existence of distribution costs in the tradable sector. Third, distortionary non-oil taxes generate an intertemporal substitution effect. Firms want to increase production of tradable and nontradable goods right after the shock as the implicit non-oil tax rate drops in response to the shock. Fourth, there is a sectorial reallocation effect. Changes in the relative price of nontradable goods make the marginal product of labor and capital temporarily higher in the nontradable sector, so households are inclined to allocate more capital and labor in the nontradable sector. Distortionary taxes and changes in relative prices—combined—affect the timing of production for both types of output. Finally, the fifth ingredient is government purchases in the utility function. Households attain utility from effective consumption, which is a CES aggregator of private consumption and government purchases. Intuitively, for a given coefficient of relative risk aversion, and a given share governing parameter, the lower the elasticity of substitution, the higher the comovement between private and public consumption. Instead of imposing either, these parameters are estimated so as to minimize the distance between the model and the data impulse responses of output, consumption and the relative price of nontradable goods.

Empirical analysis of the effects of oil prices is complicated by the fact that many oil exporting countries have market power in the oil market. Therefore, the analysis focuses on price-taking economies. The paper presents an application to Mexico and Norway, two countries that belong to that set, and which are of general interest. It is worth emphasizing that the conclusions drawn here also apply to smaller price-takers with a lower participation in the oil market. What matters is not their absolute size in the oil market, but rather the relative size of the oil sector with respect to GDP and government revenue.[1]

To assess the relevance of the fiscal channel, the model is calibrated and estimated for Mexico and then for Norway. The calibration matches several features of each economy and the estimation minimizes the distance between the data and the model impulse responses of consumption, output and the relative price of nontradable goods. For each country, a VAR is used to evaluate the effects of oil prices on government revenue, government purchases, transfers, tradable and nontradable output, private consumption and the relative price of nontradable goods. The oil-price-taking behavior assumption is used in the identification of the structural oil price shock. It turns out that for the purposes of this paper, partial identification is sufficient and convenient, as it avoids ordering issues (on all variables other than oil) and the introduction of instrumental variables.

Taking fiscal policy as given by a partially-identified structural VAR, this model is capable of explaining the impulse responses of consumption, output and the price of nontradable goods to an oil price shock. Notably, absent the country's own fiscal policy data responses, the model cannot explain the data impulse responses of interest, suggesting that the fiscal channel is a key transmission mechanism of oil price shocks.

Fiscal policy not only seems to be a transmission mechanism, but it also seems to be capable of regulating the size of pass-through. Simulating data from the original model and the counterfactuals, I compute for each country the share of the variance of consumption, output, the relative price of nontradable goods and government purchases that is attributed to the oil price shock. As expected, for most variables and horizons, "Norwegianizing" Mexico insulates the economy from the oil price shock and hence decreases the share of variance attributed to the oil price shock, and "Mexicanizing" Norway increases the exposure to the shock, hence raising the share of variance attributed to the oil price shock.

Welfare analysis, not surprisingly, indicates that insulation is welfare improving. I compute the welfare gain of switching from the original fiscal policy to the one provided by the counterfactual (i.e. own policy for Mexico versus "Norwegianizing" it, and own policy for Norway versus "Mexicanizing" it). It turns out that switching to the counterfactual

[1] Therefore, the analysis conducted here can be applied to any commodity exporting small open economy, whose resource income represents an important share of GDP and fiscal revenue.

yields a welfare gain of 7.57 percent of consumption in Mexico, whereas switching makes Norway incur in a welfare loss of 14.46 percent of consumption. Hence, fiscal policies that insulate the country from exogenous oil price shocks seem to be welfare improving over those that are procyclical.

As a robustness check, the Appendix considers three extensions to the basic model. Extension 1 allows for the distribution sector to use oil products as one of its inputs, while leaving the rest of the model unmodified. Extension 2 keeps the distribution sector unmodified, and allows instead for demand of oil-related products by households and firms. Finally, Extension 3 combines Extensions 1 and 2. Each extension includes oil-related products rather than crude oil itself, since in reality households and firms do not use unrefined crude oil. For each extension, the model is calibrated to match features regarding energy use and expenditures, of the Mexican and the Norwegian economies, and the parameters are reestimated. It turns out that adding these features to the model does not alter the main findings of the basic model.

The rest of the paper is organized as follows. Section 1 describes the theoretical model. Section 2 reviews the empirical evidence in Mexico (1980-2006) and Norway (1985-2006).[2] Section 3 shows the consequences of an oil price shock by calibrating and estimating the model for Mexico. Section 4 gauges the importance of fiscal policy as a propagation mechanism by calibrating and estimating the model for Norway. Section 5 assesses the role of fiscal policy as an insulation device and it measures its welfare implications. Finally, section 6 concludes.

1 Model

There are three sectors, oil (O), non-oil tradable (T) and nontradable (N). Oil output (Y_t^O) is an endowment that is not consumed domestically, so it only provides an additional source of income from export sales. Tradable (Y_t^T) and nontradable output (Y_t^N) are produced competitively.

I assume that the world price of a unit of the tradable good is 1 dollar and that purchasing power parity (PPP) holds at the wholesale level for tradable goods. This means that prices measured in dollars are equivalent to relative prices expressed in units of the tradable good at the wholesale level. PPP does not hold at the retail level for tradable goods due to distribution costs.

The world oil price is exogenous and it is denoted by p_t^O (in dollars). Total output

[2] The sample start date is determined in both cases by quarterly data availability. Using the same sample length for both countries (1985-2006) does not affect the main results and conclusions.

(GDP), measured in dollars, is given by

$$GDP_t = Y_t^T + p_t^N Y_t^N + p_t^O Y_t^O \quad . \tag{1}$$

1.1 Distribution sector

The sale of tradable goods to consumers requires the retailer to use γ units of the nontradable good as an input. As in Burstein, Neves, and Rebelo (2003), the distribution sector is competitive so the retail price of tradable goods is equal to the marginal cost. Formalizing this implies that

$$p_t^T = 1 + \gamma p_t^N \quad , \tag{2}$$

where p_t^T and p_t^N are, respectively, the retail prices of tradable and nontradable goods expressed in dollars. Since there are no distribution costs in the nontradable sector, there is no difference between the wholesale and retail prices of nontradable goods.

1.2 Tradable production

Tradable goods (T) are produced competitively using labor and capital. Firms maximize profits

$$\Pi_t^T = \left(1 - \tau_t^{NO}\right) Y_t^T - w_t L_t^T - r_t^K K_t^T \tag{3}$$

by choosing K_t^T and L_t^T where

$$Y_t^T = A^T \left(K_t^T\right)^{1-\alpha} \left(L_t^T\right)^{\alpha}, \quad \alpha \in (0,1) \tag{4}$$

A^T is a time-invariant technology parameter, r_t^K is the rental rate of capital, w_t is the dollar wage rate and τ_t^{NO} is the non-oil tax rate.

The associated first order conditions are:

$$\left[K_t^T\right] \;:\; r_t^K = \left(1 - \tau_t^{NO}\right)(1-\alpha)\frac{Y_t^T}{K_t^T} \tag{5}$$

$$\left[L_t^T\right] \;:\; w_t = \left(1 - \tau_t^{NO}\right)\alpha\frac{Y_t^T}{L_t^T} \tag{6}$$

Since there is perfect competition, after-tax marginal products equal input prices.

1.3 Nontradable production

Nontradable goods (N) are produced competitively using labor, capital and land.[3] Firms choose the amount of each type of input in order to maximize profits

$$\Pi_t^N = \left(1-\tau_t^{NO}\right) p_t^N Y_t^N - w_t L_t^N - r_t^K K_t^N - q_t S \quad , \tag{7}$$

where

$$Y_t^N = \left\{ \nu \left[A^N \left(K_t^N\right)^{1-\eta} \left(L_t^N\right)^{\eta} \right]^{\frac{\rho-1}{\rho}} + (1-\nu)\, S^{\frac{\rho-1}{\rho}} \right\}^{\frac{\rho}{\rho-1}} ; \quad \eta \in (0,1)\,; \quad \nu \in (0,1)\,; \quad \rho \geq 0, \tag{8}$$

and S denotes land, q_t is the rental rate of land, A^N is a time invariant technology parameter, η is the share of labor in value-added, ν is the parameter governing the share of value-added in nontradable production, and ρ denotes the elasticity of substitution between land and the other factors of production. The associated first order conditions are:

$$\left[K_t^N\right] \; : \; r_t^K = \left(1-\tau_t^{NO}\right) p_t^N (1-\eta) \left(Y_t^N\right)^{\frac{1}{\rho}} \frac{\nu \left[A^N \left(K_t^N\right)^{1-\eta} \left(L_t^N\right)^{\eta} \right]^{\frac{\rho-1}{\rho}}}{K_t^N} \tag{9}$$

$$\left[L_t^N\right] \; : \; w_t = \left(1-\tau_t^{NO}\right) p_t^N \eta \left(Y_t^N\right)^{\frac{1}{\rho}} \frac{\nu \left[A^N \left(K_t^N\right)^{1-\eta} \left(L_t^N\right)^{\eta} \right]^{\frac{\rho-1}{\rho}}}{L_t^N} \tag{10}$$

$$[S] \; : \; q_t = \left(1-\tau_t^{NO}\right) p_t^N \left(\frac{Y_t^N}{S}\right)^{\frac{1}{\rho}} (1-\nu) \tag{11}$$

Once again, since there is perfect competition, after-tax marginal products equal input prices.

1.4 Households

Households enjoy leisure, so they choose sequences of labor (L_t), consumption in tradables $\left(c_t^T\right)$ and nontradables $\left(c_t^N\right)$, investment (I_t) and assets (a_{t+1}) in order to maximize their

[3] This production function has been used by Burstein, Neves, and Rebelo (2003) and Rebelo and Vegh (1995), to generate permanent changes in p_t^N, as the marginal cost of producing Y_t^N with additional (K_t^N, L_t^N) is increasing even though it is assumed that nontradable goods are produced with overall constant returns. This is consistent with the Balassa-Samuelson theorem, which says that the relative price of nontradables increases permanently as a country gets wealthier.

lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma} \left([\tilde{c}_t - \psi L_t^{\varpi}]^{1-\sigma} - 1 \right); \quad \psi > 0;\ \varpi > 1;\ \sigma > 0;\ \ 0 < \beta < 1, \tag{12}$$

where $\tilde{c}_t$ denotes effective consumption, which is a constant elasticity of substitution aggregator of private consumption (c_t) and government purchases (g_t).[4] Private consumption is a bundle of tradable and nontradable consumption. Formally,

$$\tilde{c}_t = \left[\phi c_t^{\frac{\varkappa-1}{\varkappa}} + (1-\phi)\, g_t^{\frac{\varkappa-1}{\varkappa}} \right]^{\frac{\varkappa}{\varkappa-1}}; \quad 0 \leq \phi \leq 1; \quad 0 \leq \varkappa, \tag{13}$$

$$c_t = \left(c_t^T\right)^{\theta} \left(c_t^N\right)^{1-\theta}; \quad 0 \leq \theta \leq 1, \tag{14}$$

where ϕ is a distribution parameter that governs the expenditure share of private consumption in effective consumption and $\varkappa$ is the elasticity of substitution between private consumption and government purchases.[5,6]

At date t, firms receive from households the stock of capital they acquired at date $t-1$, which can be freely reallocated across production sectors

$$K_{t-1} = K_t^N + K_t^T. \tag{15}$$

Given the absence of adjustment costs, the law of motion for capital is given by

$$K_t = \left(1 - \delta^k\right) K_{t-1} + I_t, \tag{16}$$

[4] Correia, Neves, and Rebelo (1995) show that the ability of small open economy models to replicate business cycle features depends heavily on the choice of instantaneous utility. In particular, they show that GHH preferences generate more realistic cyclical volatilities of the variables in the national income accounts identity, as well as countercyclical trade balances. GHH preferences perform much better than 'standard' closed economy preferences (such as those in Hansen (1985)), which yield much lower volatility of consumption and procyclical trade balances. Therefore, GHH preferences have become widely used in the small open economy literature.

[5] Bouakez and Rebei (2007) consider a similar framework, with complementarity between private consumption and government purchases in the context of a one-sector closed economy. Their work assumes fully separable preferences between effective consumption and labor, and log utility $(\sigma = 1)$, so the complementarity between government purchases and private consumption $(\varkappa < 1)$ also automatically implies Edgeworth complementarity (i.e. $U_{cg} > 0$) . In this paper, on the other hand, $\sigma > 1$ is possible, so $U_{cg} > 0$ depends on the interaction between $\varkappa$ and σ, and hence U_{cg} may be negative (Edgeworth substitutes) even though $\varkappa < 1$.

[6] The expenditure share of c in $\tilde{c}$ is given by $[((1-\phi)/\phi)^{\varkappa} (p_t^c/p_t^g)^{\varkappa-1} + 1]^{-1}$. It is obtained from solving the expenditure minimization problem: min $p_t^{\tilde{c}} \tilde{c}_t = p_t^c c_t + p_t^g g_t$ subject to (13). When $\varkappa = 1$, as in the Cobb-Douglas case, the expenditure share is equal to ϕ. Note that $p_t^c = (p_t^T/\theta)^{\theta} (p_t^N/(1-\theta))^{1-\theta}$ is obtained from solving the minimization problem min $p_t^c c_t = p_t^T c_t^T + p_t^N c_t^N$, subject to (14), and $p_t^g = (1/\theta_g)^{\theta_g} (p_t^N/(1-\theta_g))^{1-\theta_g}$ can be derived from solving min $p_t^g g_t = g_t^T + p_t^N g_t^N$, subject to (32). Therefore, $p_t^g g_t$ is equivalent to $\tilde{g}_t$ in (25).

where I_t denotes investment. Households own the two types of firms. Their after-tax income (Υ_t) consists of returns to the factors of production, profits from each type of firm (which are zero due to perfect competition), after-tax oil income (where τ_t^O denotes the oil tax rate), returns from real assets acquired in the previous period and government transfers (v_t) net of lump-sum taxes (τ_t^L). After-tax income is used to consume and to save, both in capital and in assets. Thus, the flow budget constraint of households is given by

$$\Upsilon_t \geq p_t^T c_t^T + p_t^N c_t^N + I_t + (a_{t+1} - a_t), \tag{17}$$

where $\Upsilon_t = \left(w_t L_t + r_t^K K_{t-1} + q_t S\right) + \left(1 - \tau_t^O\right) p_t^O Y_t^O + r a_t + v_t - \tau_t^L$. Maximizing (12) subject to (17) yields the following first order conditions:

$$\begin{aligned}
\left[c_t^T\right] &: \quad \theta \phi \frac{c_t}{c_t^T} \left[\tilde{c}_t - \psi L_t^{\varpi}\right]^{-\sigma} \left(\frac{\tilde{c}_t}{c_t}\right)^{\frac{1}{\varkappa}} = \lambda_t p_t^T && (18)\\
\left[c_t^N\right] &: \quad (1-\theta) \phi \frac{c_t}{c_t^N} \left[\tilde{c}_t - \psi L_t^{\varpi}\right]^{-\sigma} \left(\frac{\tilde{c}_t}{c_t}\right)^{\frac{1}{\varkappa}} = \lambda_t p_t^N && (19)\\
\left[a_{t+1}\right] &: \quad \beta (1+r) E_t \lambda_{t+1} = \lambda_t && (20)\\
\left[\lambda_t\right] &: \quad \Upsilon_t = p_t^T c_t^T + p_t^N c_t^N + \left(K_t - \left(1-\delta^k\right) K_{t-1}\right) + a_{t+1} - a_t && (21)\\
\left[L\right] &: \quad \left[\tilde{c}_t - \psi L_t^{\varpi}\right]^{-\sigma} \varpi \psi L_t^{\varpi - 1} = \lambda_t w_t && (22)\\
\left[K_t\right] &: \quad \beta \left[E_t \lambda_{t+1} r_{t+1}^K + \left(1-\delta^k\right) E_t \lambda_{t+1}\right] = \lambda_t && (23)
\end{aligned}$$

Here λ_t is the Lagrange multiplier associated with the budget constraint (17) and it represents the marginal utility of wealth in units of wholesale tradable goods. Equations (18) and (19) depict the first order conditions for tradable and nontradable consumption, respectively. In both equations, the left hand side shows the marginal benefit from consuming one additional unit of that type of good, which is equal to the marginal cost of consuming it. Combining them yields the familiar expression where the marginal rate of substitution equals the ratio of relative prices.[7] Expressions (20) and (23) are the intertemporal Euler equations associated with real asset and capital holdings, respectively, and they set the current price equal to the discounted expected value of tomorrow. Equation (21) makes the budget constraint binding and equation (22) is the Euler equation associated with the labor decision.

[7] Note that GHH preferences imply a marginal rate of substitution that is independent from labor. Hence, there is no wealth effect on labor, only in consumption.

