Not-For-Publication Appendix:
Monetary Policy Responses to Oil Price Fluctuations

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1 Model Description

This appendix provides a full description of the model used in the analysis.

1.1 Households and Firms

The preferences of the representative household are given by:

\[
E_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma_1} \left( Z_{1,t}^c C_{1,t+j} - \kappa_1 C_{1,t+j-1}^A \right)^{1-\sigma_1} + \frac{\chi_{0,1}}{1-\chi_1} (1 - L_{1,t+j})^{1-\chi_1} \right\}. \tag{1}
\]

The variables \( C_{1,t} \) and \( L_{1,t} \) represent consumption and hours worked, respectively. The term \( Z_{1,t+j}^c \) models a preference shock to consumption. In addition, a household’s utility from consumption is affected by the presence of external consumption habits, parameterized by \( \kappa_1 \). \( C_{1,t-1}^A \) is the per capita aggregate consumption level.

The time \( t \) budget constraint of the household states that:

\[
P_{1,t}^c C_{1,t} + P_{1,t}^i I_{1,t} + \frac{e_{1,t} P^b_{2,t} B_{1,t}}{\phi^b_{1,t}} + \int_S P^d_{1,t,t+1} D_{1,t,t+1}(h) - D_{1,t-1,t} = W_{1,t} L_{1,t} + R^k_{1,t} K_{1,t-1} + \Gamma_{1,t} + P_{1,t}^o Y_{1,t}^o + T_{1,t} + e_{1,t} B_{1,t-1}. \tag{2}
\]

Final consumption and investment goods, \( C_{1,t} \) and \( I_{1,t} \), are purchased at the prices \( P_{1,t}^c \) and \( P_{1,t}^i \), respectively. The household earns labor income \( W_{1,t} L_{1,t} \) and capital income \( R^k_{1,t} K_{1,t-1} \). The household also receives an aliquot share \( \Gamma_{1,t} \) of firm and union profits, a share of the country’s (unrefined) oil endowment \( P_{1,t}^o Y_{1,t}^o \), and net transfers of \( T_{1,t} \).

Households accumulate financial assets by purchasing state-contingent domestic bonds, and a non state-contingent foreign bond. The state contingent domestic bonds are denoted by \( D_{1,t,t+1} \). The term \( B_{1,t+1} \) in the budget constraint represents the quantity of the non state-contingent bond purchased by a typical household that pays one unit of foreign currency in the subsequent period, \( P_{2,t}^b \) is the foreign currency price of the bond, and \( e_{1,t} \) is the exchange rate expressed in units of home currency per unit of foreign currency. \( \phi^b_{1,t} \) captures intermediation costs incurred to purchase the foreign bond and render the dynamics of \( B_{1,t+1} \) stationary.
The evolution of the capital stock follows:

\[ K_{1,t} = (1 - \delta_1) K_{1,t-1} + Z_{1,t}^i I_{1,t} \left( 1 - \frac{1}{2} \psi^i_1 \left( \frac{I_{1,t}}{I_{1,t-1}} - \mu_z \right)^2 \right), \]  

(3)

where \( \delta_1 \) is the depreciation rate of capital. For \( \psi^i_1 > 0 \), changing the level of gross investment from the previous period is costly, so that the acceleration in the capital stock is penalized. The term \( Z_{1,t}^i \) captures an investment-specific technology shock. \( \mu_z \) is the deterministic growth rate of labor augmenting technological change discussed below.

In every period \( t \), household \( h \) maximizes the utility functional (1) with respect to consumption, labor supply, investment, end-of-period capital stock, and holdings of domestic and foreign bonds, subject the budget constraint (2), and the transition equation for capital (3).

**Labor Bundling**

Households supply their homogenous labor to intermediate labor unions. These unions introduce distinguishing characteristics on the labor services and resell them to intermediate labor bundlers. The unions use Calvo contracts to set the wages charged to the intermediate bundlers. In turn, firms purchase a labor bundle \( L_{1,t}^d \) from the labor bundlers.

The labor bundle demanded by firms takes the from:

\[ L_{1,t}^d = \left[ \int_0^1 L_{1,t}(h) \theta^w_{1,t} dh \right]^{\frac{1}{1+\theta^w_{1,t}}}, \]  

(4)

where \( \theta^w_{1,t} \) is time-varying reflecting shocks to the wage markup.

