“Energy taxes and oil price shock”

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Introduction

- Oil shocks often leads to political pressure to obtain tax reductions (issue debated during the 2008 presidential campaign in US, similar debates in France)

- **Argument:** low income individuals are more heavily affected by sudden and significant increase in energy prices than high income people (Share of energy in total spending tends to decrease with income)

- **Question:** Should energy tax reduction be used to mitigate exogenous energy price shocks?

The model (1)

- The model is based on CGL (JPubE - 1998, JPubE - 2003 and JEEM - 2010)
- The model derives second best optimal energy taxes in the presence of externalities generated by energy consumption
- The model is adapted to study the impact of an exogenous shock in the before tax price on energy
- The model is calibrated on US and French data
- We consider that energy prices are subject to an exogenous shock; for different levels of this shock the model calculates the optimal tax mix including income, commodity and energy taxes

The private sector

- An open economy; 3 factors of production: labor, L, capital, K and energy, D
- 2 categories of consumption goods: Non-polluting, x, and polluting, y (energy)
- Labor is heterogeneous with different types having different productivity levels
- All labor are domestic; all capital and energy are imported at world prices r an p_D respectively

Production

- The technology of production is represented by a "nested CES" production function

$$O = \mathbf{O}\left(L, K, D\right) = B\left[\left(1-\beta\right)L^{\frac{\sigma-1}{\sigma}} + \beta\Gamma^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

$$\Gamma = A\left[\alpha K^{\frac{\delta-1}{\delta}} + \left(1-\alpha\right)D^{\frac{\delta-1}{\delta}}\right]^{\frac{\delta}{\delta-1}}$$

- Aggregate output, O, is the numeraire and the units of x and y are chosen such that their producer prices are equal to one

- Competitive markets ⇒ FOC for firms' optimum:

$$\begin{aligned}\mathbf{O}_L(L,K,D) &= w\\ \mathbf{O}_K(L,K,D) &= r\\ \mathbf{O}_D(L,K,D) &= p_D(1+\tau_D)\end{aligned}$$

- w is endogenously determined,
- r is fixed at world market prices,
- p_D is fixed at world market prices,
- τ_D is the tax on energy input

Preferences

- Four types of individuals characterized by different productivity level and tastes
- Type j has productivity $n^j \Rightarrow$
  - L^j hours supplied by j yields $n^j L^j$ "effective hours"
  - Wage is: $w^j = n^j w$ (w = price of one unit of effective labor)
- Linked to L in production function according to,

$$L = \sum_j \pi^j n^j L^j$$

where π^j denotes the proportion of people of type j in the economy

- Each person is endowed with "one unit of time"
- Population size is normalized at one

- Preferences are given by:

$$\mho^j = U\left(x, y, L^j; \theta^j\right) - \phi(E), \quad j = 1, 2, 3, 4$$

  - y: energy consumption (polluting good)
  - x: non-energy consumption (non-polluting good)
  - L^j: hours of work supplied by individual j
  - θ^j is a vector of "taste parameters"
  - E: is aggregate emissions

- We have:

$$E = \sum_{j=1}^{4} \pi^j y^j + D$$

- Assume U is nested CES:

$$U\left(x, y, \frac{I}{w^j}; \theta^j\right) = \left[b^j Q^{j\,\frac{\rho-1}{\rho}} + \left(1-b^j\right)\left(1-\frac{I}{w^j}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$$

where,

$$Q^j = \left[a^j x^{\frac{\omega-1}{\omega}} + \left(1-a^j\right) y^{\frac{\omega-1}{\omega}}\right]^{\frac{\omega}{\omega-1}}$$

  – Same ρ (elasticity of substitution between leisure and non-leisure goods) for everyone;

  – Same ω (elasticity of substitution between energy and non-energy goods) for everyone;

  – Different tastes captured by different a^j's, b^j's $(j = 1, 2, 3, 4)$:

- Assume constant marginal desutility of pollution, $\varphi \Rightarrow \phi(E) = \varphi E$

	Type 1	Type 2	Type 3	Type 4
π	35.18%	28.90%	28.86%	7.06%
$I = wL$	68711.85	40147.16	31887.37	44111.02
px	51134	34742	29155	37498
qy	3051	2612	2520	3100
$qy/\left(px+qy\right)$	5.63%	6.99%	7.96%	7.64%
n	1.33620	0.90094	0.71472	0.88815
L	0.50731	0.43961	0.44015	0.48998
t	28%	15%	15%	15%
G	9797	2195	2280	2363
M	-5085	1035	2290	741
a	0.999972	0.999934	0.999889	0.999906
b	0.532012	0.399702	0.394383	0.467470