1.5 Government

The structure of the government's budget constraint is as follows. The government collects oil and non-oil revenue (T^O and T^{NO}, respectively). Oil GDP is taxed at the rate τ_t^O, and non-oil output is taxed at the rate τ_t^{NO}. The government levies lump sum taxes $\left(\tau_t^L\right)$ just so that it can satisfy its lifetime budget constraint. Hence, total revenue in dollars is given by

$$\tau_t = T_t^O + T_t^{NO} + \tau_t^L = \tau_t^{NO}\left(Y_t^T + p_t^N Y_t^N\right) + \tau_t^O p_t^O Y_t^O + \tau_t^L. \tag{24}$$

The government buys tradable and nontradable goods at producer prices, so its purchases measured in dollars are[8,9]

$$\tilde{g}_t = g_t^T + p_t^N g_t^N. \tag{25}$$

It sends transfers (v_t) to households and issues dollar-denominated debt (b_t) which yields the world interest rate r. Thus, the government's flow budget constraint is given by

$$b_{t+1} = \tilde{g}_t + v_t - \tau_t + (1+r)\, b_t \tag{26}$$

Government purchases, transfers and proportional tax rates respond to the oil price shock and to other shocks in the economy. Thus, fiscal variables $h_t = [g_t^T, g_t^N, v_t, \tau_t^{NO}, \tau_t^O]'$ have the moving average representation

$$h_t = \xi_h(L)\, \epsilon_t^O + \pi_h(L)\, \tilde{\epsilon}_t \quad , \tag{27}$$

where $\xi_h(L)$ and $\pi_h(L)$ are square summable nonnegative polynomials in the lag operator L, ϵ_t^O is the shock to the price of oil and $\tilde{\epsilon}_t$ is a vector that represents other shocks assumed to be orthogonal to ϵ_t^O.

Note that (27) represents a set of implicit policy rules for h_t. Furthermore, the parameters of the polynomial $\xi_h(L)$ can be obtained from a structural VAR.

1.6 Market clearing conditions

The market clearing condition for the tradable sector is given by

$$Y_t^T + p_t^O Y_t^O + r f_t = c_t^T + g_t^T + I_t + \left(f_{t+1} - f_t\right), \tag{28}$$

[8] Assuming that the government can purchase at wholesale prices is consistent with the empirical evidence found by Burstein, Neves, and Rebelo (2003).

[9] As mentioned in footnote 8, $\tilde{g}_t$ is equivalent to $p_t^g g_t$.

where $f_t \equiv a_t - b_t$ denotes net foreign assets in dollars. This condition states that the country's tradable income is constituted by tradable output, oil income and the return on last period's net foreign assets. Tradable income can be used for private and public consumption, for investment and to adjust net asset holdings.

For the nontradable sector, the market clearing condition is given by

$$Y_t^N = c_t^N + g_t^N + \gamma c_t^T. \tag{29}$$

Nontradable goods are either consumed by households, purchased by the government or used as inputs in the distribution sector.

Total labor is allocated between the two production sectors. Thus, the labor market clearing condition is given by

$$L_t = L_t^N + L_t^T. \tag{30}$$

Similarly, the capital market clearing condition (15) indicates that the stock of capital acquired last period is allocated today across the two production sectors.

1.7 Equilibrium

A competitive equilibrium in this framework consists of sequences of allocations $\{c_t^N,\ c_t^T,\ I_t,\ a_{t+1},\ b_{t+1}, L_t^N,\ L_t^T,\ L_t,\ K_t,\ K_t^N,\ K_t^T,\ g_t^N,\ g_t^T\}_{t=0}^{\infty}$ and prices $\{p_t^T,\ p_t^N,\ w_t,\ r_t^k,\ q_t\}_{t=0}^{\infty}$ such that, taking as given b_0, a_0, K_{-1}, S and the exogenous processes $\{p_t^O,\ Y_t^O,\ g_t,\ v_t,\ \tau_t^{NO},\ \tau_t^O,\ \tau_t^L\}_{t=0}^{\infty}$:

- $\{c_t^N,\ c_t^T,\ a_{t+1},\ K_t,\ I_t\ ,\ L_t\}_{t=0}^{\infty}$ solve the households' problem
- $\{K_t^T,\ L_t^T\}_{t=0}^{\infty}$ solve the tradable goods firm's problem
- $\{K_t^N,\ L_t^N\}_{t=0}^{\infty}$ solve the nontradable goods firm's problem
- The government optimally chooses the expenditure allocation $\{g_t^N,\ g_t^T\}_{t=0}^{\infty}$, and its flow and lifetime budget constraints are satisfied
- Market clearing conditions for tradable and nontradable goods, land, labor and capital markets are satisfied

1.8 Dynamics after an oil price shock

From (27), the impulse response of h_t to a shock in oil prices can be computed as

$$\frac{\partial E_t h_{i,t+s}}{\partial \epsilon_t^O} = \xi_{h,s}^i \qquad \text{for} \qquad s \geq 0 \quad . \tag{31}$$

When an oil shock occurs, households use the estimated values of $\xi_h(L)$ to form forecasts of future values of h_t, and use these forecasts in making their consumption, labor and savings decisions.

In order to analyze the dynamics of the model after an oil price shock, I solve the model by log-linearizing the system of equations formed by (5), (6), (9) - (11), (26), (18) - (23), (28), (29) - (15), around the steady state.[10]

Given that the model-based impulse responses will be compared with those obtained from the data, it is important to use data-equivalent variables. This requires some additional modeling assumptions. First, g_t^T and g_t^N are not separately observable in the data, so I assume that the fiscal authority chooses a level of g_t, which is a composite of g_t^T and g_t^N,

$$g_t = \left(g_t^T\right)^{\theta_g}\left(g_t^N\right)^{1-\theta_g}, \tag{32}$$

so as to minimize real government expenditure (G_t)—which is observable—. Formally, I assume that the government solves the following problem:

$$G_t \equiv \min_{\{g_t^T, g_t^N\}} g_t^T + p^N g_t^N$$

subject to (32). Unlike $\tilde{g}_t$ (defined in (25)), G_t is priced in units of a base year, so it assumes a fixed relative price p^N. The first order conditions of this problem yield $g_t^T = \theta_g G_t$; and $g_t^N = [(1-\theta_g)/p^N]G_t$. Given that g_t^T and g_t^N are proportional to G_t, their deviations from steady state are the same as those of G_t, $\hat{g}_t^T = \hat{g}_t^N = \hat{G}_t$.

Second, there is no available data on tax rates, so I back out the implicit tax rate responses from those of revenue. In the model, oil revenue (T^O) is proportional to oil GDP, so I define the implied tax response as $\hat{\tau}_t^O = \hat{T}_t^O - \hat{p}_t^O - \hat{Y}_t^O$. Similarly, in the model non-oil revenue (T^{NO}) is proportional to non-oil GDP (see (24)), so $\hat{\tau}_t^{NO} = \hat{T}_t^{NO} - [Y^T/(Y^T + p^N Y^N)]\hat{Y}_t^T - [p^N Y^N/(Y^T + p^N Y^N)](\hat{Y}_t^N + \hat{p}_t^N)$.

Third, c_t^T and c_t^N are not separately observable in the data either. Therefore, I need to compare the VAR-based impulse response function of total consumption (in real currency)

[10] I define $\hat{x}_t = \ln(x_t/x)$, where x is the steady state value of each variable, except for f_t, which is defined as $\hat{f}_t = \ln(f_t/GDP)$.

with an equivalent model-based impulse response. For that purpose, I set steady state prices equal to those in the base year, so that the deviation of consumption in real currency (C_t) from steady state is given by $\hat{C}_t = \theta \hat{c}_t^T + (1-\theta)\,\hat{c}_t^N$.

2 Empirical evidence

In recent years, Mexico has been the world's third largest non-OPEC oil supplier, taking the bottom place among the top ten oil exporters. Its oil company, PEMEX, is state-owned, and over two-thirds of its profits are sent directly to the federal government via taxes, oil rights and benefits. Mexico's oil export price is determined as a function of four international oil varieties. Specifically, Mexico offers mixes of crude oils of different densities both in the domestic and in the foreign market, classified as Maya (heavy), Istmo (light) and Olmeca (super-light), and their export price is determined as a function of two American crude oils, West Texas Sour (WTS) and Light Louisiana Sweet (LLS); one British (Brent) and a fuel oil, US Gulf Coast No.6 3.0% Sulfur, which is only used in daily formulas for the international price of the Maya crude.

Norway is the world's third largest net oil exporter. Norwegian oil is extracted and sold by commercial companies, so producers on the shelf sell crude oil at market conditions. As everywhere else, the price depends on the situation in the oil market and the quality of the oil that is sold. British Brent crude is the reference for oil from the North Sea basin.

In Mexico, oil revenue has accounted throughout the sample (1980:Q1-2006:Q4) for about a third of total government revenue, whereas oil production has accounted on average for about 7 percent total GDP (see top and second panels of Figure 1). Crude oil exports, on the other hand, have accounted for a larger amount of total GDP during the mid-eighties (up to 12 percent of GDP), and they currently account only for about 4 percent (See third panel of Figure 1).

Oil also constitutes a large source of income for the Norwegian economy. Throughout the sample (1980:Q1-2006:Q4 for national accounts and fiscal revenue, 1985:Q1-2006:Q4 for fiscal expenditure), there has been a sustained participation of oil in total revenue and an increasing share in GDP, representing almost forty percent of total revenue and twenty percent of GDP by the end of 2006 (see top and second panels of Figure 1). Crude oil exports constitute an important share of total GDP (see third panel of Figure 1). Their share has increased since the mid-eighties, recently accounting for about 16 percent of total GDP, about four times as much as in Mexico.

Unlike Mexico, Norway shields the economy from oil price fluctuations. Since the nineties, Norway transfers the totality of its oil cash flow to a sovereign wealth fund, currently known as the Government Pension Fund (GPF), and formerly known as the State Petroleum Fund.[11] According to its policy guidelines, only the expected real return on the Fund is returned to the budget for general spending purposes. Additionally, the capital in the Global part of the Fund (GPF-G)—which constitutes the vast majority—is invested abroad, providing protection against Norway-specific idiosyncratic shocks. The Norwegian commitment to protecting the economy from oil-related fluctuations dates back to the early seventies. Soon after the discovery of the Ekofisk field in the North Sea in December 1969, the government became aware of the potential domestic distortions generated by their oil wealth. Therefore, as early as 1973, it recommended that Norway's oil revenues should be used "in the development of a qualitatively better society, while avoiding an outcome characterized only by fast and uncontrolled growth in the use of material resources, without any changes to society".[12,13]

2.1 Oil price stationarity

There is a long standing debate in the literature regarding the stationarity of oil prices. The lack of consensus is in part derived from the different definitions of price, the frequency of the data and the sample used. The bottom panel of Figure 1 depicts the real crude oil prices for Mexico and Norway (Brent) used in this paper.[14]

Multiple papers have tested for stationarity of oil prices. Many of them find real prices stationary (see for instance Ahrens and Sharma (1997), Pindyck (1999), Lee, List, and Strazicich (2006), Li and Thompson (2010), just to name a few), while others (such as Berck and Roberts (1996), Slade (1988), Sadorsky (1999)) cannot reject the hypothesis that oil prices have a unit root.

In the macroeconomics literature, several authors support the stationarity of real oil

[11] The Petroleum Fund was established in 1990 to counter the effects of the anticipated decline in income and to smooth the disrupting effects of highly fluctuating oil prices. In 2006 the mission of the State Petroleum Fund was modified to specifically serve as a long-term saving device that will help finance future healthcare and pensions expenditures associated with the ageing population. Given that it derives its financial backing from oil profits and not pension contributions, in the strictest sense, it is not a pension fund.

[12] Cited in Ang (2008).

[13] It is important to keep in mind though that the restrictions imposed upon policy makers by the Fund are extremely weak, so the quality of Norwegian institutions is in great part responsible for their fiscal discipline. As described by Humphreys and Sandbu (2007), GPF-G outflows cover the balance of the government budget, which is decided by the Parliament. The Parliament, however, is in principle unconstrained, but politicians have committed to an informal "handling rule" not to spend more than 4% of the balance of the fund per annum.

[14] Series in linearly detrended logarithms. Since Mexican export prices were not available prior to 1980, I have also included in Figure 1 the West Texas Intermediate price, which is the closest international marker for the Mexican blend.

prices (see for instance Finn (2000), Rotemberg and Woodford (1996), Kilian (2009)), while others work on research questions that require the analysis of nominal prices, in which case they treat them as non-stationary, introducing measures such as the net oil price increase or price changes into their VAR systems (see for example Hamilton (1983), Hamilton (1996), Hamilton (2003), Bernanke, Gertler, and Waston (1997), Leduc and Sill (2004), among others). This paper works with real oil price data and assumes stationarity of real oil prices.[15]

2.2 Vector autoregression

I assume that innovations to oil prices are exogenous with respect to economic developments in Mexico and Norway. Assuming a small open economy position in the oil market seems a reasonable assumption for both countries, since they produce only about 8 and 6 percent of the total oil among top ten producers (respectively), and also, their exports constitute only about 5 and 8 percent of the total among top ten exporters (respectively).

From the perspective of the SOE, it is irrelevant whether the oil price shock is supply or demand driven, as long as it is not significantly influenced by a structural shock whose origin is in the SOE. Neither Norway nor Mexico have suffered structural shocks that have disrupted world supply or altered world demand. Therefore, it seems safe to treat the shock as strictly exogenous. Another issue to keep in mind is that external demand plays no role in SOE models, as the assumption is that there is an infinitely elastic demand for the SOE's goods. Therefore, global demand shocks that affect oil prices have no incidence in this type of model, beyond the oil price shock they might generate.

Full identification of the remaining structural shocks is not necessary, given that this paper only aims at analyzing the direct and indirect effects of oil price shocks on domestic variables. The effects generated by all other structural shocks—though interesting—are out of the scope of the paper. Imposing strict exogeneity of oil prices allows the identification of the structural oil price shock while working with a restricted reduced-form VAR. All other shocks remain unidentified, and the ordering within the $\boldsymbol{x}$ vector is irrelevant.

[15] Due to the high persistence of these processes, unit root tests on the price series used are inconclusive. Therefore, I have also estimated the VAR for each country using first differences on oil prices and the responses of the endogenous variables are robust. Therefore, the main results of the paper are unaffected by either choice (oil prices in detrended log levels or in first differences). Anecdotally, in surveys of professional forecasters, the vast majority of respondents feel that there is a steady state level of the oil price to which the price will converge, whereas a small fraction is unwilling to specify such a level.

Hence, the following system constitutes the benchmark VAR

$$\begin{aligned} p_t^O &= \boldsymbol{A}(L)\, p_{t-1}^O + u_t^O \\ \boldsymbol{x}_t &= \tilde{\boldsymbol{H}}(L)\, p_t^O + \tilde{\boldsymbol{J}}(L)\, \boldsymbol{x}_{t-1} + \boldsymbol{u}_t^x; \end{aligned} \tag{33}$$

where p_t^O is the oil price; $\boldsymbol{x}_t$ is a vector of domestic variables $\equiv \{Y_t^O$, Y_t^T, Y_t^N, T_t^O, T_t^{NO},G_t, v_t, p_t^N, $C_t\}$; u_t^O denotes the oil price shock, and $\boldsymbol{u}_t^x$ denotes the reduced-form shocks pertaining to the variables in $\boldsymbol{x}_t$.[16] Note that (33) allows for a contemporaneous effect of oil prices on domestic variables in the second equation of (33), and this poses no identification problem because p_t^O is exogenous.

For each country, (33) is estimated at quarterly frequency, including four lags. In Mexico, p^O is obtained from the (dollar) nominal oil export price published by PEMEX, deflated with the U.S. GDP deflator (base 1993 for consistency with Mexican data). The data in $\boldsymbol{x}_t$ was obtained from the Instituto Nacional de Estadística y Geografía (INEGI) and from the Secretaría de Hacienda y Crédito Público de México. The sample goes from 1980Q1 to 2006Q4. All the variables in $\boldsymbol{x}_t$ are in constant (1993) pesos, except for oil production, which is in millions of barrels. All variables are linearly detrended logarithms.[17]

In Norway, p^O is computed using the nominal Brent crude oil price, deflating it with the U.S. GDP deflator (base 2000 for consistency with Norwegian data). The data in $\boldsymbol{x}_t$ was obtained from Statistics Norway. The sample goes from 1985:Q1 to 2006:Q4.[18] All the variables in $\boldsymbol{x}$ are in constant (2000) Norwegian krone, except for oil production, which is in millions of barrels. All variables are linearly detrended logarithms.

2.2.1 Variance decomposition

To assess the relevance of the oil price shock, I compute the variance decomposition associated with the benchmark VAR. For each country, Panel A on Table 1 shows the contribution of the oil shock to the variance of Y^T, Y^N, p^N, C, and G, at several horizons $t = 1$, 4, 8, 12, 20.

In Mexico, the oil shock has a non-negligible contribution to the variance of these variables. For instance, by the eighth quarter after an oil price shock, 23.22 percent of the variance of nontradable output can be attributed to the oil shock. Comparing across variances, the oil shock has the highest impact on the variance of consumption, explaining

[16] Tradable GDP Y^T includes agriculture, non-oil mining and manufactures.

[17] I linearly detrend the real oil price just for consistency with the other variables, but using the log-level instead produces almost identical results.

[18] The starting year in the sample is bounded by the availability of fiscal accounts at quarterly frequency. National accounts data at quarterly frequency is available since 1978.

over a quarter of its fluctuation. The highest contribution of oil shocks to the variance Y^N, C and G occurs around the twelfth quarter, accounting for 24.54, 29.85 and 22.09 percent of the total variance, respectively. In the case of p^N, the contribution peaks around the eighth quarter, accounting for 9.62 percent of the total variance. In all cases, by the twentieth quarter the oil shock still explains a non-negligible amount of the variance. Interestingly, the shock contributes to a larger share of the variance of G in longer horizons rather than on impact.