The labor bundlers buy the labor services \( L_{1,t}(h) \) from unions, combine them to obtain \( L_{1,t}^d \), and resell them to the intermediate goods producers at wage \( W_{1,t} \). In a perfectly competitive environment, profit maximization by the bundlers implies:

\[ L_{1,t}(h) = \left[ \frac{W_{1,t}(h)}{W_{1,t}} \right]^{\frac{1+\theta^w_{1,t}}{\theta^w_{1,t}}} L_{1,t}^d, \]  

(5)

and the zero-profit condition yields:

\[ W_{1,t} = \left[ \int_0^1 W_{1,t}(h) \frac{1}{\theta^w_{1,t}} dh \right]^{-\theta^w_{1,t}}. \]  

(6)
Labor bundlers purchase labor from the unions that intermediate between the households and the labor bundlers. The unions allocate and differentiate the labor services from the households and choose a wage subject to the labor demand equation. Labor unions take the real wage desired by the household, \( W_{1,t+j}^f + \xi_1^w \), as the cost of labor services. In the spirit of Calvo, a union can readjust a wage with probability \( 1 - \xi_1^w \) in each period. For those unions which cannot adjust wages in a given period, wages grow by a geometric average of last period’s nominal wage inflation and the wage inflation rate along the balanced growth path. The problem of a union \( h \) is given by:

\[
\max_{W_t(h)} \sum_{j=0}^{\infty} (\xi_1^w)^j \psi_{t,t+j} \left[ (1 + \tau_1^w) \omega_t^j W_t(h) L_{t+j}(h) - W_{t+j}^f L_{t+j}(h) \right] \\
\text{s.t.} \\
L_{1,t}(h) = \left[ \frac{W_{1,t}(h)}{W_{1,t}} \right]^{-\frac{1+\theta_1^p}{\theta_1^d}} L_{1,t}^d, \\
\omega_{t,j}^j = \prod_{s=1}^j \left\{ (\omega_{t-1+s}^j)^t \pi^* \right\}^{1-t}\pi^* \right\}.
\]

The subsidy \( \tau_1^w \) guarantees the efficient level of labor supply along the balanced growth path.

**Bundlers of Varieties**

A continuum of representative bundlers combines differentiated intermediate products into a composite home-produced good \( Y_{1,t} \) according to:

\[
Y_{1,t}^d = \left[ \int_0^1 Y_{1,t}^d (i) \frac{1}{1+\theta_1^p} \, di \right]^{1+\theta_1^p} L_{1,t}^d.
\]

where \( Y_{1,t}^d \) is used as the domestic input in producing all final use goods, including exports. One unit of the sectoral output index sells at the price:

\[
P_{1,t}^d = \left[ \int_0^1 P_{1,t}^d (i) \frac{1}{1+\theta_1^p} \, di \right]^{-\theta_1^p}.
\]

Under producer currency pricing, the exports sell at the foreign price \( P_{2,t}^m = P_{1,t}^d / e_{1,t} \).

**Production of Domestic Intermediate Goods**

There is a continuum of differentiated intermediate goods indexed by \( i \in [0, 1] \), each of which is produced by a single monopolistically competitive firm.
Firm $i$ faces a demand function:

$$Y_{1,t}(i) = \left[\frac{P_{1,t}(i)}{P_{d}^{1}}\right]^{\frac{1}{\theta_{1,t}^{P}}} Y_{1,t}^{d},$$

where $\theta_{1,t}^{P} > 0$ is time-varying in order to allow for price mark-up shocks.

The production technology of each firm is a nested CES production function. The cost minimization problem is given by:

$$\min_{K_{1,t-1}(i),L_{1,t}(i),O_{1,t}(i)\forall i} R_{1,t} \left( K_{1,t-1}^{s}(i) \right) + W_{1,t} L_{1,t}(i) + P_{1,t}^{o} O_{1,t}(i)$$

s.t.

$$Y_{1,t}(i) = \left( (\omega_{1}^{K})^{\frac{\rho_{1}^{o}}{1+\rho_{1}^{o}}} (V_{1,t}(i))^{\frac{1}{1+\rho_{1}^{o}}} + (\omega_{1}^{o})^{\frac{\rho_{1}^{o}}{1+\rho_{1}^{o}}} (\mu_{2,1} Z_{1,t}^{o} O_{1,t}(i))^{\frac{1}{1+\rho_{1}^{o}}}) \right)^{1+\rho_{1}^{o}}$$

$$V_{1,t}(i) = \left( (\omega_{1}^{K})^{\frac{\rho_{1}^{o}}{1+\rho_{1}^{o}}} (K_{1,t}^{s}(i))^{\frac{1}{1+\rho_{1}^{o}}} + (\omega_{1}^{L})^{\frac{\rho_{1}^{o}}{1+\rho_{1}^{o}}} (\mu_{2,1}^{L} Z_{1,t}^{o} L_{1,t}(i))^{\frac{1}{1+\rho_{1}^{o}}}) \right)^{1+\rho_{1}^{o}}.$$  