The Government

- The government is designing an optimal tax system consisting of:
  - A non-linear income tax
  - Linear taxes on energy as a consumption good and as an input

Data

- Data source:
  - PSID and US Bureau of Labor Statistics: data on household's consumption, income and labor
  - US Bureau of Economic Analysis: Data from EUKLEMS on capital labor and energy
- 4 categories of households: only those with wage income
  - Managers & professionals (type 1)
  - Technical sales & clerical workers (type 2)
  - Service workers, operators, fabricators & laborers (type 3)
  - Construction workers & mechanics (type 4)

Calibration

- Some based on the existing estimates in the literature (σ, δ), others to make the data consistent with our model (see details in CGL 2010)
- The MSD of emissions: we use 3 different values for φ
  - $\varphi = 0$: no externality
  - $\varphi = 0.05$: the marginal social damage of a unit of polluting good (or input) would imply a 10 % Pigouvian tax at first best
  - $\varphi = 0.24$: the marginal social damage of a unit of polluting good (or input) would imply a 50 % Pigouvian tax at first best

The Social welfare function

$$W = \frac{1}{1-\eta} \sum_{j=1}^{4} \pi^{j} \left(\mho^{j} \right)^{1-\eta} \quad \eta \neq 1 \text{ and } 0 \leq \eta < \infty$$

- η, is the "*inequality aversion index*", the higher is η the more the society cares about equality
- We use η: 0.1, a value chosen according to the observed degree of redistribution of existing tax system (see Bourguignon and Spadaro (2000))

General income tax + linear commodity taxes

- Let $c^j \equiv G^j + w_n^j L^j$ (G^j is the income adjustment term needed for linearizing the budget constraint)
- Determine "conditional" demand functions;

$$x^j = \mathbf{x}(p, q, c^j; \theta^j)$$
$$y^j = \mathbf{y}(p, q, c^j; \theta^j)$$

- $\Rightarrow$

$$\mathbf{V}\left(p, q, c^j, \frac{I^j}{wn^j}; \theta^j\right) = \mathbf{U}\left(\mathbf{x}(p, q, c^j; \theta^j), \mathbf{y}(p, q, c^j; \theta^j), \frac{I^j}{wn^j}; \theta^j\right)$$

- Deriving the optimal tax structure: the government chooses q, c^j, I^j, K, D, w to maximize,

$$\frac{1}{1-\eta}\sum_{j=1}^{4}\pi^j\left[\mathbf{V}\left(p,q,c^j,\frac{I^j}{wn^j};\theta^j\right)-\varphi\left(\sum_{j=1}^{4}\pi^j\mathbf{y}(p,q,c^j;\theta^j)\right)-\varphi D\right]^{1-\eta}$$

under the resource constraint,

$$\mathbf{O}(L,K,D)-\sum_{j=1}^{4}\pi^j\left[\mathbf{x}\left(p,q,c^j;\theta^j\right)+p_D\mathbf{y}(p,q,c^j;\theta^j)\right]-rK-p_DD-\bar{R}\geq 0$$

the incentive compatibility constraints,

$$\mathbf{V}\left(p,q,c^j,\frac{I^j}{wn^j};\theta^j\right)\geq\mathbf{V}\left(p,q,c^k,\frac{I^k}{wn^j};\theta^j\right)\quad j\neq k=1,2,3,4$$

and the endogeneity of wage condition,

$$w-\mathbf{O}_L(L,K,D)=0 \text{ with } L=\sum_{j=1}^{4}\pi^jn^jL^j$$

Simulations

- The government's problem is solved for many values of the parameters:
  - 11 values of p_D are considered: from $p_D = 1$ (no shock) to 2 (100% energy shock)
  - 3 values of φ are considered: 0 (no externality), 0.05 (weak externality) and 0.24 (strong externality)
- We calculate two different energy prices:
  - The Pigouvian price (price when the pigouvian rule is applied)
  - The optimal price (price when the second best optimal tax is applied)