Notice the difference in the transmission mechanism for Norway. In the short run, the oil price shock explains similar amounts of variance as in Mexico for nontradable output and relative price of nontradables, but for the rest, it explains much less. For instance, in period 1, the oil shock contributes to 2.36 percent of the total variance in consumption, whereas in Mexico the oil shock explains 7.11 of the variance in consumption. For longer horizons the oil shock contributes much less to the variance of all variables than it does in Mexico. For example, the oil price shock only explains 1.11 of the variance in consumption after twenty periods, whereas in Mexico it still explains 27.56 percent of its variance at that date.

2.2.2 Impulse responses

Figure 2 depicts the impulse responses to a one standard deviation shock to the oil price in Mexico. The solid line denotes the impulse response and the shaded area defines the 95 percent confidence interval.[19] Note that a one standard deviation shock to the oil price raises the price by 17 percent on impact, and makes it remain significantly above its steady state level for nine quarters. Additionally, the shock generates significant hump-shaped responses from all the variables in the system, except oil production. Nontradable output, government purchases and consumption peak at the eighth quarter, whereas tradable output peaks in the fourth quarter. Furthermore, there is a statistically significant appreciation of p^N for nine quarters.

Figure 3 depicts the impulse responses to an oil price shock in Norway. Even though there is a significant increase in oil revenue, tradable and nontradable output, government purchases do not rise significantly as a response to the oil price shock, as they do in Mexico. Furthermore, non-oil revenues and transfers decrease on impact and significantly for about three quarters.

[19] The confidence bands were computed by bootstrapping the residuals of the estimated VAR. As the small sample distribution may not be normal, the bands need not be centered around the impulse responses.

3 Fiscal policy as transmission mechanism: Mexico

3.1 Calibration, estimation and steady state

Let Θ be the parameter set, which I divide into three subsets: Θ_1, Θ_2 and Θ_3. $\Theta_1 = \{\beta,$ $\gamma,\ \theta,\ \delta^K,\ \varpi\}$ collects parameters calibrated to match features of the Mexican data. Θ_2 contains $\{\sigma, \rho, \varkappa,\ \phi,\ \alpha,\ \eta,\ \nu\}$, which I estimate by minimizing the distance between the model and empirical impulse response functions. Finally, Θ_3 is a function of Θ_1 and Θ_2 and it contains $\{\psi,\ A^N,\ A^T\}$.

Following Christiano, Eichenbaum, and Evans (2005), let $\hat{\Psi}$ be the empirical impulse response estimates and let $\Psi(\Theta)$ be the mapping from Θ to the model impulse response function. Thus,

$$\hat{\Theta}_2 \arg\min_{\Theta_2} J = \left(\hat{\Psi}_i - \Psi_i(\Theta)\right)' V^{-1} \left(\hat{\Psi}_i - \Psi_i(\Theta)\right) \tag{34}$$

where $i = \{Y^T, Y^N, p^N$, consumption$\}$ and V is a diagonal matrix with the sample variances of the data impulse response functions along the diagonal. Since impulse response functions are a description of the autocovariance structure of the data, and autocovariances are moments, minimizing the expression in (34) can be interpreted as a type of GMM estimation.

In the lines that follow, I describe the calibration of Θ_1, and some additional restrictions imposed to match features of the Mexican data. Since the frequency of the model is quarterly, I follow Schmitt-Grohé and Uribe (2001) and calibrate $\beta = 1/(1+r)$ assuming that the net quarterly interest rate in the steady state is $r = 0.0159$. Following Burstein, Neves, and Rebelo (2003), I define the distribution margin (s^d) as the fraction of the retail price that reflects distribution costs: $s^d = \gamma p^N/(1+\gamma p^N)$. Thus, I set $\gamma = 0.5029$ so that combined with the steady state value of p^N (explained below) implies a 43 percent distribution margin, which is consistent with the estimates of Burstein, Neves, and Rebelo (2003). I set $\theta = 0.442$ so that the share of tradable goods in private consumption is consistent with the weight of tradable goods in the Mexican CPI. Also following Burstein, Neves, and Rebelo (2003), I set the depreciation rate of capital (δ^K) equal to 2.5 percent. I assume the wage elasticity is equal to $\epsilon^w = 0.5$, which implies $\varpi = (1/\epsilon^w) + 1 = 3$.

Without loss of generality, I set $Y^T = Y^N = Y^O = 1$. That way, relative size differences across sectors are captured by relative prices. In order to pin down L, I follow Correia, Neves, and Rebelo (1995) and I calibrate it so that $L =$ employment rate $\times\ 40/(7 \times 14)$; where 40 is the average work week and 7×14 is the number of hours per week. Defining the employment rate as the number of employed people within the economically active population (EAP), the average employment rate in Mexico is equal to 0.8806, which yields

$L = 0.3594$.[20] Making use of the information available in the Mexican Employment Surveys (ENOE) published by INEGI, I calibrate the share of labor in the tradable sector (s_{L^T}) equal to 35 percent, so $L^T = 0.35 \times 0.3594 = 0.1258$ and $L^N = 0.3594 - 0.1258 = 0.2336$. I set the share of land in GDP equal to 46 percent.

According to Schmitt-Grohé and Uribe (2001), tradable output (inclusive of oil production) represents 44.2 percent of GDP in Mexico. Since oil production represents, on average, 7.1 percent of GDP, I set the steady state share of non-oil tradable goods in output to $s_T \equiv Y^T/GDP = 0.371$. Since $Y^T = 1$, this implies that the steady state value of $GDP = 1/0.371 = 2.70$. Since the steady state share of oil production in GDP is $s_O \equiv p^O Y^O/GDP = 0.071$, $Y^O = 1$, and $GDP = 2.70$, this implies that the steady state value of $p^O = 0.071 \times 2.70 = 0.191$. Finally, since the steady state share of nontradable goods in GDP is $s_N \equiv p^N Y^N/GDP = 0.558$, $Y^N = 1$, and $GDP = 2.70$, the implied steady state value of $p^N = 0.558 \times 2.70 = 1.50$.

Government purchases of goods and services represent, on average, 13 percent of GDP in Mexico. Hence, I set the steady state value of $s_g \equiv \left(g^T + p^N g^N\right)/GDP = 0.13$. Taking "other current expenditures" plus "financial capital expenditures" as a proxy for tradable purchases, I assume that government expenditure on tradable goods, g^T, represents 26.1 percent of total government purchases, so $g^T = 0.261 \times s_g \times GDP = 0.0916$. This further implies that $g^N = (1 - 0.261) \times s_g \times GDP/p^N = 0.173$. Government revenue represents, on average, 25 percent of GDP in Mexico. Hence I set the steady state value of $\tau = 0.25 \times GDP = 0.67$. Oil-based revenue represents, on average, 9 percent of GDP, so I set τ^O so that $\tau^O p^O Y^O = 0.09 \times GDP$. Given the values p^O, Y^O and GDP, this implies that $\tau^O = 1.27$. It follows that non-oil revenue represents 16 percent of GDP, so I set $\tau^L = 0$ and set τ^{NO} so that $\tau^{NO}(Y^T + p^N Y^N) = 0.16 \times GDP$. Given the values of p^N, Y^T, Y^N, and GDP, this implies that $\tau^{NO} = 0.172$. Government transfers represent, on average, 9 percent of GDP in Mexico. Hence I set the steady state value of $v = 0.09 \times GDP = 0.24$.

The first panel of Table 2 summarizes the calibration restrictions based on features of the Mexican data (fourth column), the second panel contains the parameter choices for Θ_1, and the third one depicts the estimated parameter values.

3.2 Consequences of a positive oil price shock

The left column of Figure 4 compares the model responses of consumption, output and the relative price of nontradables with those from the data. The model responses lie within

[20] EAP and unemployment data were obtained from the National Urban Employment Survey (Encuesta Nacional de Empleo Urbano) published by INEGI, and the total population was obtained from the International Financial Statistics of the IMF.

the empirical confidence bands and they do a good job matching the empirical responses, both in shape and size.

The solid lines on the bottom row of Figure 7 depict the implied tax rate impulse responses. The oil price shock temporarily reduces the model's oil and non-oil tax rates. The lower non-oil tax rate generates an intertemporal substitution effect as firms want to produce more now while the after-tax marginal product of capital and labor is higher, and cut back on production once the tax rate goes up again. Hence, both types of firms demand more labor and capital. The added demand of tradable and nontradable goods puts pressure on the relative price of the latter, raising p^N and boosting the marginal product of the nontradable sector. This generates a sectorial reallocation of factors of production, towards the nontradable sector, so the response of L^N and K^N is relatively larger than the one of L^T and K^T. Labor supply is not dampened by the wealth effect, due to GHH preferences. Given that land is a fixed factor of production, higher demand for land increases its price. The lower oil tax rate increases the after-tax household income, strengthening the wealth effect and increasing consumption demand. The wealth effect is further enlarged by the increase in government transfers made to households (see Figure 2). Finally, the low elasticity of substitution between government purchases and private consumption generates comovement between these variables, contributing to generate a hump-shaped response for consumption.

4 Fiscal policy as transmission mechanism: Norway

As mentioned earlier, Figure 3 shows the Norwegian impulse responses to a 1 standard deviation in oil prices. Fiscal variables respond very differently from those in Mexico. Here, government purchases do not rise significantly as a response to the oil price shock, and transfers and non-oil revenue if anything drop. On the private side, the responses of nontradable output and the relative price of nontradables are not statistically different from zero at any period and those of tradable output and consumption only rise significantly during the fourth quarter.

Even though most of the data responses are not statistically significant, it is a test to the model to perform the same exercise as with Mexico and see whether the model is capable of generating impulse responses that match the Norwegian ones.

4.1 Calibration, estimation and steady state

Just as before, I divide Θ into three subsets: Θ_1, Θ_2 and Θ_3. $\Theta_1 = \{\beta,\ \gamma,\ \theta,\ \delta^K,\ \varpi\}$ collects parameters calibrated to match features of the Norwegian data. I estimate $\Theta_2 = \{\sigma, \rho, \varkappa,\ \phi,\ \alpha,\ \eta,\ \nu\}$ in order to minimize (34), and $\Theta_3 (\Theta_1, \Theta_2) = \{\psi,\ A^N,\ A^T\}$.

I continue to set r equal to 0.0159, the depreciation rate of capital (δ^K) equal to 2.5 percent, ϖ equal to 3 and $Y^T = Y^N = Y^O = 1$. I set γ equal to 0.0859. Combining γ with the steady state value of p^N (explained below) implies a 29.3 percent distribution margin, which is consistent with the estimates of Goldberg and Campa (2006). I set the share of tradable consumption in total private consumption (θ) equal to 0.5298, so that the share of tradable goods in private consumption is equal to the average weight of tradable goods in the Norwegian CPI. Using labor and employment by sector statistics, I calibrate $L =$ employment rate $\times\ 40/(7 \times 14) = 0.9633\times\ 40/(7 \times 14) = 0.3932$.

I require the model to match several key features of the Norwegian economy. The average share of oil extraction in GDP in Norway is 19.07 percent, and the share of tradables in value added is 13.9 percent. Since $Y^T = 1$, this implies that the steady state value of $GDP = 1/0.139 = 7.1942$. Since the steady state share of oil production in GDP is $s_O \equiv p^O Y^O / GDP = 0.1907$, then the steady state value of $p^O = 0.1907 \times GDP = 1.3719$. Finally, since the steady state share of nontradable goods in GDP is $s_N \equiv 1 - s_O - s_T = p^N Y^N / GDP$, then the implied steady state value of $p^N = (1 - s_O - s_T) \times GDP = 4.8223$.

The share of general government total revenue in GDP is 46.93 percent in Norway, so $\tau = 0.4693 \times GDP = 3.3751$. Oil-based revenue represents, on average, 8.84 percent of GDP, so $\tau^O p^O Y^O = 0.884 \times GDP$. Given the values of p^O, Y^O and GDP, this implies that $\tau^O = 0.4635$. I set $\tau^L = 0$. It follows that non-oil revenue constitutes $46.93 - 8.84 = 38.09$ percent of GDP. Therefore, $\tau^{NO}(Y^T + p^N Y^N) = 0.3809 \times GDP$. Given the values of p^N, Y^T, Y^N, and GDP, $\tau^{NO} = 0.4706$. Total general government expenditures net of transfers represent are on average 25.8 percent of GDP. Hence, I set the steady state value of $g = 0.258 \times GDP = 1.8555$. Taking wages + 60 percent of goods and services + other operating expenses to equal the value of nontradable government expenditures, I get $g^T = 0.4141 \times g = 0.7683$ and $g^N = 0.2255$. General government transfers represent, on average, 19 percent of GDP. Hence I set the steady state value of $v = 0.19 \times GDP = 1.3664$.The first panel of Table 2 summarizes the calibration restrictions based on features of the Norwegian data (last column), the second panel contains the parameter choices for Θ_1, and the third one depicts the estimated parameter values.

4.2 Consequences of a positive oil price shock

The right column on Figure 4 depicts the model responses of output, consumption and $p_{t.}^{N}$. Once again, the model responses lie within the empirical confidence bands and they do a good job matching the empirical responses, both in shape and size.

The solid lines on the bottom row of Figure 6 show the implied tax rate impulse responses. On impact, the oil price shock reduces the implied oil tax rate, but it quickly rises, capturing more oil revenue and hence dampening the wealth effect for households. The fiscal authority further reduces the wealth effect by cutting back on the transfers made to households (see Figure 3). As the wealth effect is rather small, households do not want to consume much more than before. The lower non-oil tax generates a small intertemporal substitution effect as firms want to produce more now while the after-tax marginal product of capital and labor is higher, and cut back on production once the tax rate goes up again. But since households barely want to consume more, production of both types of goods has a minor response. There is some pressure on p^N, that translates into relatively higher marginal products in the nontradable sector, generating relatively stronger responses in its factors of production.

5 Assessing the role of fiscal policy

In this section, I gauge the role of fiscal policy as a transmission mechanism of oil price shocks. First, I deconstruct the model to show what each feature of the model provides. Next, I run two counterfactuals, introducing different fiscal policies into each economy, keeping the calibration and estimation as obtained above, and I check whether the model can still replicate the data responses for consumption, output and p^N. Following that, I evaluate the role of fiscal policy as an insulation device, by comparing the model variance decomposition under the original policy and the counterfactual. Finally, I compare the welfare attained under the original and counterfactual policies.

5.1 Deconstructing the responses

First, imagine for a moment that Y^T and Y^N are fixed endowments. Consider what happens when oil prices rise but there is no fiscal response. This is a pure wealth effect. Households want to consume more of both types of goods, but since there is scarcity of nontradable goods, there is an appreciation of p^N. Not only is there higher demand for nontradable goods for consumption, but there is also demand for the distribution of tradable consumption. Since the model is frictionless, households smooth consumption perfectly, and the relative price and levels of consumption of tradables and nontradables adjust immediately to the temporarily higher oil price. They reach new steady state values: $\bar{p}^N > p_0^N$, $\bar{c}^N < c_0^N$, $\bar{c}^T > c_0^T$, where (p_0^N, c_0^N, c_0^T) denote initial steady state values. These new levels satisfy the first order conditions of the households and goods market clearing conditions. To complete the new equilibrium, lump sum taxes τ_t^L adjust so that the government's lifetime budget constraint continues to be satisfied.

Now, reintroduce production, but suppose government purchases do not enter effective consumption ($\phi = 1$). Consider what happens when oil prices rise and the only fiscal variable that responds as in the data is government purchases. In terms of (31), let

$$\frac{\partial E_t g_{t+s}^{T,N}}{\partial \epsilon_t^O} = \xi_s^{g^{T,N}} \quad ; \quad \frac{\partial E_t h_{i,t+s}}{\partial \epsilon_t^O} = 0 \quad \text{for all} \quad h_i \neq g^{T,N},\ \phi = 1$$

When government purchases are allowed to respond, and if they rise (as in Mexico), the scarcity of nontradable goods is exacerbated. This adds upward pressure to p^N, downward pressure on c_t^N and leaves less room for c_t^T to rise, tending to depress overall private consumption. In this case, however, firms can address the scarcity of nontradable goods by increasing production. The temporary rise in p^N increases the marginal product of capital and labor in the nontradable sector, generating a sectorial reallocation of factors of production. Increased nontradable production mitigates the appreciation. By providing more nontradable goods, households are also better able to satisfy their increased demand for tradable and nontradable goods. The dash-dot responses in Figure 5 depict this scenario. Note that rather than reestimating Θ_2 excluding ϕ, these responses are plotted using the values from the joint estimation of Θ_2, imposing ex-post $\phi = 1$. Similarly, letting transfers respond as in the data generates upward pressure on p^N (if transfers rise), as an increase in v_t adds slack to the households' budget constraint.

Consider instead what happens if the model implied tax rates respond to the oil price shock, while government purchases remain unresponsive. In terms of (31), first consider

$$\frac{\partial E_t \tau_{t+s}^O}{\partial \epsilon_t^O} = \xi_s^{\tau^O} \quad ; \quad \frac{\partial E_t h_{i,t+s}}{\partial \epsilon_t^O} = 0 \quad \text{for all} \quad h_i \neq \tau^O$$

In this frictionless environment, movements in the implied oil tax rate are fully internalized on impact, resizing the perceived wealth effect for households. Just as with the endowment scenario described above, households smooth consumption perfectly, and the relative price and levels of consumption of tradables and nontradables adjust immediately. In this case, production is able to respond to higher demand of nontradable goods, and due to capital dynamics (see eq. (15), it takes one period to attain the new steady state level. The responses with a “+” marker in Figure 5 depict this case.