Utilizing capital $K_{1,t}^{s}(i)$ and labor services $L_{1,t}(i)$, the firm produces a value-added input $V_{1,t}(i)$, which is then combined with oil $O_{1,t}(i)$ to produce the domestic nonoil variety $Y_{1,t}(i)$. The term $Z_{1,t}^{o}$ represents a stochastic process that influences the oil intensity in production while $\mu_{2,1}^{L}$ denotes a constant rate of oil efficiency gains.

The prices of intermediate goods $P_{1,t}(i)$ are determined by Calvo-style staggered contracts, see Calvo (1983) and Yun (1996) with reoptimization probability, $1 - \xi_{1}^{P}$. The probabilities are constant and independent across firms, time, and countries. Firms that do not reoptimize their price partially index it to the inflation rate in the aggregate price $P_{1,t}^{d}$. The indexation scheme for prices is analogous to that for wages in Equation (9) with indexation weight $\nu^{P}$.

Production of Consumption Goods

The consumption basket $C_{1,t}$ that enters the household’s budget constraint is produced by perfectly competitive consumption distributors whose production function mirrors the
preferences of households over home and foreign nonoil goods and oil:

$$\min_{C^{d}_{1,t}, M^{i}_{1,t}, C^{ne}_{1,t}, O_{1,t}} \quad P^{d}_{1,t}C^{d}_{1,t} + P^{m}_{1,t}M^{i}_{1,t} + P^{o}_{1,t}O_{1,t}$$

s.t.

$$C^{d}_{1,t} = \left( (\omega^{cc}_1)^{\rho^{o}_{1}} (C^{ne}_{1,t})^{\frac{1}{1+\rho^{o}_{1}}} + (\omega^{oc}_1)^{\rho^{o}_{1}} (\mu^{t}_{z0}Z^{o}_{1,t}O_{1,t})^{\frac{1}{1+\rho^{o}_{1}}} \right)^{1+\rho^{o}_{1}} \quad (16)$$

$$C^{ne}_{1,t} = \left( (\omega^{c}_1)^{\rho^{c}_{1}} (C^{d}_{1,t})^{\frac{1}{1+\rho^{c}_{1}}} + (\omega^{mc}_1)^{\rho^{c}_{1}} (Z^{m}_{1,t}M^{i}_{1,t})^{\frac{1}{1+\rho^{c}_{1}}} \right)^{1+\rho^{o}_{1}} \quad (17)$$

Each distribution firm produces a nonoil aggregate $C^{ne}_{1,t}$ from the home and foreign intermediate consumption aggregates $C^{d}_{1,t}$ and $M^{i}_{1,t}$, which is then combined with oil $O_{1,t}$. The same shock $Z^{o}_{1,t}$ that affects oil intensity in production also affects the oil intensity of consumption. The term $Z^{m}_{1,t}$ captures an import preference shock.

The price of the consumption aggregate $P^{c}_{1,t}$ coincides with the Lagrange multiplier on Equation (17) in the cost minimization problem of a distributor. The price of the nonoil consumption good $C^{ne}_{1,t}$ is referred to as the “core” price level $P^{ne}_{1,t}$.

**Production of Investment Goods**

The investment good is also produced by perfectly competitive distributors. The cost minimization of a representative investment distributor is:

$$\min_{I^{d}_{1,t}, M^{i}_{1,t}} \quad P^{d}_{1,t}I^{d}_{1,t} + P^{m}_{1,t}M^{i}_{1,t}$$

s.t.

$$I^{i}_{1,t} = \left( (\omega^{i}_1)^{\rho^{i}_{1}} (I^{d}_{1,t})^{\frac{1}{1+\rho^{i}_{1}}} + (\omega^{mi}_1)^{\rho^{i}_{1}} (Z^{m}_{1,t}M^{i}_{1,t})^{\frac{1}{1+\rho^{i}_{1}}} \right)^{1+\rho^{i}_{1}} \quad (19)$$

The same import preference shock $Z^{m}_{1,t}$ also affects investment imports. The Lagrangian from the problem of investment distributors determines the price of new investment goods $P^{i}_{1,t}$, that appears in the household’s budget constraint.