Optimal energy taxes

- There are 2 forces at work:
  - The Pigouvian one to correct for the marginal social damage of emissions
  - A subsidy to mitigate the regressive bias of the energy tax (the share of energy expenditures tends to decrease with income)
- In case of energy input, only the first of the 2 forces is at work
- In case of energy consumption goods the 2 forces are at work (optimally designed income tax cannot eliminate completely the redistributive bias)

Optimal and Pigouvian taxes of energy

- Expressed in units of the numeraire output the Pigouvian tax is given by (it does not directly depends on p_D)

$$\tau^{pig} = q^{pig} - p_D = \left[\boldsymbol{V}\left(p, q, c^j, \frac{I^j}{wn^j}; \theta^j\right) - \varphi \sum_{j=1}^{4} \pi^j \boldsymbol{y}\left(p, q, c^j; \theta^j\right) - \phi D \right]^{-\eta} \frac{\varphi}{\mu},$$

- The optimal energy tax is given by,

$$q - p_D = \tau^{pig} + \frac{\sum_{j=1}^{4} \sum_{k \neq j} \lambda^{kj} \left\{ \mathbf{V}_c\left(q, c^j, \frac{I^j}{wn^k}; \theta^k\right) \left[\mathbf{y}\left(q, c^j; \theta^j\right) - \mathbf{y}\left(q, c^j; \theta^k\right) \right] \right\}}{\mu \sum_{j=1}^{4} \pi^j \widetilde{\mathbf{y}}_q\left(q, c^j; \theta^j\right)}$$

The Pigouvian tax ($\varphi = 0.24$)

- Expressed in units of the numeraire the energy input tax slightly decreases with the international price of energy (from 0.48 to 0.44), expressed as a percentage of the energy price it is divided by more than 2 when p_D is increased by 100%

p_D	τ^{pig}	τ^{pig}/p_D
1.0	0.4823	48,23%
1.1	0.4769	43,35%
1.2	0.4718	39,32%
1.3	0.4668	35,91%
1.4	0.4622	33,01%
1.5	0.4577	30,51%
1.6	0.4534	28,34%
1.7	0.4493	26,43%
1.8	0.4454	24,74%
1.9	0.4416	23,24%
2.0	0.4380	21,90%

The Redistributive subsidy

- The optimal tax rate, $(q - p_D)/p_D$, is the sum of a Pigouvian term, τ^{pig}/p_D and of a redistributive subsidy $\left(q - q^{pig}\right)/p_D$

$$\frac{q - p_D}{p_D} = \frac{\left(q - q^{pig}\right) + \left(q^{pig} - p_D\right)}{p_D} = \frac{q - q^{pig}}{p_D} + \frac{\tau^{pig}}{p_D},$$

The optimal tax ($\varphi = 0.24$)

- The optimal tax rate, $(q - p_D)/p_D$, decreases because the Pigouvian term, τ^{pig}/p_D, decreases; the redistributive subsidy, $\left(q - q^{pig}\right)/p_D$, moves only slightly

p_D	q^{pig}	q	$q - p_D$	$q - q^{pig}$	τ^{pig}	$\frac{q-p_D}{p_D}$	$\frac{q-q^{pig}}{p_D}$	τ^{pig}/p_D
1.0	1.4823	1.3359	0.3359	-0.1464	0.4823	33.59 %	-14.64%	48,23%
1.1	1.5769	1.4210	0.3210	-0.1559	0.4769	29.19 %	-14.17%	43,35%
1.2	1.6718	1.5064	0.3064	-0.1654	0.4718	25.53 %	-13.78%	39,32%
1.3	1.7668	1.5920	0.2920	-0.1748	0.4668	22.46 %	-13.45%	35,91%
1.4	1.8622	1.6777	0.2777	-0.1845	0.4622	19.84 %	-13.18%	33,01%
1.5	1.9577	1.7637	0.2637	-0.1940	0.4577	17.58 %	-12.93%	30,51%
1.6	2.0534	1.8499	0.2499	-0.2035	0.4534	15.62 %	-12.72%	28,34%
1.7	2.1493	1.9362	0.2362	-0.2131	0.4493	13.89 %	-12.54%	26,43%
1.8	2.2454	2.0226	0.2226	-0.2228	0.4454	12.37 %	-12.38%	24,74%
1.9	2.3416	2.1092	0.2092	-0.2324	0.4416	11.01 %	-12.23%	23,24%
2.0	2.4380	2.1960	0.1960	-0.2420	0.4380	9.80 %	-12.10%	21,90%