Now let τ^{NO} respond instead. Formally,

$$\frac{\partial E_t \tau^{NO}_{t+s}}{\partial \epsilon^O_t} = \xi^{\tau^{NO}}_s \quad ; \quad \frac{\partial E_t h_{i,t+s}}{\partial \epsilon^O_t} = 0 \quad \text{for all} \quad h_i \neq \tau^{NO}$$

The non-oil tax rate generates intertemporal substitution effects in both types of production, as it affects the shape of the after-tax marginal product of capital and labor in both sectors. A drop of τ^{NO}_t on impact makes after-tax marginal product of capital and labor higher in both sectors, so both types of firm want to increase production to take advantage of the temporary tax relief. This generates upward pressure in factor prices, that in turn provide some additional slack to the household's budget constraint allowing for additional consumption and investment (see dashed responses in Figure 5).

Allowing all the fiscal variables in vector h to responses together, but still preventing government purchases to enter effective consumption ($\phi = 1$), generates the responses with the squared marker. Letting all fiscal variables respond and letting ϕ take the estimated value yields the “Full Model” responses in Figure 5. In Mexico, government purchases in effective consumption magnify the response of output, nontradable relative prices and consumption, whereas in Norway they mitigate them (except for tradable production). Putting all the model features together improves the match with the data responses. In order to see how much of the match improvement is due to government purchases in the utility function, I also analyze the scenario where only government purchases respond and they are part of effective consumption. Formally,

$$\frac{\partial E_t g^{T,N}_{t+s}}{\partial \epsilon^O_t} = \xi^{g^{T,N}}_s \quad ; \quad \frac{\partial E_t h_{i,t+s}}{\partial \epsilon^O_t} = 0 \quad \text{for all} \quad h_i \neq g^{T,N},\ \phi \neq 1$$

The responses for this scenario have a “v” marker in Figure 5. While in Mexico the responses of nontradable output, p^N and consumption are highly dependent on this feature, tradable output is not. In fact, allowing the implied nontradable tax rate to respond is crucial for matching Mexican tradable output. The same is true for Norwegian tradable output, and consumption. Norwegian nontradable prices and output, on the other hand, also rely on ϕ as in the Mexican case.

5.2 Counterfactuals

Next, I run two counterfactuals to assess the relevance of the fiscal policy as a transmission mechanism of oil price shocks. I introduce different fiscal policies into each economy, keeping the calibration and estimation as obtained above, and I assess whether the model can still replicate the data responses for consumption, output and p^N. If it still can, then it means that fiscal policy is not an important propagation mechanism of oil price shocks. Note that I do not reestimate Θ_2 in either exercise because these are deep parameters. Even though they were estimated using past fiscal data, they do not depend on future fiscal outcomes.[21]

For each country, I change the fiscal policy so that fiscal variables respond to an oil shock the way they do in the other country. I implement this by replacing the estimated coefficients from the equations of the fiscal variables (T^{NO}, T^O, G, v) in the country's own benchmark VAR with the corresponding coefficients from the other country's benchmark VAR.

5.2.1 "Mexicanizing" Norway

In the first counterfactual, I change the fiscal policy so that fiscal variables respond to an oil shock the way they do in Mexico. I replace the estimated coefficients from the equations of the fiscal variables (T^{NO}, T^O, G, v) in the Norwegian benchmark VAR with the corresponding coefficients from the Mexican benchmark VAR. I feed them into the model, calibrated and estimated for Norway.[22] Given that Norwegian fiscal responses in the data are so different from the Mexican ones, if the model calibrated and estimated for Norway can still match the Norwegian data impulse responses for consumption, output and the relative price of nontradable goods—despite the use of alternative fiscal policy rules—then it means that the fiscal variables do not constitute an important transmission mechanism of oil shocks.

Figure 6 depicts the results of this exercise. The wealth effect is larger because the counterfactual fiscal policy does not prevent the resource windfall to arrive into the economy. This translates, among other things, into a drop of the implied oil tax rate and an increase in transfers to households (see transfers response in Figure 2). The increased demand for consumption due to the larger wealth effect—combined with the increase in government purchases—generates an appreciation of nontradable goods. The implied non-oil tax rate is higher in the counterfactual relative to the original model, because $\hat{T}_t^{NO,\text{ Mexico}} > \hat{T}_t^{NO,\text{ Norway}}$. Thus, the intertemporal substitution effect brought on by τ^{NO} is smaller than in the original model. On the other hand, the marginal product of capital and labor in the nontradable sector is higher due to the rise in p^N, so there is a stronger sectorial re-

[21] Recall that households use $\xi_h(L)$ as described in (27) to form forecasts of future values of h_t and internalize these forecasts in their consumption, labor and saving decisions.

[22] I could have introduced generic procyclical responses, but it is helpful to use the actual Mexican responses so that the model responses generated in the counterfactual can also be compared to those obtained in the Mexican case.

allocation of factors towards nontradable production. The higher substitutability between consumption and government purchases in Norway (relative to Mexico), is magnified by the size of the counterfactual response of government purchases. Since government purchases rise so much under the counterfactual, they generate a drop in private consumption.

Thus, under the counterfactual, the model generates dynamics inconsistent with the behavior of the data responses of consumption, nontradable production and p^N. Introducing a different policy specification from the one seen in the data reduces the model's ability to explain the behavior of the variables of interest, highlighting the relevance of fiscal policy as a transmission mechanism of oil price shocks.

5.2.2 "Norwegianizing" Mexico

In the second counterfactual, I change the fiscal policy so that fiscal variables respond to an oil shock the way they do in Norway. I feed them into the model, calibrated and estimated for Mexico. Figure 7 compares the data, original model and counterfactual's responses.

With this fiscal policy, the resource windfall is much smaller, as the excess oil revenue is set aside and cannot be spent immediately by the government or the private sector. Hence, there is a smaller wealth effect. This is reflected, among other things, in a drop in transfers and in $\hat{\tau}_t^{O,\text{ Counterfactual}} > \hat{\tau}_t^{O,\text{ Mexico}}$. The intertemporal substitution effect stemming from the non-oil tax rate is now different, as $\hat{\tau}_t^{NO,\text{ Counterfactual}}$ drops in the first few quarters twice as much as $\hat{\tau}_t^{NO,\text{ Mexico}}$, simply because $\hat{T}_t^{NO,\text{ Norway}} < \hat{T}_t^{NO,\text{ Mexico}}$. The lower non-oil tax rate increases the after-tax marginal product of capital and labor in both sectors, generating an intertemporal substitution effect. Nevertheless, the response of tradable production ends up being larger than the one in the nontradable sector, because p^N (which affects the after-tax marginal product of capital and labor in the nontradable sector) does not rise as much in as in the original model.

Since the Mexican elasticity of substitution between government and private consumption is lower than the Norwegian, a moderate response of government expenditure to oil price shocks also contributes to a modest response of consumption. The relative price of nontradable goods still rises as a reaction to the shock, because there is still scarcity in the nontradable market, but less so than in the original model, since consumption as a whole does not respond as much. Since there are distribution costs associated with c^T, a rise in c^T still generates tension on p_t^N, given the modest response of nontradable output to the oil shock.

In sum, introducing a completely different policy specification from the one seen in the data reduces the model's ability to explain the behavior of consumption, output and the relative price of nontradable goods, suggesting that the fiscal framework is a key transmission mechanism of the oil price shocks.

5.3 Fiscal policy as an insulation device

The two counterfactuals show that the model's ability to explain the behavior of consumption, output and the relative price of nontradable goods depends on the fiscal policy introduced. Now, in order to understand the power of fiscal policy as an insulation device, for each country, I simulate data from the original model and the counterfactual, and I decompose the variance of output, p^N, consumption and government purchases, to see how much of their variance is attributed to the oil price shock. Intuitively, "Norwegianizing" Mexico should insulate the economy from the oil price shock and hence it should decrease the share of variance attributed to the oil price shock, relative to the original model. Similarly, "Mexicanizing" Norway should raise the exposure to the shock, and hence, it should increase the share of variance attributed to the oil price shock.

Panel B on Table 1 reports the ratio of percentage of variance attributed to the oil price shock in the counterfactual, to percentage attributed in the original model. A value of 1 implies that the counterfactual model assigns equal percentage of variance to the oil price shock as the original model. As expected, for most variables and horizons, "Norwegianizing" Mexico insulates the economy from the oil price shock and hence decreases the share of variance attributed to the oil price shock, and "Mexicanizing" Norway increases the exposure to the shock, hence raising the share of variance attributed to the oil price shock. Therefore, fiscal policy not only seems to be a transmission mechanism, but it also seems to be capable of regulating the size of pass-through.

5.4 Welfare implications

Implementability constraints aside, it is natural to wonder whether there would be a welfare improvement for Mexico if it could switch from its actual fiscal policy regime to the Norwegian one. Intuitively, given the insulation properties explored above, Norway should be worse off if it would switch from its actual policy to the Mexican one. To assess this, I compute the welfare gain of switching from the actual, reference policy (R) to the counterfactual (CF) policy, as the amount ξ of stochastic consumption that households in country i would have to give up under the counterfactual in order to be back at the welfare level provided by its own, reference policy, R. If $\xi > 0$, it means that households are better off with the counterfactual policy, and $\xi < 0$ means that switching to CF would be welfare deteriorating. Formally, the welfare gain is defined as

$$E\sum_{j=0}^{\infty}\beta^{j}U\left(c_{t+j}^{R},g_{t+j}^{R},L_{t+j}^{R}\right)=E\sum_{j=0}^{\infty}\beta^{j}U\left(\left(1-\xi\right)c_{t+j}^{CF},g_{t+j}^{CF},L_{t+j}^{CF}\right) \tag{35}$$

To compute ξ, I rewrite (35) letting welfare (V) under policy j, for country i be defined recursively as

$$V_{i,t}^{j} = U\left(c_{i,t}^{j},g_{i,t}^{j},L_{i,t}^{j}\right)+\beta E_{t}V_{i,t+1}^{j}, \quad j=R,CF, \quad \text{and I define} \tag{36}$$

$$\widetilde{V_{i,t}^{CF}} = U\left(\left(1-\xi\right)c_{i,t}^{CF},g_{i,t}^{CF},L_{i,t}^{CF}\right)+\beta E_{t}\widetilde{V_{i,t+1}^{CF}} \tag{37}$$

as the welfare attained when households give up a fraction ξ of their consumption under the counterfactual policy. To evaluate the welfare gain of switching from policy R to policy CF, I set ξ such that

$$\widetilde{V_{i,t}^{CF}}=V_{i,t}^{R} \tag{38}$$

As mentioned above, if $\xi>0$,then households are better off with the counterfactual policy, whereas $\xi<0$ implies that switching to CF would reduce their welfare. In order to compute ξ properly (taking into account all second order effects), I perform a second order approximation of the welfare function, under policies R and CF. I simulate and compute the unconditional welfare under R and CF and I apply (38) to find ξ. Table 3 summarizes the results.

As anticipated, Mexican households would benefit from implementing the Norwegian fiscal policy. They would forgo 7.57 percent of consumption under the counterfactual in order to go back to the welfare attained under their own policy. Furthermore, they would face less uncertainty under the counterfactual regime, as the volatility of consumption would be reduced. Norwegian households, on the other hand, would incur in a 14.46 percent loss in consumption by switching policy regimes and would increase consumption volatility. Therefore, fiscal policies that insulate the country from exogenous oil price shocks seem to be welfare improving over those that are procyclical.

6 Concluding remarks

In this paper I analyze the impact of oil price shocks in an economy where oil revenue constitutes a large component of total government revenue, making fiscal policy directly sensitive to oil prices. I find that fiscal policy is a very important transmission mechanism, as it largely determines the degree of exposure of domestic variables to an external shock of this kind.

To illustrate the mechanisms through which oil prices affect the economy, I consider a two sector DSGE model that captures several key features. First, an oil price shock generates a wealth effect. Both households and government want to consume more tradable and nontradable goods as their income rises due to higher oil prices. Second, there is a scarcity effect. Private and public willingness to consume—brought about by the wealth effect—generates short-run scarcity of nontradable goods that drives up their relative price. This scarcity is exacerbated by the existence of distribution costs in the tradable sector. Third, distortionary taxes generate an intertemporal substitution effect. Both types of firms want to increase production right after the shock as the implicit non-oil tax rate drops in response to the shock. Fourth, there is a sectorial reallocation effect. Changes in relative prices make the marginal product of labor and capital temporarily higher in the nontradable sector, so households are inclined to allocate more capital and labor on this sector. Distortionary taxes and changes in relative prices—combined—affect the timing of production for both types of output. Finally, the fifth ingredient is government purchases in the utility function.

I assess the relevance of the fiscal channel by conducting an empirical analysis for Mexico and Norway, two oil-rich countries with different fiscal frameworks. I find that in Mexico an oil price shock generates significant and hump-shaped increases in government purchases, consumption and output, as well as a real appreciation. Norwegian data, on the other hand, does not yield the same predictions. I find that a temporary but persistent oil price shock does not generate significant increases in tradable output, nontradable output or government purchases, despite generating significant rises in oil revenue. Arguably, this occurs because unlike Mexico, Norway successfully shields the economy from oil price fluctuations—among others—by transferring the totality of its oil cash flow to a Fund (Government Pension Fund-Global), and only the expected real return on the Fund is returned to the budget for general spending purposes. Additionally, the capital in the Fund is invested abroad, providing protection against Norway-specific idiosyncratic shocks.

To gauge the model's performance, I calibrate and estimate the model so that it matches features of each economy, and I compare the impulse responses of consumption, output and the relative price of nontradable goods implied by the model with the corresponding responses in the data, which are measured—as mentioned above—using a VAR. Taking each country's fiscal framework as given—by assuming that government purchases, transfers and government revenue respond to the oil shock in the model as they do in the data—I find that the model is able to explain the data responses for both countries.

Absent the actual fiscal policy responses, the model cannot explain the data, suggesting that the fiscal channel is the key transmission mechanism of oil price shocks. I run two counterfactuals to illustrate this point. I introduce a different fiscal policy into each economy, and I assess whether the model can still replicate the data responses for consumption, output and the real exchange rate. If it still can, then it means that fiscal policy is not an important propagation mechanism of oil price shocks. In the first counterfactual, I "Mexicanize" Norway by changing the fiscal policy so that Norwegian fiscal variables respond to an oil shock the way they do in Mexico. In the second counterfactual, I "Norwegianize" Mexico, by changing the fiscal policy so that Mexican fiscal variables respond to an oil shock the way they do in Norway. As it turns out, in both cases the model is unable to explain the behavior of output the relative price of nontradable goods and consumption, suggesting that the fiscal framework is a key transmission mechanism of the oil price shocks.

In order to understand the power of fiscal policy as an insulation device, for each country, I simulate data from the original model and the counterfactual, and I decompose the variance of output, p^N, consumption and government purchases, to see how much of their variance is attributed to the oil price shock. As expected, "Norwegianizing" Mexico insulates the economy from the oil price shock and hence it decreases the share of variance attributed to the oil price shock, relative to the original model. Similarly, "Mexicanizing" Norway raises the exposure to the shock, and hence, it increases the share of variance attributed to the oil price shock. Therefore, fiscal policy not only seems to be a transmission mechanism, but it also seems to be capable of regulating the pass-through rate.

I conduct welfare analysis to verify whether insulation is welfare improving. I compute the welfare gain of switching from the original fiscal policy to the one provided by the counterfactual. I find a welfare gain of 7.57 percent of consumption in Mexico, and a welfare loss of 14.46 percent of consumption in Norway. Not surprisingly, fiscal policies that insulate the country from exogenous oil price shocks seem to be welfare improving over those that are procyclical.

Finally, as a robustness check, I consider in the Appendix three extensions to the basic model. Extension 1 allows for the distribution sector to use oil products as one of its inputs, while leaving the rest of the model unmodified. Extension 2 keeps the distribution sector unmodified, and allows instead for demand of oil-related products by households and firms. Finally, Extension 3 combines Extensions 1 and 2. Each extension includes oil-related products rather than crude oil itself, since in reality households and firms do not use unrefined crude oil. For each extension, I calibrate the model to match features regarding energy use, etc., of the Mexican and the Norwegian economies, and I reestimate the parameters in Θ_2. I find that adding these features to the model does not alter the main findings of the basic model.

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7 Tables and Figures

Table 1: Variance Decomposition Analysis

A. Percentage of Variance Due to the Oil Price Shock in the Benchmark VAR

	Mexico					Norway				
t	Y^T	Y^N	p^N	C	G	Y^T	Y^N	p^N	C	G
1	4.70	2.84	3.95	7.11	1.62	2.14	3.15	3.22	2.36	0.76
4	12.48	16.78	9.19	21.29	6.09	4.09	3.70	2.23	5.29	3.76
8	8.75	23.22	9.62	28.14	19.30	2.28	3.28	2.31	2.56	7.94
12	9.87	24.54	8.91	29.85	22.09	1.73	2.06	1.89	1.59	10.38
20	20.89	21.89	7.86	27.56	21.51	1.32	1.52	2.23	1.11	10.67

B. Comparing the Percentage of Variance Attributed to the Oil Price Shock: Counterfactual / Original Model

	Mexico					Norway				
t	Y^T	Y^N	p^N	C	G	Y^T	Y^N	p^N	C	G
1	0.26	0.11	0.11	0.05	0.39	0.01	1.79	0.23	1.20	2.63
4	2.02	0.28	0.56	0.35	0.30	0.3	1.52	0.86	1.34	3.02
8	2.34	0.50	0.63	0.55	0.47	0.36	1.63	1.00	1.49	2.06
12	2.20	0.68	0.76	0.71	0.65	0.9	1.68	1.06	1.59	1.48
20	0.93	0.65	0.73	0.68	0.62	1.42	1.73	1.09	1.77	1.53

Panel A shows the contribution of the oil shock to the variance of Y^T, Y^N, p^N, C, and G in the benchmark VAR, at several horizons $t = 1$, 4, 8, 12, 20. Panel B reports the ratio of percentage of variance attributed to the oil price shock in the counterfactual, to percentage attributed in the original model. A value of 1 implies that the counterfactual model assigns equal percentage of variance to the oil price shock as the original model.

