The Long-run Macroeconomic Impacts of Fuel Subsidies in an Oil-importing Developing Country

Michael Plante
Federal Reserve Bank of Dallas

November 6, 2012
The results presented here are my own and do not necessarily reflect the official views of the Federal Reserve Bank of Dallas nor the Federal Reserve System as a whole.
Fuel subsidies are an important policy issue for several reasons:

- Expensive to finance.
- Very difficult to remove.

See del Granado et al. (2010), Baig et al. (2007), Coady et al. (2006), IEA (various).
Introduction

Not many results from a macro perspective:

- Bouakez et al. (2008) (optimal monetary policy)
- Coady et al. (2006) (distributional issues)
- del Granado et al. (2010) (distributional issues)
Introduction

My contributions / twists:

▶ Focus on (long-run) distortions.

▶ Incorporate general equilibrium effects from funding of subsidy.

▶ Focus on analytical results in a tractable model.
Introduction

Preview of results:

- Subsidy increases use of oil products in economy.
- Subsidy increases output.
- But can crowd out non-oil consumption and distort labor supply decisions.
Model overview

Standard features:

1. Small open economy model

2. Representative household

3. Representative firm produces traded good
Non-standard features:

1. Currency substitution (no access to capital markets)
2. Household and firm demand for oil products
3. Economy imports oil products
4. Government funded subsidy on oil products
Household

The agent maximizes

\[
\int_0^\infty \left[ U(C^T, O^h) - V(L^T) + \phi(m, F) \right] e^{-\rho s} ds. \tag{1}
\]

Real flow constraint

\[
\dot{A} = W^T L^T + rb - C^T - P^s O^h - T - \pi m. \tag{2}
\]
Production

Technology

\[ Q^T = Q^T \left( L^T, O^T \right). \] (3)

Firm maximizes

\[ Q^T - W^T L^T - P^s O^T. \] (4)
The Government

Government budget constraint (steady state)

\[ \bar{T} + \bar{\pi} \bar{m} = (\bar{P}^o - \bar{P}^s) \left( \bar{O}^h + \bar{O}^T \right). \]  

Domestic oil price set ad hoc

\[ P^s \leq P^o. \]
Foreign asset accumulation

Flow equation

\[ \dot{F} = Q^T - C^T - P^o (O^h + O^T). \]  

(7)

Steady state equation ($\dot{F} = 0$)

\[ \bar{Q}^T = \bar{C}^T + \bar{P}^o \left( \bar{O}^h + \bar{O}^T \right). \]
Functional forms

- CES functions used for utility and production functions.

- $\sigma_c$ - Elasticity of substitution between $C^T$ and $O^h$.

- $\tau$ - Intertemporal elasticity of substitution.

- $\mu$ - Frisch elasticity of labor supply.
The Exercise

1. Evaluate equations at a long-run equilibrium (steady state).

2. Consider a (log) differential change in the subsidy, $\hat{P}^s$.

3. Assume domestic price lowered, i.e. $\hat{P}^s < 0$.

4. Solve for and, where possible, sign solutions for variables.

5. Lump sum taxation or inflation rate increased to finance spending.
The Exercise

Consider following cases:

1. Subsidy for households only
2. Subsidy for firms only
3. Subsidy for both
Subsidy Benefits Household Only

From household’s first order conditions

\[
\hat{O}^h = - \frac{\sigma_c}{\frac{1}{\tau} + \frac{1}{\mu}} \left[ \frac{\tau \gamma_{oh} + \sigma_c \gamma_{ct}}{\sigma_c \tau} + \frac{\theta_{ct}}{\mu (1 - \theta_{ot})} \right] \hat{P}^s, \quad (8)
\]

\[
\hat{C}^T = \frac{\sigma_c}{\frac{1}{\tau} + \frac{1}{\mu}} \left[ -\frac{(\tau - \sigma_c) \gamma_{oh}}{\sigma_c \tau} + \frac{\theta_{oh}}{\mu (1 - \theta_{ot})} \right] \hat{P}^s. \quad (9)
\]
Subsidy Benefits Household Only

Signing the solution for $C^T$ (Case 1):

- If $(\tau - \sigma_c) \leq 0$ then $C^T$ falls when $\hat{P}^s < 0$.