**1.2 The Oil Market**

Each period the home and foreign countries are endowed with exogenous supplies of oil $Y^{o}_{1,t}$ and $Y^{o}_{2,t}$, respectively. The two endowments are governed by distinct stochastic processes.
With both domestic and foreign oil supply determined exogenously, the oil price \( P_{o,t} \) adjusts endogenously to clear the world oil market:

\[
Y_{1,t}^o + \frac{1}{\xi_1} Y_{2,t}^o = O_{1,t} + \frac{1}{\xi_1} O_{2,t},
\]

where \( O_{i,t} = O_{i,t}^y + O_{i,t}^c \).

### 1.3 Fiscal Policy

Government purchases have no direct effect on household utility and are given by:

\[
G_{d,1,t} = g_1 Z_{1,t} Y_{1,t}^d.
\]

The stochastic component to this autonomous spending is \( Z_{1,t}^g \). The budget is balanced each period:

\[
P_{d,1,t} G_{d,1,t} + T_{1,t} = 0.
\]

### 1.4 Monetary Policy

Monetary policy follows the interest rate policy reaction function:

\[
i_{1,t} = \bar{i}_1 + g_1 (i_{1,t-1} - \bar{i}_1) + (1-g_1) \left[ (\pi_{1,t}^{core} - \bar{\pi}_{1,t}^{core}) + \gamma_1 (\pi_{1,t}^{core} - \bar{\pi}_{1,t}^{core} - \bar{\pi}_{1,t}^{core}) + \gamma_1 \pi_{1,t}^{gap} \right].
\]

The terms \( \bar{i}_1 \) and \( \bar{\pi}_{1,t}^{core} \) are the steady state values for the nominal interest rate and inflation, respectively. The inflation rate \( \pi_{1,t}^{core} \) is expressed as the logarithmic percentage change of the core price level, i.e., inflation in nonoil consumer prices \( \pi_{1,t}^{core} = \log(P_{ne,1,t} / P_{ne,1,t-1}) \). The term \( \pi_{1,t}^{gap} \) denotes the log deviation of gross output from the value of gross output in a model that excludes nominal rigidities, but is otherwise identical to the one described. The term \( \bar{\pi}_{1,t}^{core} \) reflects a time varying inflation target.
1.5 Resource Constraints for Nonoil Goods and Net Foreign Assets

The resource constraint for the nonoil goods sector of the home economy can be written as:

\[ Y_{1,t}^d = C_{1,t}^d + I_{1,t}^d + G_{1,t}^d + \frac{1}{\zeta_1} \left( M_{2,t}^c + M_{2,t}^i \right), \]  

(25)

where \( M_{2,t} = M_{2,t}^c + M_{2,t}^i \) denotes the per capita imports of the foreign country, which accounts for the population scaling factor \( \frac{1}{\zeta_1} \).

The evolution of net foreign assets can be expressed as:

\[ \frac{e_{1,t} P_{2,t}^b B_{1,t}}{\phi_{1,t}^b} = e_{1,t} B_{1,t-1} + \frac{1}{\zeta_1} e_{1,t} P_{2,t}^m (M_{2,t}^c + M_{2,t}^i) - P_{1,t}^m (M_{1,t}^c + M_{1,t}^i) + P_{1,t}^o (Y_{1,t}^o - O_{1,t}). \]  

(26)

2 Estimation

The model is estimated by the method of maximum likelihood based on quarterly data for 1984.I through 2008.III using fifteen observed series: the log of U.S. and foreign GDP, U.S. and foreign oil production, the U.S. dollar price of oil (deflated by the U.S. GDP deflator), U.S. hours worked per capita, and the real dollar trade-weighted exchange rate; the GDP share of U.S. private consumption expenditures, the GDP share of U.S. oil imports, the GDP share of U.S. nonoil goods imports, the GDP share of U.S. goods exports, the GDP share of U.S. fixed investment; the level of U.S. core PCE inflation, U.S. wage inflation (demeaned), and the U.S. federal funds rate (demeaned). The presample starting in 1974.I is used to train the Kalman filter used to form the likelihood.\(^1\)

The model is just identified in that it contains fifteen exogenous shock processes: U.S. and foreign productivity (\( Z_{1,t} \) and \( Z_{2,t} \)), U.S. and foreign oil supply (\( Y_{1,t}^o \) and \( Y_{2,t}^o \)), U.S. and foreign oil intensity (\( Z_{1,t}^o \) and \( Z_{2,t}^o \)), U.S. autonomous spending (\( Z_{1,t}^g \)), U.S. and foreign consumption preferences (\( Z_{1,t}^c \) and \( Z_{2,t}^c \)), U.S. and foreign import preferences (\( Z_{1,t}^m \) and \( Z_{2,t}^m \)).