Table 2: Features of the Mexican and Norwegian Data, Θ_1 and Θ_2

Calibration Restrictions			Mexico	Norway
Symbol	Definition	Description	Value	
s_O	$\frac{p^O Y^O}{GDP}$	Share of oil production in GDP	0.07	0.191
s_T	$\frac{Y^T}{GDP}$	Share of tradable output in total GDP	0.37	0.139
s_N	$\frac{p^N Y^N}{GDP}$	Share of nontradable output in total GDP	0.56	0.67
s_g	$\frac{g}{GDP}$	Share of government current and capital expenditures in GDP	0.13	0.258
s_τ	$\frac{\tau}{GDP}$	Share of total revenue in GDP	0.25	0.4635
s_{τ^O}	$\frac{\tau^O p^O Y^O}{GDP}$	Share of oil revenue in GDP	0.09	0.884
s_v	$\frac{v}{GDP}$	Share of government transfers in GDP	0.09	0.19

Θ_1	Symbol	Description	Value	
	β	Discount factor	0.984	0.984
	γ	Distribution costs parameter	0.5	0.0859
	θ	Share of tradable goods in private consumption	0.442	0.5298
	δ^K	Depreciation rate of capital	0.025	3
	ϖ	Preference parameter	3	0.025

Θ_2	Symbol	Description	Value	
	σ	Coefficient of relative risk aversion	2.012	2.341
	ρ	Elasticity of substitution between value added and land	0.058	5.814
	$\varkappa$	Elasticity of substitution between private and public consumption	0.059	0.393
	ϕ	Distribution parameter effective consumption	0.987	0.556
	α	Share of labor in tradable production	0.622	0.894
	η	Share of labor in nontradable value added	0.898	0.757
	ν	Distribution parameter nontradable production	0.986	0.751

Figure 1: Stylized Facts About the Mexican and Norwegian Economies

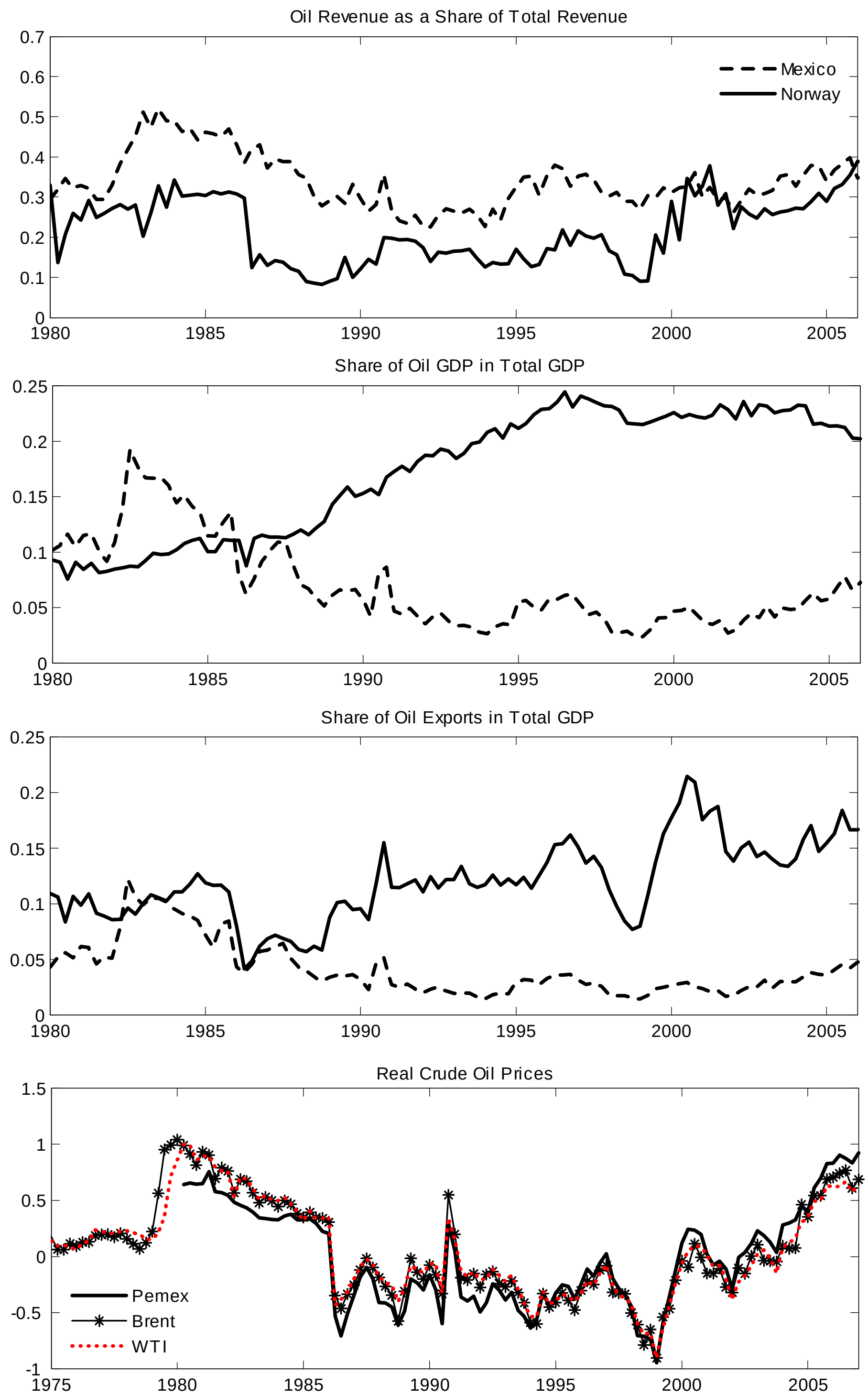


Figure 2: Impulse Responses to a 1 Standard Deviation in Oil Prices: Benchmark VAR, Mexico

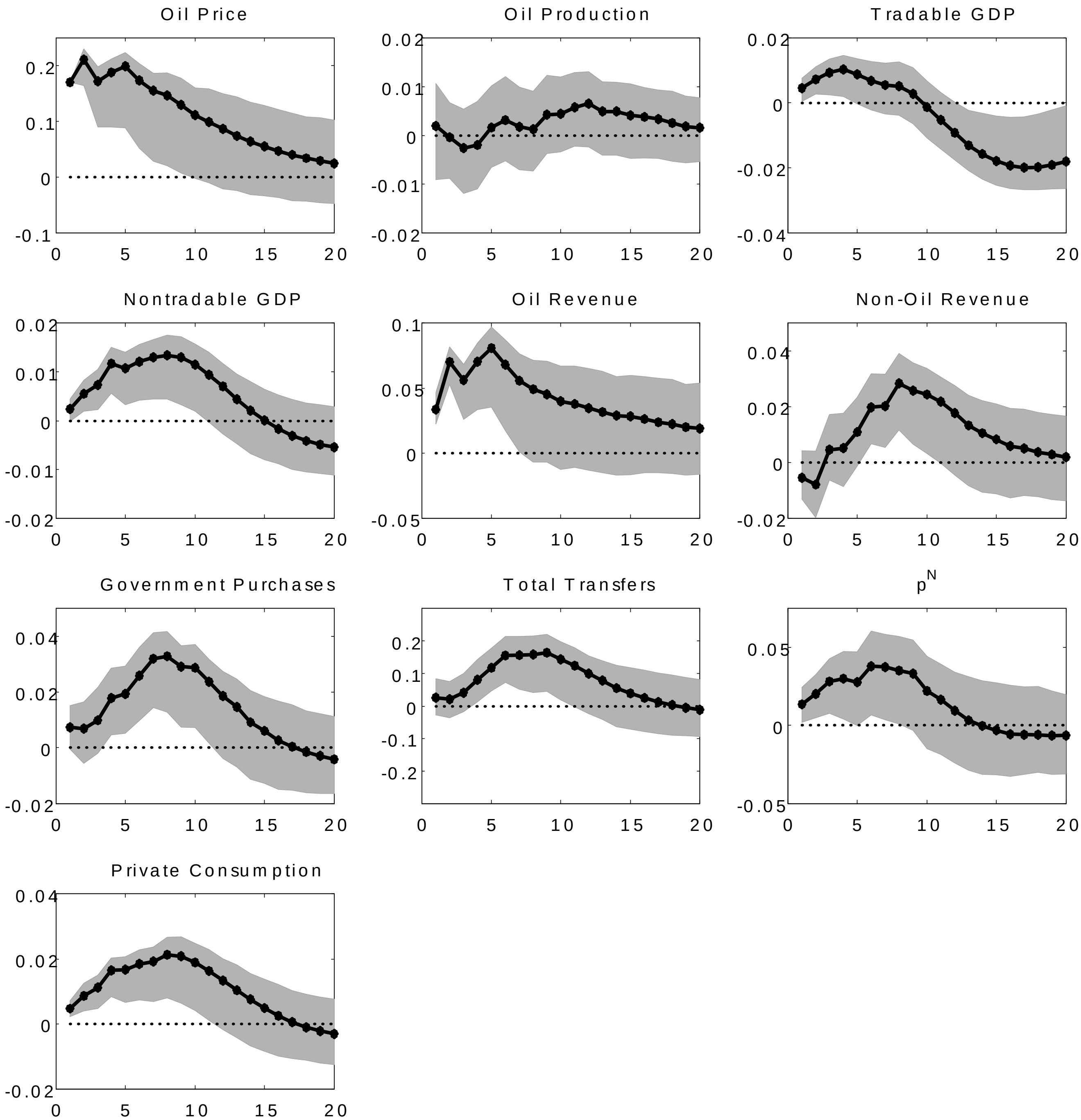


Figure 3: Impulse Responses to a 1 Standard Deviation Increase in Oil Prices: Benchmark VAR, Norway