- Substitution and income effects point in same direction.
Subsidy Benefits Household Only

Signing the solution for \( C^T \) (Case 2):

- If \((\tau - \sigma_c) > 0\) then \( C^T \) rises iff

\[
\mu > \frac{\theta_{oh}\sigma_c\tau}{(1 - \theta_{ot})\gamma_{oh}(\tau - \sigma_c)}.
\]
Subsidy Benefits Household Only

Signing the solution for $C^T$ (Case 2):

- If $(\tau - \sigma_c) > 0$ then $C^T$ rises iff

\[ \mu > \frac{\theta_{oh}\sigma_c \tau}{(1 - \theta_{ot})\gamma_{oh}(\tau - \sigma_c)}. \]

- Tradeoff: Pay taxes by consuming less and working more.
Subsidy Benefits Household Only

Other results:

- $\hat{L}^T > 0$ when $\hat{P}^s < 0$.
- $\hat{Q}^T > 0$ when $\hat{P}^s < 0$
Subsidy Benefits Firms Only

Firm’s first order condition

\[
\hat{W}^T = -\frac{\alpha_0^T}{\alpha_1} \hat{P}^s,
\]

(10)
Subsidy Benefits Firms Only

Firm’s first order condition

\[ \hat{W}^T = -\frac{\alpha_o^T}{\alpha_i^T} \hat{P}^s, \]  \hspace{1cm} (10)

Household’s first order conditions

\[ \hat{O}^h = \frac{1}{\tau} + \frac{1}{\mu} \left[ -\frac{\sigma_T}{\mu \alpha_i^T (1 - \theta_{ot})} \hat{P}^s + \hat{W}^T \right], \]  \hspace{1cm} (11)

\[ \hat{C}^T = \hat{O}^h. \]  \hspace{1cm} (12)
Subsidy Benefits Firms Only

Household’s first order conditions

\[
\hat{O}^h = \frac{1}{\frac{1}{\tau} + \frac{1}{\mu}} \left[ -\frac{\sigma_T (\alpha^T_o - \theta_{ot})}{\mu \alpha^T} (1 - \theta_{ot}) \hat{P}^s + \hat{W}^T \right]. \tag{13}
\]
Subsidy Benefits Firms Only

Household’s first order conditions

$$\hat{O}^h = \frac{1}{\tau + \frac{1}{\mu}} \left[ -\frac{\sigma_T (\alpha_o^T - \theta_{ot})}{\mu \alpha_f^T (1 - \theta_{ot})} \hat{P}^s + \hat{W}^T \right].$$ (13)

Coefficient negative iff

$$\mu > \frac{\sigma_T (\theta_{ot} - \alpha_o^T)}{(1 - \theta_{ot}) \alpha_o^T}.$$ 

Intuition: Taxes can be paid by working more and/or consuming less.
Subsidy Benefits Firms Only

Signing other solutions:

- \( \hat{L}^T > 0 \) when \( \hat{P}^s < 0 \).
- \( \hat{Q}^T > 0 \) when \( \hat{P}^s < 0 \).
Monetary Variables

- Possible to derive analytical solutions

- But impossible to sign with any surety
## Subsidy Benefits Households and Firms

### Table 1: Qualitative Changes in Select Macroeconomic Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Household</th>
<th>Firm</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P^s$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
</tr>
<tr>
<td>$C^T$</td>
<td>$?$</td>
<td>$?$</td>
<td>$?$</td>
</tr>
<tr>
<td>$O^h$</td>
<td>$+$</td>
<td>$?$</td>
<td>$?$</td>
</tr>
<tr>
<td>$L^T$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>$O^T$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>$Q^T$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>$W^T$</td>
<td>0</td>
<td>$+$</td>
<td>$+$</td>
</tr>
</tbody>
</table>
Conclusions

- Subsidy increases use of oil products in economy.