\(^1\) To maximize the likelihood, we employ a combination of optimization algorithms. We rely on simulated annealing to identify a candidate global maximum and refine the estimates through Nelder-Mead and Newton-Raphson algorithms. The candidate global maximum needs to survive repeated calls to the simulated annealing algorithm with a high initial temperature and a slow cooling process.
U.S. investment specific technology \( (Z_{1,t}) \), U.S. price markup \( (\theta^p_{1,t}) \), U.S. labor supply \( (\theta^w_{1,t}) \), and U.S. monetary policy \( (\pi^\text{core}_{1,t}) \). Our first estimation attempt involved specifying all shock processes as auto-regressive of order one. However, the estimates of the parameters governing some of the shock processes chafed against the upper bound of the unit circle. To avoid constraining the shock processes arbitrarily, we introduced AR(2) processes for the following shocks: domestic and foreign productivity, domestic and foreign oil supply, domestic and foreign oil intensity, domestic and foreign import preferences. While allowing for distinct estimates of the scale of the shock process, we constrained the autoregressive parameters for the home and foreign shocks to be the same in the case of the shocks to productivity, oil intensity, consumption preferences, and import preferences. Table 1 summarizes the stochastic processes of the shocks and the data used in the estimation procedure.

We estimate all the parameters governing the shock processes listed in Table 1. We also estimate all behavioral parameters in the model with the exception of the depreciation rate of capital, \( \delta_1 \), which is fixed at 0.025; the intertemporal elasticity of consumption, \( \sigma_1 \), which is set to 1; the curvature of the intermediation cost for foreign bonds, \( \phi_{1,b} \), which is set to 0.0001; and the discount factor \( \beta_1 \), which is fixed so that, taking into account the estimate for trend productivity growth, the steady state real interest rate is 4% per year. The foreign parameters take on the same values as for the home country.

Table 2 lists the parameters and settings that influence the linearized equilibrium conditions of our model. Values chosen for government spending \( g_1 \), and \( \omega^k_1 \) are consistent with data from the National Income and Product Accounts (NIPA). The parameter \( \zeta_1 \) implies that nonoil production in the U.S. is half the size of nonoil production in the rest of the world, consistent with World Bank data.

The values for \( \omega^{gy}_1 \) and \( \omega^{oc}_1 \) are determined by the overall nominal share of oil in output, and the ratios of the quantity of oil used as an intermediate input in production relative to the quantity used as a final input in consumption. Based on data from the Energy Information Administration of the U.S. Department of Energy for 2008, the overall oil share of the domestic economy is set to 4.2 percent of GDP. The relative size of oil in
consumption and production is pinned down using the U.S. Input-Output Use tables. Over the period 2002-2008, for which the tables are available annually, the Use tables indicate a low in 2002 of 0.30 and a peak in 2008 of 0.39. We use the sample average of 0.35 over the last ten years, which implies that $\omega^u_1 = 0.026$ and $\omega^c_1 = 0.021$.

U.S. oil imports are set to 70 percent of total consumption in the steady state, implying that 30 percent of oil consumption is satisfied by domestic production. This estimate is based on 2008 NIPA data. In the foreign bloc, the overall oil share is set to 8.2 percent. The oil endowment abroad is 9.5 percent of foreign GDP, based on oil production data from the Energy Information Administration. $\mu_o$ is fixed at 1.0026, consistent with the 0.26 percent average growth per quarter in world crude oil production over the sample period.

The parameters $\omega^{mc}_1$ and $\omega^{mi}_1$ are chosen to reflect NIPA data for nonoil imports while equalizing the nonoil import-intensity of consumption and investment. This calibration implies a ratio of nonoil goods imports relative to GDP for the home country of about 12 percent and values of for both $\omega^{mc}_1$ and $\omega^{mi}_1$ equal to 0.15. Given that trade is balanced in steady state, and that the oil import share for the home country is 3 percent of GDP, the goods export share is 15 percent of GDP.