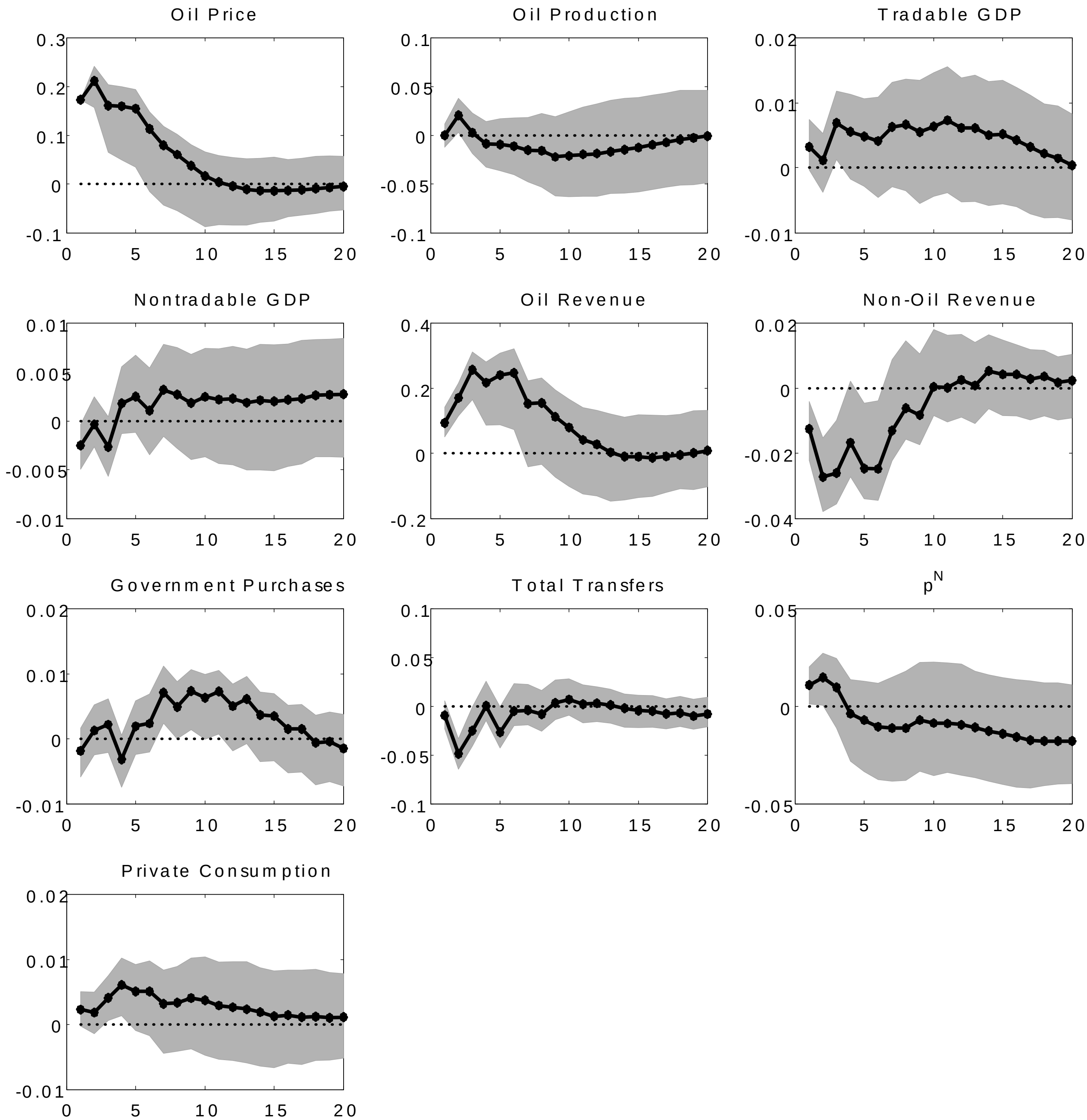


Figure 4: Impulse Responses to a 1 Standard Deviation Increase in Oil Prices

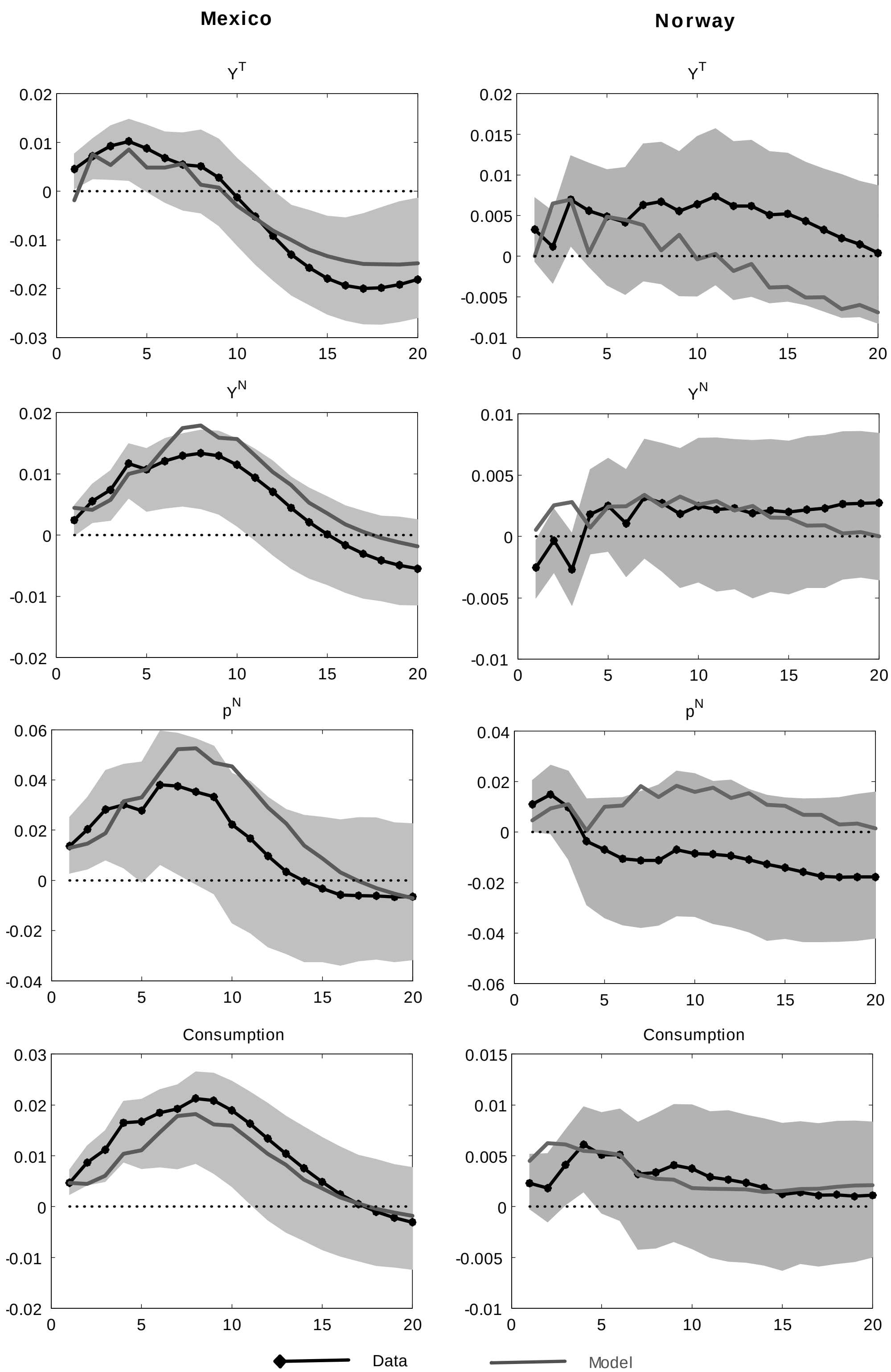


Figure 5: Deconstructing the Model Responses by Feature

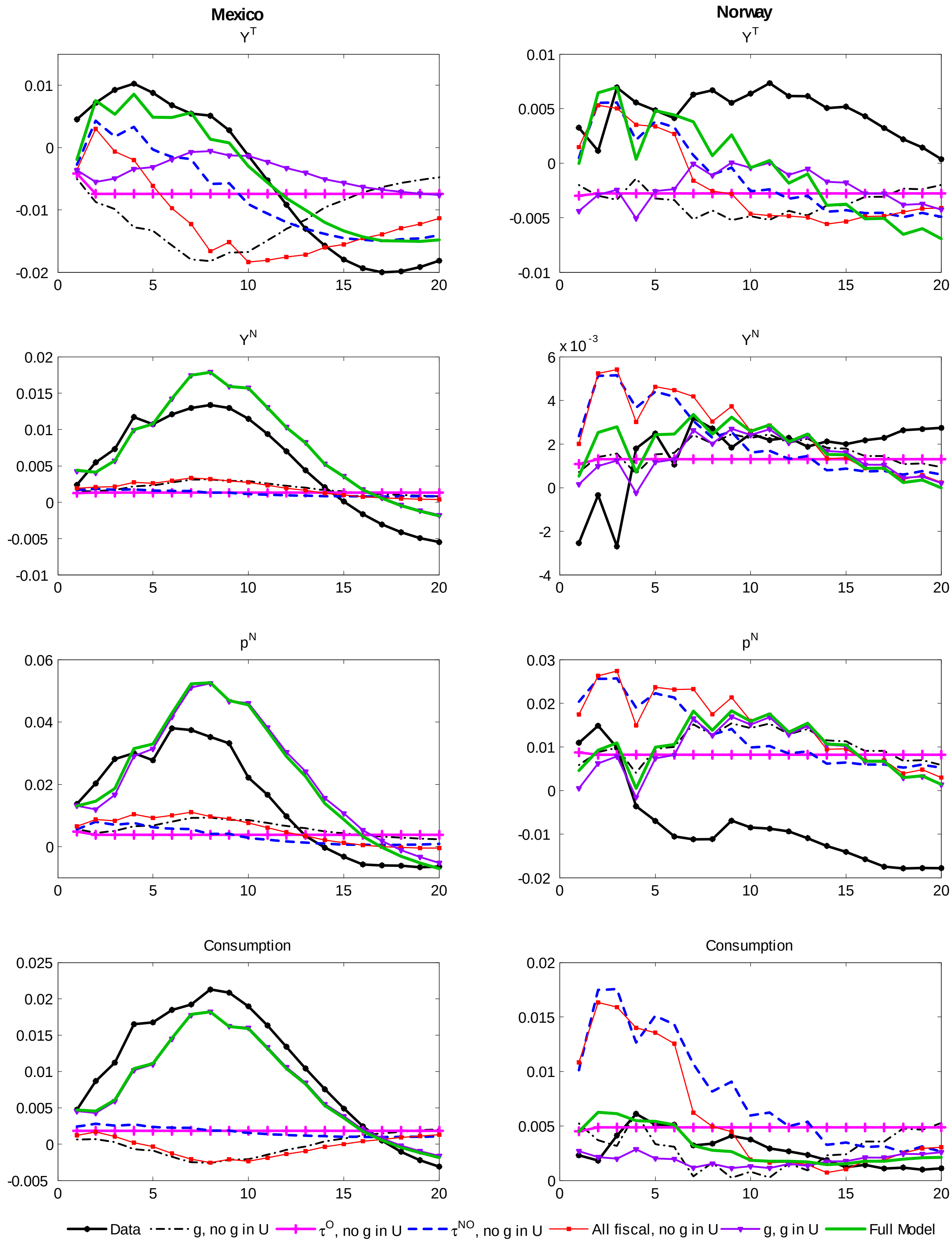


Figure 6: Impulse Responses to a 1 Standard Deviation Increase in Oil Prices: "Mexican-izing" the Fiscal Responses of Norway

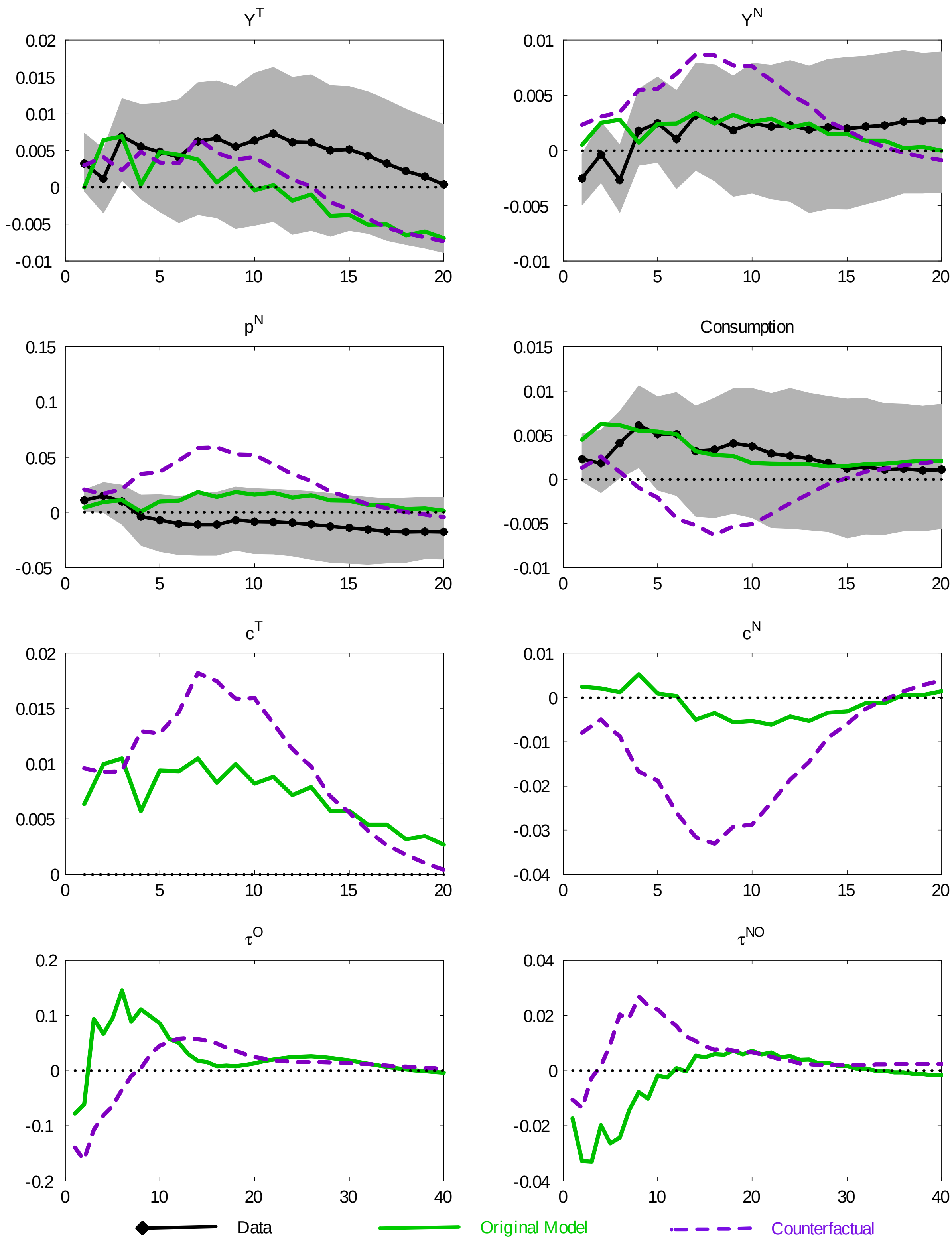


Figure 7: Impulse Responses to a 1 Standard Deviation Increase in Oil Prices: "Norwegianizing" the Fiscal Responses of Mexico

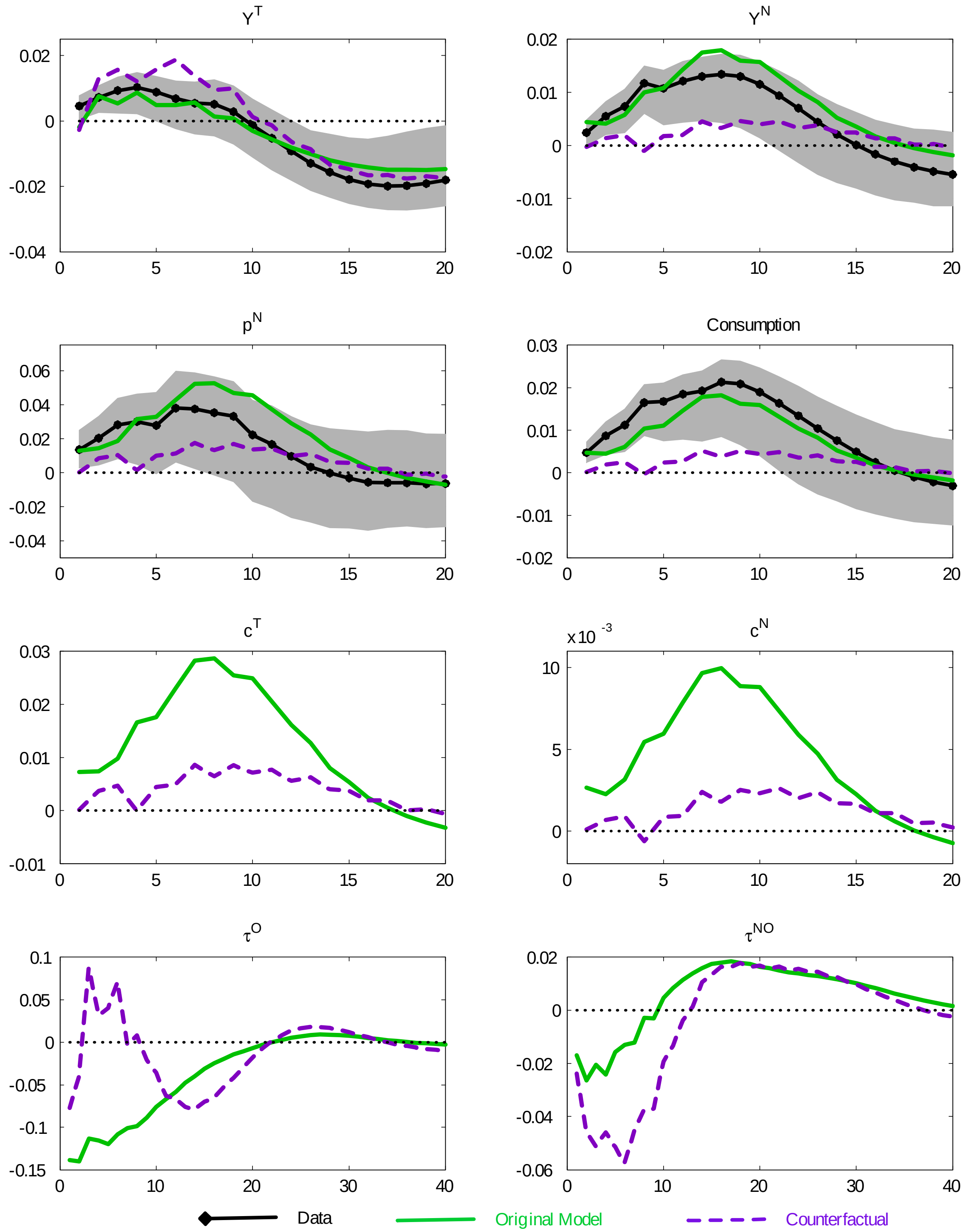


Table 3: Welfare Gain, ξ, of Switching from Own Policy to the Counterfactual, (R to CF)

	ξ	Steady State	Mean	Std Dev	Mean/Steady State
V^{R}_{Mexico}	0	-40.684	-45.918	2.227	1.129
V^{CF}_{Mexico}	0	-40.684	-40.183	0.989	0.988
$\widetilde{V}^{CF}_{Mexico}$	7.572%	-46.394	-45.918	0.975	0.990
V^{R}_{Norway}	0	18.390	22.919	2.464	1.246
V^{CF}_{Norway}	0	18.390	17.752	3.543	0.965
$\widetilde{V}^{CF}_{Norway}$	-14.461%	23.511	22.919	3.308	0.975

A Extensions

It seems natural to consider a richer model where households and firms use oil for consumption and production. Looking in the data, however, there are several interesting facts. First, households and firms consume refined oil products, not crude oil. Second, oil products do not comove with crude oil prices as perfectly as one would think. There are taxes and subsidies that sometimes dampen the correlation between them. Third, and most importantly, expenditures on oil related products account for a small amount of total expenditures for households and firms in all sectors, except transportation. Therefore, adding oil consumption features to the model, and calibrating it to match these stylized facts turns out not to alter the results obtained with the basic model.

For each country, Table 4 reports on the top row the weight of energy expenditure in the total budget of households and firms. In Mexico, there are biannual expenditure surveys for households and firms that facilitate computing these shares. In Norway, unfortunately, there are only household surveys available. Mexican households allocate 9.01 percent of their budget in Housing, Conservation Services, Electricity and Oil Products altogether.[23] In Norway, on the other hand, households allocate 4.53 percent of their budget on energy, most of which (3.82) is spent in electricity. Only 0.32 percent of their budget is spent in liquid fuels. On the firm's side, in Mexico, the manufacturing sector allocates about 2 percent of its budget to oil products, exceeding the share of the budget allocated to this category by retail (0.44 percent), construction (0.4 percent) and other services (1.68 percent).

Table 4 also contains energy use data. Breaking down energy use by sector, in Mexico (Norway), 18.81 (21.64) percent of total energy consumption is done by households, 28.13 (40.7) percent by tradable goods industries, 12.83 (14.24) percent by nontradable goods industries, and 40.25 (23.42) percent by the transportation sector. Within energy consumption, households in Mexico mainly use oil products (41.12 percent) and biomass (41.10 percent, mostly firewood), whereas Norwegian households mainly use electricity (78.41 percent). As for tradable goods firms, in Mexico they mainly use dry gas and oil products (40.69 and 30.4 percent, respectively), while in Norway they mainly consume electricity (59.53 percent). Nontradable goods firms consume similar amounts of electricity and oil products in Mexico (38.76 and 34.3 percent, respectively), while in Norway they mostly consume electricity (74.59 percent). An important caveat for the energy use data in Mexico is that it classifies all vehicles in the transportation sector, so gasoline and diesel

[23] The summary statistics provided by INEGI on consumer survey expenditures merge expenditures on Housing, Conservation Services, Electricity and Oil Products, so this figure provides an upper bound for consumption of oil products.

use would hold a higher share within energy use of households and firms if vehicles were classified by ownership rather than use.

Figure 8 depicts the raw series of crude oil, gasoline and diesel for Mexico and Norway. While the producer price in Mexico comoves strongly with the price of crude oil, the IEPS tax (works like a subsidy) smoothes out the final price of both products, dampening the correlation with the price of crude oil. Norwegian fees, on the other hand, are proportional and do not smooth the final price of gasoline and diesel.

In the lines that follow I consider three extensions. Extension 1 allows for the distribution sector to use fuel as one of its inputs, while leaving the rest of the model unmodified. Extension 2 keeps the distribution sector unmodified, and allows instead for demand of oil-related products by households and firms. Finally, Extension 3 combines Extensions 1 and 2. Note that each extension includes oil-related products rather than crude oil itself, since in reality households and firms do not use unrefined crude oil. For each extension, I calibrate the model to match features regarding energy expenditure and use of the Mexican and the Norwegian economies, and I reestimate the parameters in Θ_2. I find that adding these features to the model does not alter the main findings of the basic model.

To identify the response of fuel prices and quantities (which I denote by p_t^E and E_t, respectively) to an oil price shock, I estimate an accessory VAR, with the same structure as (33), except that $\boldsymbol{x}_t = [p_t^E, E_t]$. For Norway, as before, I use for p^O the nominal Brent crude oil price in dollars, and I obtain the real series by deflating it with the U.S. GDP deflator (base 2000 for consistency with Norwegian data). According to Table 4, diesel is the most used fuel within oil products (across the board), so for p^E I use the nominal final price of diesel deflated by the GDP deflator. For E, I use total deliveries of diesel, in millions of liters, published by Statistics Norway. Due to data availability constraints for the deliveries series, I use quarterly data from 1995 to 2006. For Mexico, as before, I use for p_t^O the nominal oil export price published by PEMEX, and I obtain the real series by deflating it with the U.S. GDP deflator (base 1993 for consistency with Mexican data). As mentioned above, on Table 4, private vehicles are classified in the transportation sector, so gasoline and diesel would hold a higher share within energy consumption of Mexican households and firms if vehicles were classified by ownership rather than use. For p_t^E I use the nominal final price of Magna gasoline (in pesos), deflated by the GDP deflator. Finally, for E_t, I use PEMEX's internal gasoline sales as a proxy for gasoline consumption. This seems like a reasonable proxy, given that PEMEX is the only gasoline supplier in the country, and given that gas station inventories are reportedly minimal. Gasoline price data is available starting in 1993. For consistency with Norway, I use quarterly data from 1995 to 2006. Both VARs use linearly detrended logarithms. Figure 9 shows the impulse responses for this auxiliary VAR in both countries. Neither prices nor quantities respond significantly to the crude oil price shock.