- But can crowd out consumption and lead to inefficiently high labor use.

- Consumers of oil products get one benefit but incur other costs.
Some future work based on referee comments

- Hand to mouth consumers to consider distributional issues
- Consider subsidies beyond fuel products
- Distortionary taxation
Considering Non-traded Goods

- Consumption of non-traded good (use CES function again)
- Non-traded good produced using oil
- Solve for steady state changes as before
Production

Technology in non-traded sector

\[ Q^n = \left[ \left( A^n L^n \right)^{\sigma_n^{-1}} + d_1 \left( O^n \right)^{\sigma_n^{-1}} \right]^{\sigma_n} \sigma_n^{-1}, \]

Market clearing in non-traded sector

\[ C^n = Q^n. \]
Subsidy Benefits Only Households

From firms’ first order conditions

\[ \hat{W} = 0, \quad (14) \]
\[ \hat{P}^n = 0. \quad (15) \]
Subsidy Benefits Only Households

\[ \hat{O}^h = -\frac{\sigma_c}{\frac{1}{\tau} + \frac{1}{\mu}} \left[ \frac{\tau \gamma_{oh} + \sigma_c (1 - \gamma_{oh})}{\sigma_c \tau} + \frac{\eta (\theta_{ct} + \theta_{cn})}{(1 - \theta_{ot}) \mu} + \frac{1 - \eta}{\mu} \right] \hat{P}^s, \] (16)

\[ \hat{C}^T = -\frac{\sigma_c}{\frac{1}{\tau} + \frac{1}{\mu}} \left[ \frac{(\tau - \sigma_c) \gamma_{oh}}{\tau \sigma_c} - \frac{\eta \theta_{oh}}{\mu (1 - \theta_{ot})} \right] \hat{P}^s, \] (17)

\[ \hat{C}^n = \hat{C}^T, \] (18)

If \( \tau > \sigma_c \) then non-oil consumption rises iff

\[ \mu > \frac{\eta \theta_{oh} \tau \sigma_c}{(1 - \theta_{ot})(\tau - \sigma_c) \gamma_{oh}}, \]
Complications with Analytical Results

If the subsidy benefits firms

\[
\hat{W} = - \frac{\alpha^T_o}{\alpha^T_l} \hat{P}^s, \quad (19)
\]

\[
\hat{P}^n = \frac{\alpha^n_o - \alpha^T_o}{\alpha^T_l} \hat{P}^s, \quad (20)
\]

Change in \( P^n \) creates additional substitution effects, analytical results difficult to sign.
Experiment

- Initial value of $P^s$ set to world price of oil
- Reduce price by 10% (roughly 1% of GDP in new steady state)
- Consider several settings of $\mu$, $\sigma_c$, $\tilde{O}^N$
Calibration

Table 2: Calibrated Parameters and Steady State Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Baseline Value</th>
<th>Alternative Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau$</td>
<td>Intertemporal Elasticity of Substitution</td>
<td>0.50</td>
<td>—</td>
</tr>
<tr>
<td>$\sigma_c$</td>
<td>Elasticity of Substitution (Consumption)</td>
<td>0.25</td>
<td>0.75</td>
</tr>
<tr>
<td>$\sigma_m$</td>
<td>Elasticity of Substitution (Money)</td>
<td>0.75</td>
<td>—</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Rate of Time Preference</td>
<td>0.04</td>
<td>—</td>
</tr>
<tr>
<td>$\chi$</td>
<td>Inflation Rate</td>
<td>0.06</td>
<td>—</td>
</tr>
<tr>
<td>$\sigma_T$</td>
<td>Elasticity of Substitution (Traded Sector)</td>
<td>0.50</td>
<td>—</td>
</tr>
<tr>
<td>$\sigma_n$</td>
<td>Elasticity of Substitution (Non-traded Sector)</td>
<td>0.50</td>
<td>—</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Wage Elasticity of Labor Supply</td>
<td>1</td>
<td>$\frac{1}{8}$</td>
</tr>
<tr>
<td>$m$</td>
<td>Ratio of Real Money Balances to GDP</td>
<td>0.15</td>
<td>—</td>
</tr>
<tr>
<td>$F$</td>
<td>Ratio of Stock of Foreign Currency to GDP</td>
<td>0.15</td>
<td>—</td>
</tr>
<tr>
<td>$P^sO^h$</td>
<td>Oil to GDP Ratio (Households)</td>
<td>0.05</td>
<td>—</td>
</tr>
<tr>
<td>$P^sO^T$</td>
<td>Oil to GDP ratio (Traded Sector)</td>
<td>0.025</td>
<td>0.01, 0.04</td>
</tr>
<tr>
<td>$P^oO^n$</td>
<td>Oil to GDP Ratio (Non-traded Sector)</td>
<td>0.025</td>
<td>0.04, 0.01</td>
</tr>
</tbody>
</table>
Table 3: Percent Change Across Steady States when $T$ Adjusts, $\sigma_c = .25$