Table 3 reports estimates of the main behavioral parameters and confidence intervals. The 95% confidence interval reported in the table is obtained by repeating the maximum likelihood estimation exercise on 1000 bootstrap samples of length equal to that of the observed estimation sample. The bootstrap samples were generated taking the point estimates in Table 3 as pseudo-true values for the parameters in the model. Bodenstein and Guerrieri (2011) provide additional discussion of these estimates.
Table 1: Shocks and Data

<table>
<thead>
<tr>
<th>Shock</th>
<th>Stochastic Process</th>
<th>Data Series</th>
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</thead>
<tbody>
<tr>
<td><strong>Home Shocks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>neutral technology</td>
<td>[ \ln(Z_{1,t}) = (1 + \rho_1^i - \rho_2^c) \ln(Z_{1,t-1}) - \rho_1^i Y_{z,t-1} + \sigma_1^i \epsilon_{1,t} ]</td>
<td>U.S. GDP</td>
</tr>
<tr>
<td>investment</td>
<td>[ \ln(Z_{1,t}) = \rho_1^i \ln(Z_{1,t-1}) + \sigma_1^i \epsilon_{1,t} ]</td>
<td>U.S. fixed invest. (GDP share)</td>
</tr>
<tr>
<td>consumption</td>
<td>[ \ln(Z_{1,t}) = \rho_1^c \ln(Z_{1,t-1}) + \sigma_1^c \epsilon_{1,t} ]</td>
<td>U.S. consumption (GDP share)</td>
</tr>
<tr>
<td>spending</td>
<td>[ \ln(Z_{1,t}) = \rho_1^o \ln(Z_{1,t-1}) + \sigma_1^o \epsilon_{1,t} ]</td>
<td>U.S. hours worked</td>
</tr>
<tr>
<td>price markup</td>
<td>[ \theta_{1,t} = \rho_1^p \theta_{1,t-1} + \sigma_1^p \epsilon_{1,t} ]</td>
<td>U.S. core inflation</td>
</tr>
<tr>
<td>wage markup</td>
<td>[ \theta_{1,t} = \rho_1^w \theta_{1,t-1} + \sigma_1^w \epsilon_{1,t} ]</td>
<td>U.S. wage inflation</td>
</tr>
<tr>
<td>monetary policy</td>
<td>[ \pi_{1,t} = \rho_1^\pi \pi_{1,t-1} + \sigma_1^\pi \epsilon_{1,t} ]</td>
<td>U.S. federal funds</td>
</tr>
<tr>
<td><strong>Oil Shocks</strong></td>
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<td></td>
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<tr>
<td>home oil supply</td>
<td>[ \ln(Y_{1,t}^o) = (1 + \rho_1^{yo} - \rho_2^{yo}) \ln(Y_{1,t-1}^o) - \rho_1^{yo} \ln(Y_{2,t-1}^o) + \sigma_1^{yo} \epsilon_{1,t} ]</td>
<td>U.S. oil production</td>
</tr>
<tr>
<td>foreign oil supply</td>
<td>[ \ln(Y_{1,t}^o) = (1 + \rho_1^{yo} - \rho_2^{yo}) \ln(Y_{2,t-1}^o) - \rho_2^{yo} \ln(Y_{2,t-2}^o) + \sigma_2^{yo} \epsilon_{2,t} ]</td>
<td>for. oil production</td>
</tr>
<tr>
<td>home oil intensity</td>
<td>[ \ln(Z_{1,t}^o) = (1 + \rho_1^{zo} - \rho_2^{zo}) \ln(Z_{1,t-1}^o) - \rho_1^{zo} \ln(Z_{1,t-1}^o) + \sigma_1^{zo} \epsilon_{1,t} ]</td>
<td>U.S. oil imports (GDP share)</td>
</tr>
<tr>
<td>for. oil intensity</td>
<td>[ \ln(Z_{2,t}^o) = (1 + \rho_1^{zo} - \rho_2^{zo}) \ln(Z_{2,t-1}^o) - \rho_1^{zo} \ln(Z_{2,t-2}^o) + \sigma_2^{zo} \epsilon_{2,t} ]</td>
<td>real oil price</td>
</tr>
<tr>
<td><strong>Other Open-Economy Shocks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>for. neutral tech.</td>
<td>[ \ln(Z_{1,t}) = (1 + \rho_1^i - \rho_2^c) \ln(Z_{1,t-1}) - \rho_1^i \ln(Z_{1,t-2}) + \sigma_1^i \epsilon_{1,t} ]</td>
<td>for. trade-weighted GDP</td>
</tr>
<tr>
<td>home import</td>
<td>[ \ln(Z_{1,t}^m) = (1 + \rho_1^{zm} - \rho_2^z) \ln(Z_{1,t-1}^m) - \rho_1^{zm} \ln(Z_{1,t-2}^m) + \sigma_1^{zm} \epsilon_{1,t} ]</td>
<td>U.S. imports (share GDP)</td>
</tr>
<tr>
<td>foreign import</td>
<td>[ \ln(Z_{2,t}^m) = (1 + \rho_1^{zm} - \rho_2^z) \ln(Z_{2,t-1}^m) - \rho_1^{zm} \ln(Z_{2,t-2}^m) + \sigma_2^{zm} \epsilon_{2,t} ]</td>
<td>U.S. exports (share GDP)</td>
</tr>
<tr>
<td>foreign consumption</td>
<td>[ \ln(Z_{2,t}^o) = \rho^{eo} \ln(Z_{2,t-1}^o) + \sigma_2^o \epsilon_{2,t} ]</td>
<td>exch. rate (real, t.w.)</td>
</tr>
</tbody>
</table>