A.1 Extension 1: Fuel in the distribution sector

To get started, in this extension the distribution sector uses nontradable goods and fuel to deliver the wholesale tradable goods to the retailer. Fuel can be thought of as an endowment or an import. Either way, it is an intermediate good that does not create value added. This extension keeps households and firms unmodified.

A.1.1 Distribution sector

Just as in the basic model, for each unit of tradable good put on the shelf, the retailer must use γ units of distribution services, so total distribution services (D_t) are equal to

$$D_t = \gamma c_t^T. \tag{39}$$

Originally, the sector was using a linear technology

$$D_t = X_t^N,$$

where X_t^N denotes the demand for nontradable goods. Now, the technology is a bundle of nontradable goods (X_t^N) and fuel (E_t^D)

$$D_t = \left(X_t^N\right)^{\varsigma} \left(E_t^D\right)^{1-\varsigma}. \tag{40}$$

Therefore, providing distribution services now has the added cost of fuel.[24] Hence, the cost minimization problem faced by this sector is the following:

$$\underset{\left\{X_t^N, E_t^D\right\}}{Min} \quad C\left(p_t^N, p_t^E, D_t\right) = p_t^N X_t^N + p_t^E E_t^D \tag{41}$$

subject to (40), where p_t^E denotes fuel prices.

[24] In the basic model, $\varsigma = 1$, $D_t = X_t^N$, so for simplicity the sector can be eliminated by setting $X_t^N = Y_t^N$.

Solving (41) yields the following conditional factor demands

$$X_t^N\left(p_t^N, p_t^E, D_t\right) = \left(\frac{\varsigma}{1-\varsigma}\frac{p_t^E}{p_t^N}\right)^{1-\varsigma} D_t \tag{42}$$

$$E_t^D\left(p_t^N, p_t^E, D_t\right) = \left(\frac{\varsigma}{1-\varsigma}\frac{p_t^E}{p_t^N}\right)^{-\varsigma} D_t, \tag{43}$$

and the following cost function

$$C\left(p_t^N, p_t^E, D_t\right) = Z\left(p_t^N\right)^{\varsigma}\left(p_t^E\right)^{1-\varsigma} D_t \tag{44}$$

where

$$Z \equiv \left(\frac{\varsigma}{1-\varsigma}\right)^{1-\varsigma} + \left(\frac{1-\varsigma}{\varsigma}\right)^{\varsigma}.$$

As before, the distribution margin (s^d) is defined as the fraction of retail price that exceeds the producers price, so in this case

$$s^d = \frac{\gamma Z\left(p_t^N\right)^{\varsigma}\left(p_t^E\right)^{1-\varsigma}}{1+\gamma Z\left(p_t^N\right)^{\varsigma}\left(p_t^E\right)^{1-\varsigma}}$$

and

$$p_t^T = 1 + \gamma Z\left(p_t^N\right)^{\varsigma}\left(p_t^E\right)^{1-\varsigma}. \tag{45}$$

Note that in the original model $\varsigma = 1$, so the marginal distribution cost is equal to the price of nontradables. Therefore, $s^d = \gamma p_t^N / \left(1+\gamma p_t^N\right)$, and (2) holds.

A.1.2 Market clearing conditions

The demand for oil products in the distribution sector, E_t^D, must equal supply. Hence,

$$E_t^D = E_t. \tag{46}$$

Nontradable goods are still either consumed by households, purchased by the government or used as inputs in the distribution sector. Therefore, the market clearing condition for the nontradable goods sector continues to be given by

$$Y_t^N = c_t^N + g_t^N + X^N.$$

When $\varsigma = 1$, $X^N = \gamma c^T$, and (29) holds. In the more general case, substituting (39) into

(42) yields,

$$X_t^N = \left(\frac{\varsigma}{1-\varsigma} \frac{p_t^E}{p_t^N} \right)^{1-\varsigma} \gamma c^T, \tag{47}$$

so (29) becomes

$$Y_t^N = c_t^N + g_t^N + \left(\frac{\varsigma}{1-\varsigma} \frac{p_t^E}{p_t^N} \right)^{1-\varsigma} \gamma c_t^T. \tag{48}$$

Since E_t is tradable, the market clearing condition for the tradable sector is given by

$$Y_t^T + p_t^O Y_t^O + r f_t = c_t^T + g_t^T + I_t + (f_{t+1} - f_t) + p_t^E E_t. \tag{49}$$

The market clearing conditions for labor (30) and capital (15) remain unchanged.

A.1.3 Calibration and estimation

There is only one new parameter in this extension, ς, which I set equal to 0.4 for both countries. It is higher than the value reported for Mexico in Table 4 (30.47 per cent), but in a sense I want to be generous with this share and give the model a chance to show some action beyond that generated by the original model. I have no survey data available for Norway, so this is just an educated guess. Without loss of generality, the steady state levels of p^E and E are normalized to 1, and γ is recalculated so that it is still consistent with the distribution margin seen in the data for each country. The estimation strategy for Θ_2 is the same as before.

A.1.4 Consequences of a positive oil price shock

Figure 10 depicts the responses for the main variables of interest in Mexico and Norway, and it compares the responses obtained from the extension with those of the original model. Note that the original model and the extension deliver tremendously similar responses. The fact that the estimated parameters only adjust moderately in order to continue to match the data responses reflects little value added provided by the extension.

A.2 Extension 2: Households and firms using oil products

Instead of modifying the distribution sector, assume now that firms use oil products as input for production, and households use it as intermediate tradable consumption. Once again, oil products are intermediate goods, therefore, they do not generate any value added.

A.2.1 Distribution sector

In this case the distribution sector does not use oil products, so (2) holds.

A.2.2 Tradable production

Production of tradable goods (Q_t^T) now requires an additional input, E_t^T, which is an imperfect substitute of value added Y_t^T, which is still defined as in (4).

$$Q_t^T = \left[e^T \left(E_t^T \right)^{\frac{\rho^T - 1}{\rho^T}} + \left(1 - e^T \right) \left(Y_t^T \right)^{\frac{\rho^T - 1}{\rho^T}} \right]^{\frac{\rho^T}{\rho^T - 1}} ; \quad e^T \in (0,1) ; \quad \rho^T \geq 0, \tag{50}$$

Profits are now defined as

$$\Pi_t^T = \left(1 - \tau_t^{NO} \right) Q_t^T - w_t L_t^T - r_t^K K_t^T - p_t^E E_t^T . \tag{51}$$

The first order conditions associated to this problem are:

$$\left[K_t^T \right] \; : \; r_t^K = \left(1 - \tau_t^{NO} \right) (1 - \alpha) \left(1 - e^T \right) \left(\frac{Y_t^T}{K_t^T} \right) \left(\frac{Q_t^T}{Y_t^T} \right)^{\frac{1}{\rho^T}} \tag{52}$$

$$\left[L_t^T \right] \; : \; w_t = \left(1 - \tau_t^{NO} \right) \alpha \left(1 - e^T \right) \left(\frac{Y_t^T}{L_t^T} \right) \left(\frac{Q_t^T}{Y_t^T} \right)^{\frac{1}{\rho^T}} \tag{53}$$

$$\left[E_t^T \right] \; : \; p_t^E = \left(1 - \tau_t^{NO} \right) e^T \left(\frac{Q_t^T}{E_t^T} \right)^{\frac{1}{\rho^T}} \tag{54}$$

The intuition with respect to the basic model remains unchanged, after-tax marginal products equal factor prices. The only novelty is that marginal products now depend on the share oil products in gross output.

A.2.3 Nontradable production

Similarly, production of nontradable goods (Q_t^N) now requires the use of oil-related products. As in the other sector, E_t^N, is an imperfect substitute of value added Y_t^N.

$$Q_t^N = \left[e^N \left(E_t^N \right)^{\frac{\rho^N - 1}{\rho^N}} + \left(1 - e^N \right) \left(Y_t^N \right)^{\frac{\rho^N - 1}{\rho^N}} \right]^{\frac{\rho^N}{\rho^N - 1}} ; \quad e^N \in (0,1) ; \quad \rho^N \geq 0, \tag{55}$$

where Y_t^N is defined as in (8).

Profits are now defined as

$$\Pi_t^N = \left(1 - \tau_t^{NO}\right) p_t^N Q_t^N - w_t L_t^N - r_t^K K_t^N - q_t S - p_t^E E_t^N . \tag{56}$$

The first order conditions associated to this problem are:

$$\left[K_t^N\right] \quad : \quad r_t^K = \left(1 - \tau_t^{NO}\right)\left(1 - e^N\right) p_t^N \nu \left(1 - \eta\right) \left(Y_t^N\right)^{\frac{1}{\rho}} \left(\frac{Q_t^N}{Y_t^N}\right)^{\frac{1}{\rho^N}} \frac{\left[A^N \left(K_t^N\right)^{1-\eta} \left(L_t^N\right)^{\eta}\right]^{\frac{\rho-1}{\rho}}}{K_t^N} \tag{57}$$

$$\left[L_t^N\right] \quad : \quad w_t = \left(1 - \tau_t^{NO}\right)\left(1 - e^N\right) p_t^N \nu \eta \left(Y_t^N\right)^{\frac{1}{\rho}} \left(\frac{Q_t^N}{Y_t^N}\right)^{\frac{1}{\rho^N}} \frac{\left[A^N \left(K_t^N\right)^{1-\eta} \left(L_t^N\right)^{\eta}\right]^{\frac{\rho-1}{\rho}}}{L_t^N} \tag{58}$$

$$[S] \quad : \quad q_t = \left(1 - \tau_t^{NO}\right)\left(1 - e^N\right) p_t^N \left(1 - \nu\right) \left(\frac{Q_t^N}{Y_t^N}\right)^{\frac{1}{\rho^N}} \left(\frac{Y_t^N}{S}\right)^{\frac{1}{\rho}} \tag{59}$$

$$\left[E_t^N\right] \quad : \quad p_t^E = \left(1 - \tau_t^{NO}\right) e^N p_t^N \left(\frac{Q_t^N}{E_t^N}\right)^{\frac{1}{\rho^N}} \tag{60}$$

A.2.4 Households

Households still attain utility from consuming tradable and nontradable goods, so (12), (13), (14) continue to hold. Since oil products are tradable, c_t^T now becomes a bundle of oil products (c_t^E) and non-oil-related goods (c_t^{NE}):

$$c_t^T = \left(c_t^E\right)^{\theta^T} \left(c_t^{NE}\right)^{1-\theta^T} . \tag{61}$$

The budget constraint now accounts for spending on oil products,

$$\Upsilon_t \geq p_t^T c_t^{NE} + p_t^E c_t^E + p_t^N c_t^N + I_t + \left(a_{t+1} - a_t\right),$$

where

$$\Upsilon_t = w_t L_t + r_t^K K_{t-1} + q_t S + \left(1 - \tau_t^O\right) p_t^O Y_t^O + r a_t + v_t - \tau_t^L$$

The first order conditions associated to this problem are:

$$\left[c_t^{NE}\right] \quad : \quad \lambda_t p_t^T = \theta \left(1 - \theta^T\right) \phi \left(\frac{c_t}{c_t^{NE}}\right) \left(\frac{\tilde{c}_t}{c_t}\right)^{\frac{1}{\varkappa}} \left[\tilde{c}_t - \psi L_t^{\varpi}\right]^{-\sigma} \tag{62}$$

$$\left[c_t^E\right] \quad : \quad \lambda_t p_t^E = \theta \theta^T \phi \left(\frac{c_t}{c_t^E}\right) \left(\frac{\tilde{c}_t}{c_t}\right)^{\frac{1}{\varkappa}} \left[\tilde{c}_t - \psi L_t^{\varpi}\right]^{-\sigma} \tag{63}$$

$$\left[\lambda_t\right] \quad : \quad \Upsilon_t = p_t^T c_t^{NE} + p_t^E c_t^E + p_t^N c_t^N + \left(K_t - \left(1 - \delta^k\right) K_{t-1}\right) + a_{t+1} - a_t \tag{64}$$

Equations (19), (20), (22) and(23) remain unchanged.

A.2.5 Market clearing conditions

The demand for oil products from households and firms must equal the supply,

$$c_t^E + E_t^T + E_t^N = E_t. \tag{65}$$

The market clearing condition for the tradable sector is given in this case by

$$Y_t^T + p_t^O Y_t^O + r f_t = c_t^{NE} + g_t^T + I_t + (f_{t+1} - f_t) + p_t^E E_t. \tag{66}$$

The market clearing conditions for the nontradable sector (29), labor (30) and capital (15) continue to hold.

A.2.6 Calibration

The parameters added in this extension are $\left(e^T, e^N, \rho^T, \rho^N, \theta^T\right)$. According to Table 4, tradable and nontradable firms allocate in Mexico a negligible amount of their spending to oil products (1.99 percent in the tradable sector, and a similar amount in the nontradable sector: 0.44 percent in retail, 3 percent in construction and 1.22 percent in services). This is somewhat deceiving, though, because the survey collects all public and private vehicles under Transportation, instead of adding vehicle fuel expenditures to the total oil products expenditures by households and firms. From a modeling perspective, it is unclear that this classification is unhelpful, at least for firms. Vehicle use in some subsectors may be more of an operational cost rather than an actual production cost. For households, of course, it is a different matter; it is intermediate consumption. Therefore, I give the model extra room by assuming that e^T and e^N are equal to ten percent, and I also set θ^T equal to 0.1, exceeding the upper bound provided by the 9.01 percent expenditure share reported by INEGI for expenditures on housing, conservation services, electricity and oil products (See Table 4).

In Norway, (as shown in Table 4) households allocate about 0.32 percent of their total budget to liquid fuels, as most of their energy costs stem from electricity. In order to address the same problem as in Mexico regarding the classification of vehicles under Transportation I set θ^T equal to 5 percent.[25] For firms, unfortunately, there is no equivalent survey that would allow me to uncover shares of oil products expenditure in overall expenditure. Even though electricity is clearly the most popular source of energy across the board, data on

[25] According to the consumer expenditure survey, Norwegian households allocate 3.06 percent of their budget to transport services by railway (0.39), road (0.73), air (0.62), sea and inland waterway (0.3), and other services (1.02).

energy consumption by product is about volumes, not values, so it is hard to infer from it a sensible value for e^T and e^N. For instance, even though fuel only accounts for 18.38 percent of overall energy consumption in the tradable sector, its price could *in principle* be high enough to make the expenditure on fuel higher than that of electricity. Therefore, just to be safe, I set e^T and e^N equal to 0.1. Finally, for both countries, I set ρ^T and ρ^N equal to 0.9, to reflect the low short-term elasticity between value added and oil products.

A.2.7 Consequences of a positive oil price shock

Figure 11 shows the responses for the main variables of interest in Mexico and Norway, and it compares the responses obtained from the extension with those of the original model. Once again, they are very similar, and the estimated parameters adjust moderately in order to continue to match the data responses. This minor variation highlights the little value added provided by the extension.

A.3 Extension 3: Oil products in distribution, production and consumption

If oil products are used in all sectors, then (45) holds, and the problems of the firms and households are as in Extension 2.

A.3.1 Market clearing conditions

In this case, the demand of oil products comes from four sources: households, the two types of production and the distribution sector. Hence,

$$c_t^E + E_t^T + E_t^N + E_t^D = E_t. \tag{67}$$

The market clearing conditions for the tradable and nontradable sector, labor and capital are given by (66), (48), (30) and (15), respectively.

A.3.2 Calibration

The parameters $\{\varsigma, e^T, e^N, \rho^T, \rho^N, \theta^T\}$ are calibrated as in Extensions 1 and 2.

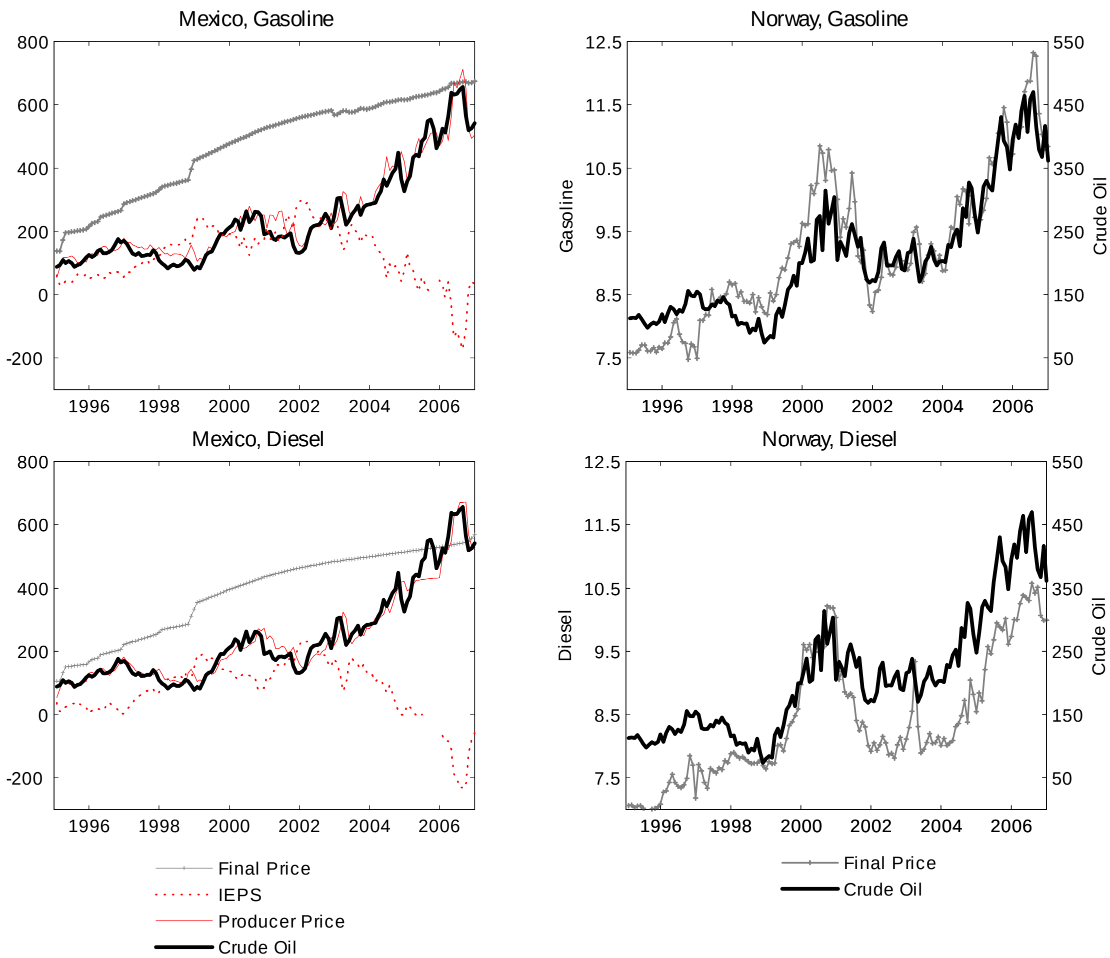
A.3.3 Consequences of a positive oil price shock

Figure 12 shows the responses for the main variables of interest in Mexico and Norway, and it compares the responses obtained from the extension with those of the original model.