<table>
<thead>
<tr>
<th></th>
<th>$\mu = 1$</th>
<th>$\mu = 1$</th>
<th>$\mu = 1$</th>
<th>$\mu = \frac{1}{8}$</th>
<th>$\mu = \frac{1}{8}$</th>
<th>$\mu = \frac{1}{8}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{O}^n$</td>
<td>0.01</td>
<td>0.025</td>
<td>0.04</td>
<td>0.01</td>
<td>0.025</td>
<td>0.04</td>
</tr>
<tr>
<td>$C^T$</td>
<td>0.28</td>
<td>0.20</td>
<td>0.13</td>
<td>0.03</td>
<td>-0.04</td>
<td>-0.12</td>
</tr>
<tr>
<td>$C^n$</td>
<td>0.13</td>
<td>0.21</td>
<td>0.29</td>
<td>-0.11</td>
<td>-0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>$O^h$</td>
<td>2.95</td>
<td>2.87</td>
<td>2.80</td>
<td>2.70</td>
<td>2.63</td>
<td>2.55</td>
</tr>
<tr>
<td>$L$</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>$L^T$</td>
<td>0.60</td>
<td>0.59</td>
<td>0.58</td>
<td>0.36</td>
<td>0.35</td>
<td>0.33</td>
</tr>
<tr>
<td>$L^n$</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>-0.16</td>
<td>-0.16</td>
<td>-0.16</td>
</tr>
<tr>
<td>$W$</td>
<td>0.80</td>
<td>0.48</td>
<td>0.19</td>
<td>0.80</td>
<td>0.48</td>
<td>0.19</td>
</tr>
<tr>
<td>$O^T$</td>
<td>3.49</td>
<td>3.40</td>
<td>3.31</td>
<td>3.24</td>
<td>3.15</td>
<td>3.06</td>
</tr>
<tr>
<td>$O^n$</td>
<td>2.95</td>
<td>2.87</td>
<td>2.80</td>
<td>2.70</td>
<td>2.63</td>
<td>2.55</td>
</tr>
<tr>
<td>$Q^T$</td>
<td>0.80</td>
<td>0.71</td>
<td>0.62</td>
<td>0.56</td>
<td>0.47</td>
<td>0.38</td>
</tr>
<tr>
<td>$Q^n$</td>
<td>0.13</td>
<td>0.21</td>
<td>0.29</td>
<td>-0.11</td>
<td>-0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>$P^n$</td>
<td>0.58</td>
<td>-0.05</td>
<td>-0.64</td>
<td>0.58</td>
<td>-0.05</td>
<td>-0.64</td>
</tr>
<tr>
<td>$m$</td>
<td>0.11</td>
<td>-0.20</td>
<td>-0.49</td>
<td>-0.13</td>
<td>-0.44</td>
<td>-0.73</td>
</tr>
<tr>
<td>$F$</td>
<td>0.11</td>
<td>-0.20</td>
<td>-0.49</td>
<td>-0.13</td>
<td>-0.44</td>
<td>-0.73</td>
</tr>
<tr>
<td>$P^{CPI}$</td>
<td>-0.22</td>
<td>-0.53</td>
<td>-0.82</td>
<td>-0.22</td>
<td>-0.53</td>
<td>-0.82</td>
</tr>
<tr>
<td>$\chi$</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Table 4: Percent Change Across Steady States when $T$ Adjusts, $\sigma_c = .75$