For shocks that occur in both countries, we impose that the autoregressive coefficients are identical except in the case of oil supply shocks.
Table 2: Steady State Ratios and Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Used to Determine</th>
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<th>Used to Determine</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta = 0.99$</td>
<td>discount factor</td>
<td>$\sigma = 1$</td>
<td>intertemporal consumption elasticity</td>
</tr>
<tr>
<td>$\delta = 0.025$</td>
<td>depreciation rate of capital</td>
<td>$\rho_0 = -2$</td>
<td>K-L sub. elasticity (0.5)</td>
</tr>
<tr>
<td>$g = 0.18$</td>
<td>steady state gov. cons. share of GDP</td>
<td>$N_{ss} = 0.33$</td>
<td>steady state labor share to fix $\chi_0$</td>
</tr>
<tr>
<td>$\mu_o = 1.0026$</td>
<td>trend growth in oil supply</td>
<td>$\omega_k = 1.54$</td>
<td>parameter on K in value added (home)</td>
</tr>
<tr>
<td>$\omega_{og} = 0.026$</td>
<td>weight on oil in production (home)</td>
<td>$\omega_{og}^* = 0.057$</td>
<td>weight on oil in production (foreign)</td>
</tr>
<tr>
<td>$\omega_{oc} = 0.021$</td>
<td>weight on oil in consumption (home)</td>
<td>$\omega_{oc}^* = 0.041$</td>
<td>weight on oil in consumption (foreign)</td>
</tr>
<tr>
<td>$\omega_{mc} = 0.068$</td>
<td>weight on imports in consumption (home)</td>
<td>$\omega_{mc}^* = 0.039$</td>
<td>weight on imports in consumption (foreign)</td>
</tr>
<tr>
<td>$\omega_{mi} = 0.40$</td>
<td>weight on imports in investment (home)</td>
<td>$\omega_{mi}^* = 0.25$</td>
<td>weight on imports in investment (foreign)</td>
</tr>
<tr>
<td>$\zeta = 1/2$</td>
<td>relative size of home country</td>
<td>$\frac{V_{c}^{ss}}{A_{c}^{ss} \cdot B_{c}^{ss}} = 0.3$</td>
<td>steady state ratio oil prod. to cons. (home)</td>
</tr>
<tr>
<td>$\phi_b = 0.0001$</td>
<td>curvature of bond intermed. cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Estimation Results