Note that once more, the responses are very similar to those obtained with the basic model.

A.4 Tables and Figures

Figure 8: Crude Oil, Gasoline and Diesel Prices, Mexico and Norway



Note: IEPS stands for Impuesto Especial sobre Produccion y Servicios (Special Tax on Production and Services). Mexican gasoline and diesel prices in tens of pesos per cubic meter, crude oil in pesos per barrel. Norwegian gasoline and diesel prices in krone per liter, crude oil in krone per barrel.

Table 4: Energy Consumption, Mexico and Norway

Mexico	Residential	Transp.	Y^T Total	Y^T Manuf.	Y^T Mining	Y^T Agric. & Fishing	Y^N Total	Y^N Retail	Y^N Constr.	Y^N Services & other
Energy Expenditure / Total Expenditures	9.01*									
Electricity		0.39[a]		1.95[b]				0.44[c]	0.40[d]	1.68[e]
Oil Products		30.47[a]		1.99[b]				0.34[c]	3.00[d]	1.22[e]
Share of Total Energy Consumption [f]	18.81	40.25	28.13	23.57	1.50	3.06	12.82	2.85	0.17	9.79
Energy Consumption By Product [f]										
Coal, Coke & Biomass	41.10		16.85	20.10	2.54		0.91			1.16
Dry Gas	3.72	0.01	40.69	46.08	38.59		25.93	3.34		33.74
Electricity	13.96	0.22	12.06	9.39	32.95	22.53	38.76	34.59	20.75	40.65
Oil Products	41.12	99.77	30.40	24.43	25.92	77.47	34.30	61.67	79.25	24.44
Solar	0.09						0.09	0.39		0.01
Oil Products Breakdown [f]										
Liquefied Gas	94.12	2.19	3.01	1.90	10.31	3.78	37.77	66.37		21.92
Kerosene	5.88	6.12	3.03	0.00		11.32	2.31			5.42
Diesel		27.40	31.78	8.08	44.00	84.90	21.22	6.76	100.00	28.33
Fuel oil		0.78	62.18	90.01	45.69		38.70	26.87		44.33
Gasoline		63.50								

Norway	Residential	Transp.	Y^T Total	Y^T Manuf. & Mining	Y^T Agric. & Fishing	Y^N Total	Y^N Constr.	Y^N Services
Energy Expenditure / Total Expenditures	4.53[g]	n.a.	n.a.			n.a.		
Electricity	3.82[g]							
Solid Fuels	0.39[g]							
Liquid Fuels	0.32[g]							
Share of Total Energy Consumption [h]	21.64	23.42	40.70	36.47	4.23	14.24	1.01	13.23
Energy Consumption By Product [h]								
Coal, Coke & Biomass	15.67		13.76	15.73	0.36	0.53	1.65	0.42
Dry Gas	0.09	1.09	7.78	8.59	2.26	1.30	0.37	1.39
Electricity	78.41	1.20	59.53	64.96	22.52	74.59	35.05	78.19
Oil Products	4.22	97.71	18.38	10.09	74.81	16.52	62.92	12.28
District Heating	1.62	0.00	0.44	0.50	0.05	7.07	0.00	7.71
Oil Products Breakdown [h]								
Liquefied Gas	3.11	0.02	11.55	20.44	0.45	3.23	9.08	1.09
Kerosene	42.02	7.20	0.15	0.13	0.17	13.74	0.51	17.94
Diesel	48.71	50.23	67.13	43.08	97.74	81.97	90.10	79.62
Fuel oil	0.08	1.03	20.80	36.34	0.81	0.98	0.08	1.34
Gasoline	6.08	41.52	0.37		0.83	0.07	0.23	0.02

∗ Expenditures on Housing, Conservation Services, Electricity and Oil Products, National Survey of Consumer Expenditures and Revenue, average 1992-2006, National Institute of Statistics, Geography, and Informatics of Mexico (INEGI). *a.* Annual Transportation Survey 2007, INEGI. *b.* Annual Industrial Activity Survey, INEGI, 205 classes of manufacturing activity, average 2000-2006. *c.* Annual Commerce Survey, INEGI, average 2003-2007. *d.* Annual Survey Construction Companies, 2007, INEGI (previous surveys lack breakdown). *e.* Annual Survey of Private Non-financial Services, INEGI, average 2003-2007. *f.* Secretaria de Energia, Mexico, average 1980-2006. *g.* Annual Consumer Expenditures Survey, Statistics Norway (SSB), average 1997-2006. *h.* Energy Balance, Statistics Norway (SSB), average 1980-2006.

Figure 9: Impulse Responses to a 1 Standard Deviation in the Price of Crude Oil, Auxiliary VARs Mexico and Norway

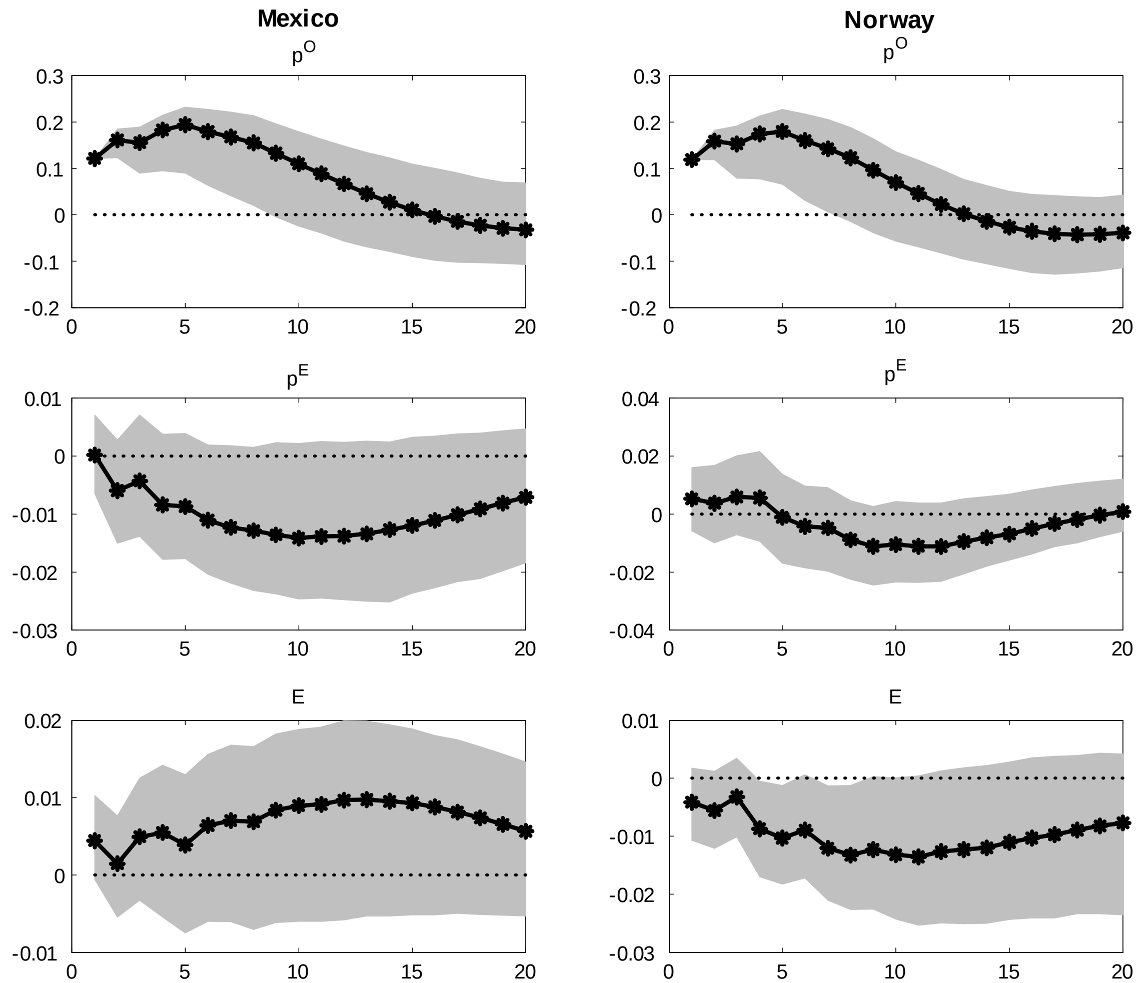


Figure 10: Comparing Impulse Responses: Extension 1 vs. Original Model

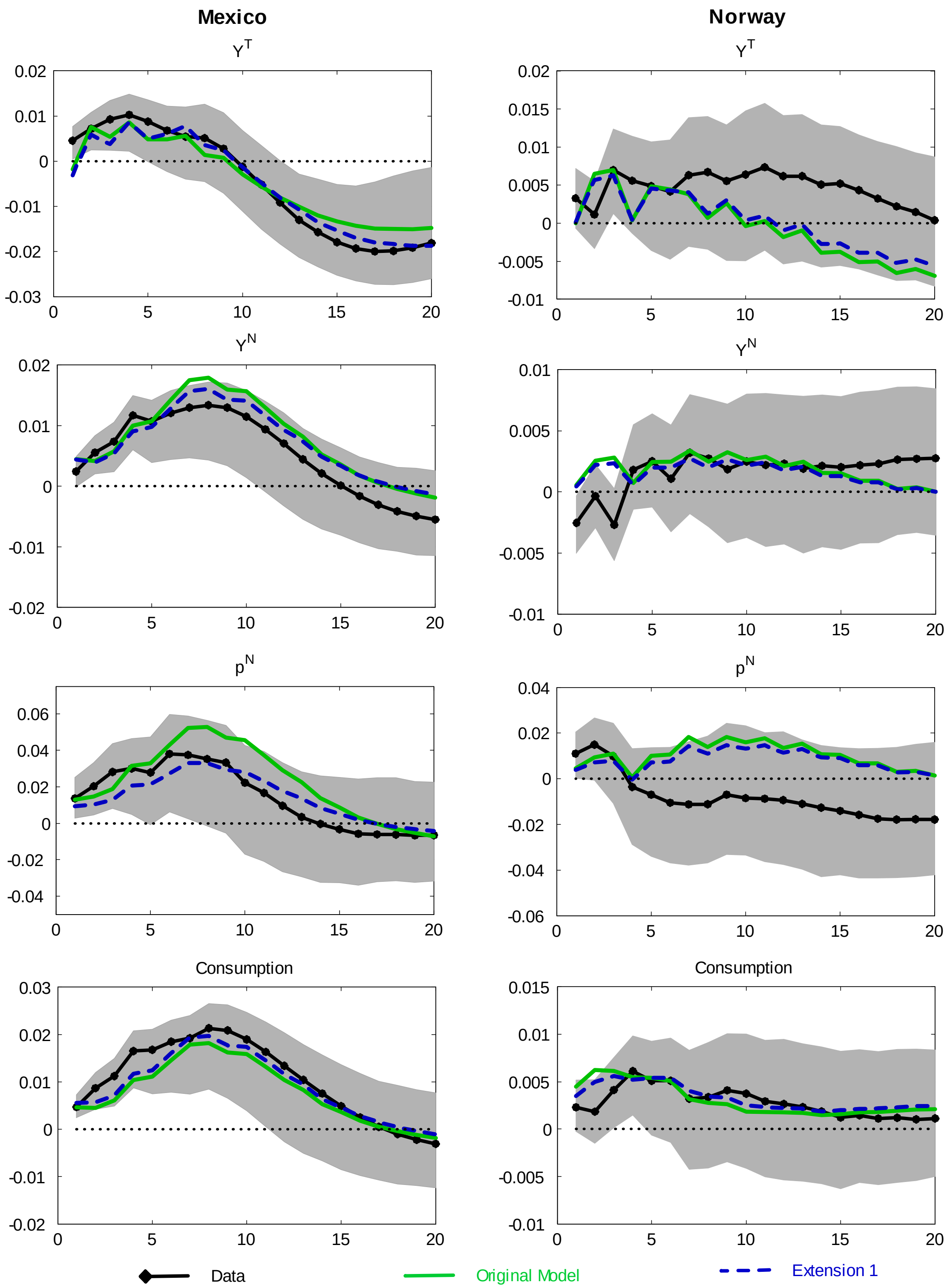


Figure 11: Comparing Impulse Responses: Extension 2 vs. Original Model

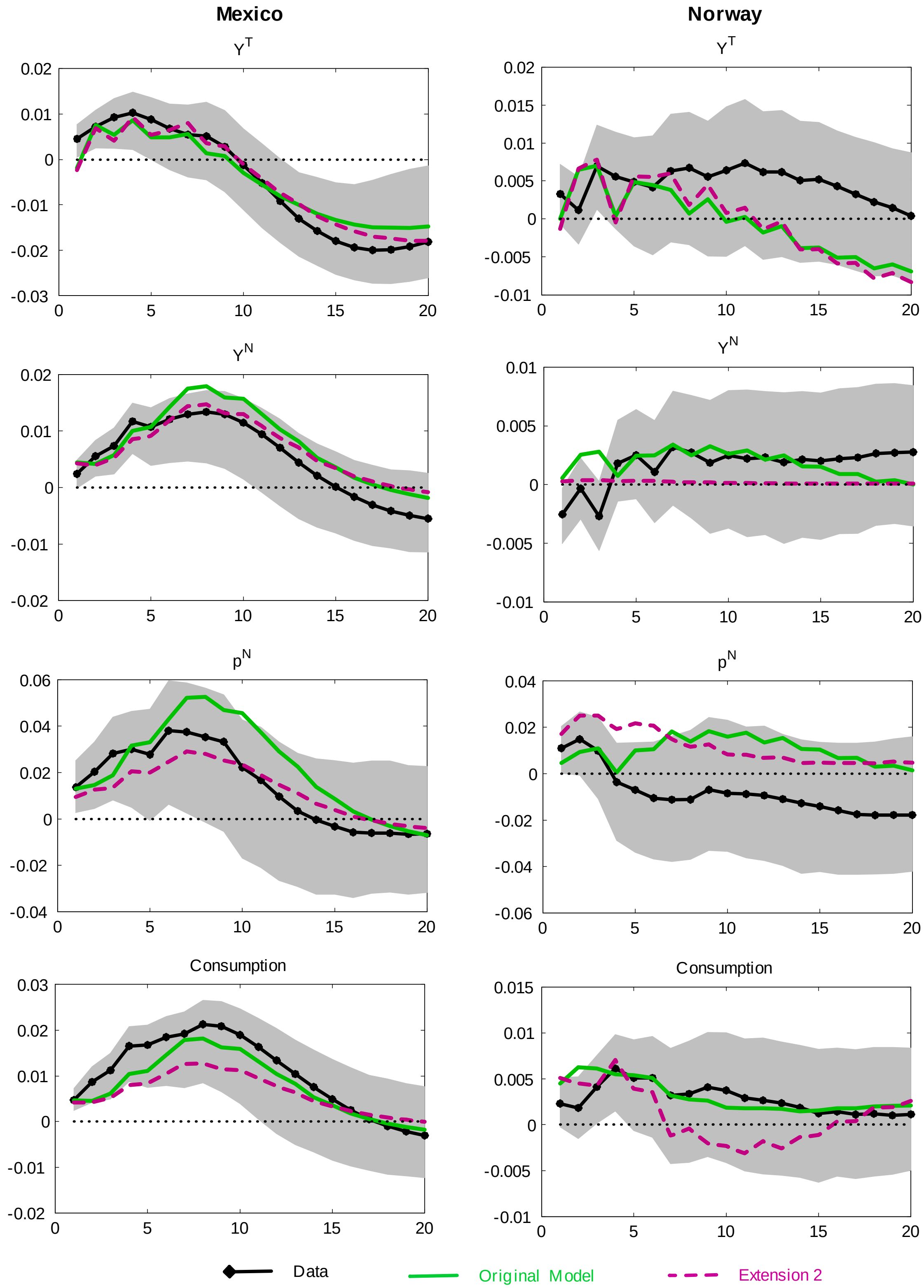


Figure 12: Comparing Impulse Responses: Extension 3 vs. Original Model