<table>
<thead>
<tr>
<th></th>
<th>$\mu = 1$ $\bar{\Omega}^n = .01$</th>
<th>$\mu = 1$ $\bar{\Omega}^n = .025$</th>
<th>$\mu = 1$ $\bar{\Omega}^n = .04$</th>
<th>$\mu = \frac{1}{8}$ $\bar{\Omega}^n = .01$</th>
<th>$\mu = \frac{1}{8}$ $\bar{\Omega}^n = .025$</th>
<th>$\mu = \frac{1}{8}$ $\bar{\Omega}^n = .04$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C^T$</td>
<td>0.16</td>
<td>-0.08</td>
<td>-0.30</td>
<td>-0.09</td>
<td>-0.33</td>
<td>-0.55</td>
</tr>
<tr>
<td>$C^p$</td>
<td>-0.27</td>
<td>-0.04</td>
<td>0.18</td>
<td>-0.52</td>
<td>-0.29</td>
<td>-0.07</td>
</tr>
<tr>
<td>$O^h$</td>
<td>8.39</td>
<td>8.14</td>
<td>7.90</td>
<td>8.12</td>
<td>7.87</td>
<td>7.63</td>
</tr>
<tr>
<td>$L$</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>$L^T$</td>
<td>1.02</td>
<td>0.84</td>
<td>0.69</td>
<td>0.77</td>
<td>0.59</td>
<td>0.43</td>
</tr>
<tr>
<td>$L^n$</td>
<td>-0.33</td>
<td>-0.17</td>
<td>-0.02</td>
<td>-0.58</td>
<td>-0.42</td>
<td>-0.27</td>
</tr>
<tr>
<td>$W$</td>
<td>0.80</td>
<td>0.48</td>
<td>0.19</td>
<td>0.80</td>
<td>0.48</td>
<td>0.19</td>
</tr>
<tr>
<td>$O^T$</td>
<td>3.93</td>
<td>3.66</td>
<td>3.42</td>
<td>3.66</td>
<td>3.40</td>
<td>3.16</td>
</tr>
<tr>
<td>$O^n$</td>
<td>2.54</td>
<td>2.62</td>
<td>2.69</td>
<td>2.28</td>
<td>2.36</td>
<td>2.43</td>
</tr>
<tr>
<td>$Q^T$</td>
<td>1.22</td>
<td>0.96</td>
<td>0.73</td>
<td>0.97</td>
<td>0.71</td>
<td>0.48</td>
</tr>
<tr>
<td>$Q^n$</td>
<td>-0.27</td>
<td>-0.04</td>
<td>0.18</td>
<td>-0.52</td>
<td>-0.29</td>
<td>-0.07</td>
</tr>
<tr>
<td>$P^n$</td>
<td>0.58</td>
<td>-0.05</td>
<td>-0.64</td>
<td>0.58</td>
<td>-0.05</td>
<td>-0.64</td>
</tr>
<tr>
<td>$m$</td>
<td>0.10</td>
<td>-0.21</td>
<td>-0.50</td>
<td>-0.15</td>
<td>-0.46</td>
<td>-0.76</td>
</tr>
<tr>
<td>$F$</td>
<td>0.10</td>
<td>-0.21</td>
<td>-0.50</td>
<td>-0.15</td>
<td>-0.46</td>
<td>-0.76</td>
</tr>
<tr>
<td>$P^{CPI}$</td>
<td>-0.23</td>
<td>-0.54</td>
<td>-0.84</td>
<td>-0.23</td>
<td>-0.54</td>
<td>-0.84</td>
</tr>
<tr>
<td>$\chi$</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Summary

- Crowding out of non-oil consumption remains a possibility.
- Increased labor supply, with possible shift into traded sector.
- Real exchange rate will be distorted.