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Conf. Interval</th>
<th>Estimate</th>
<th>Conf. Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho_1 ), Technology, growth AR coef.</td>
<td>0.2163</td>
<td>0.1736-0.3001</td>
<td>( \sigma_1 ), U.S. Import, st. dev. of innov.</td>
</tr>
<tr>
<td>( \rho_2 ), Technology, level error corr. coef.</td>
<td>0.0001</td>
<td>0.0001-0.0214</td>
<td>( \sigma_1 ), For. Import, st. dev. of innov.</td>
</tr>
<tr>
<td>( \sigma_1 ), U.S. Technology, st. dev. of innov.</td>
<td>0.0066</td>
<td>0.0058-0.0121</td>
<td>( \rho_1 ), U.S. Wage Markup, AR(1) coef.</td>
</tr>
<tr>
<td>( \sigma_{zi} ), For. Technology, st. dev. of innov.</td>
<td>0.0108</td>
<td>0.0096-0.0140</td>
<td>( \sigma_1 ), U.S. Wage Markup, st. dev. of innov.</td>
</tr>
<tr>
<td>( \rho_{zi} ), U.S. Investment Technology, AR coef.</td>
<td>0.9059</td>
<td>0.8000-0.9931</td>
<td>( \rho_1 ), U.S. Price Markup, AR(1) coef.</td>
</tr>
<tr>
<td>( \sigma_{zi} ), U.S. Inv. Tech. st. dev. of innov.</td>
<td>0.0269</td>
<td>0.0231-0.0599</td>
<td>( \sigma_1 ), U.S. Price Markup, st. dev. of innov.</td>
</tr>
<tr>
<td>( \rho_1 ), U.S. Technology, st. dev. of innov.</td>
<td>0.0066</td>
<td>0.0058-0.0121</td>
<td>( \rho_1 ), U.S. Monetary Policy, AR(1) coef.</td>
</tr>
<tr>
<td>( \sigma_1 ), For. Oil Supply, st. dev. of innov.</td>
<td>0.0126</td>
<td>0.0650-0.2070</td>
<td>( \mu_2 ), Growth Rate of Technology (gross)</td>
</tr>
<tr>
<td>( \rho_1 ), U.S. Oil Supply, growth AR coef.</td>
<td>0.0001</td>
<td>0.0001-0.0414</td>
<td>( \k_1 ), Habits in Consumption</td>
</tr>
<tr>
<td>( \rho_1 ), U.S. Oil Supply, level error corr. coef.</td>
<td>0.0037</td>
<td>0.0005-0.0308</td>
<td>( \gamma_1 ), Policy Rate Smoothing</td>
</tr>
<tr>
<td>( \sigma_1 ), For. Oil Supply, st. dev. of innov.</td>
<td>0.0181</td>
<td>0.0163-0.0234</td>
<td>( \gamma_1 ), Weight on Inflation in Mon. Pol. Rule</td>
</tr>
<tr>
<td>( \rho_1 ), For. Oil Supply, growth AR coef.</td>
<td>0.0001</td>
<td>0.0001-0.0565</td>
<td>( \gamma_1 ), Weight on Output Gap in Mon. Pol. Rule</td>
</tr>
<tr>
<td>( \rho_1 ), Oil Efficiency, growth AR coef.</td>
<td>0.0014</td>
<td>0.0061-0.0461</td>
<td>( \xi_1 ), Calvo Price Parameter</td>
</tr>
<tr>
<td>( \sigma_1 ), U.S. Oil Efficiency, st. dev. of innov.</td>
<td>0.0470</td>
<td>0.0411-0.0586</td>
<td>( \xi_1 ), Calvo Wage Parameter</td>
</tr>
<tr>
<td>( \sigma_1 ), Oil Efficiency, st. dev. of innov.</td>
<td>0.1269</td>
<td>0.1087-0.1514</td>
<td>( \epsilon_1 ), Lagged Price Indexation</td>
</tr>
<tr>
<td>( \rho_1 ), Consumption Shock, AR(1) coef.</td>
<td>0.9188</td>
<td>0.8882-0.9512</td>
<td>( \epsilon_1 ), Lagged Wage Indexation</td>
</tr>
<tr>
<td>( \sigma_1 ), U.S. Consumption, st. dev. of innov.</td>
<td>0.6484</td>
<td>0.5931-0.7894</td>
<td>( \pi_1 ), Steady State Inflation</td>
</tr>
<tr>
<td>( \sigma_1 ), For. Consumption, st. dev. of innov.</td>
<td>0.7174</td>
<td>0.6827-0.8838</td>
<td>( \psi_1 ), Investment Adjustment Cost</td>
</tr>
<tr>
<td>( \rho_1 ), Import, growth AR coef.</td>
<td>0.0001</td>
<td>0.0001-0.0476</td>
<td>( \xi ), Determines Lab. Supply El. (( \frac{1}{\pi} ))</td>
</tr>
<tr>
<td>( \rho_1 ), Import, level error corr. coef.</td>
<td>0.0019</td>
<td>0.0003-0.0082</td>
<td></td>
</tr>
</tbody>
</table>

The lower bound for the coefficient on the level error correction components is 0.0001. The 95% confidence interval reported in the table is obtained by repeating the maximum likelihood estimation exercise on 1000 bootstrap samples of length equal to that of the observed estimation sample.