Interpreting the results: implicit subsidy when $\varphi = 0$

- Define the implicit subsidy rate as the subsidy expressed as a percentage of the Pigouvian price ($\left(q^{pig} - q\right) / q^{pig}$); with no externality the Pigouvian term is 0 but the implicit subsidy still remains and is shown equal to 10% of $q^{pig} = p_D$ whatever the level of this price

p_D	q	$p_D - q$	$\frac{p_D-q}{p_D} = \frac{q^{pig}-q}{q^{pig}}$
1.0	0.8993	0.1007	10.07 %
1.1	0.9892	0.1108	10.07 %
1.2	1.0791	0.1209	10.07 %
1.3	1.1690	0.1310	10.07 %
1.4	1.2589	0.1411	10.08 %
1.5	1.3488	0.1512	10.08 %
1.6	1.4387	0.1613	10.08 %
1.7	1.5287	0.1713	10.08 %
1.8	1.6186	0.1814	10.08 %
1.9	1.7085	0.1915	10.08 %
2.0	1.7984	0.2016	10.08 %

Interpreting the results: implicit subsidy when $\varphi = 0.05$ and $\varphi = 0.24$

- The implicit subsidy rate is not affected by the externality (nearly 10% as with $\varphi = 0$) and not affected by an energy shock (nearly 10% for any value of p_D)

p_D	$\phi = 0$	$\phi = 0.05$	$\phi = 0.24$
1.0	10.07 %	10,02%	9,88%
1.1	10.07 %	10,03%	9,88%
1.2	10.07 %	10,03%	9,89%
1.3	10.07 %	10,03%	9,90%
1.4	10.08 %	10,04%	9,90%
1.5	10.08 %	10,04%	9,91%
1.6	10.08 %	10,04%	9,91%
1.7	10.08 %	10,04%	9,92%
1.8	10.08 %	10,04%	9,92%
1.9	10.08 %	10,05%	9,92%
2.0	10.08 %	10,05%	9,93%

Conclusion

- Optimal energy taxes are affected by redistributive consideration (optimal energy tax is less than Pigouvian tax)
- The difference between optimal and Pigouvian energy taxes is roughly 10% of the Pigouvian price
- An exogenous variation in the energy price has an almost negligible effect on this percentage
- Optimal energy price decreases as the price of energy, p_D, increases but this result is only explained by the fact that the Pigouvian tax rate decreases as p_D increases (because the marginal social damage does not change when p_D increases)

Extension of the model: Energy is considered as an input that together with equipments produces a service (heating, ...)

- Preferences are CES in leisure, l, and non leisure goods, C. That is,

$$u^{-\gamma} = bC^{-\gamma} + (1-b)\, l^{-\gamma} \tag{1}$$

- The subutility in non leisure goods is also CES,

$$C^{-\omega} = ay^{-\omega} + (1-a)\, h^{-\omega} \tag{2}$$

where x and h are respectively clean goods end energy services (the dirty good) consumptions.

- h is given by,

$$h^{-\rho} = dS^{-\rho} + (1-d)\, x^{-\rho}$$

- From (1) and (2), it follows,

$$u^{-\gamma} = b\left[ay^{-\omega} + (1-a)\left[dS^{-\rho} + (1-d)\, x^{-\rho}\right]^{\frac{\omega}{\rho}}\right]^{\frac{\gamma}{\omega}} + (1-b)\, l^{-\gamma} \tag{3}$$

The calibration process is similar the one used previously

- We maximize (3) under the linearized budget constraint,

$$py + qx + r\delta S = w_n L + M \tag{4}$$

- that can also be written,

$$px + qy + r\delta S + w_n l = w_n + M \tag{4'}$$

where p and q are the prices of x and y respectively.

- First order conditions gives,

$$\begin{aligned}
\frac{1-d}{d} &= \frac{p}{\delta r}\left(\frac{x}{S}\right)^{1+\rho} \\
\frac{1-a}{a} &= \frac{y^{-\omega-1}}{(1-d)\left[dS^{-\rho}+(1-d)\,x^{-\rho}\right]^{\frac{\omega}{\rho}-1} x^{-\rho-1}}\frac{q}{p} \\
\frac{b}{1-b} &= \frac{l^{-\gamma-1}}{a\left[ay^{-\omega}+(1-a)\left[dS^{-\rho}+(1-d)\,x^{-\rho}\right]^{\frac{\omega}{\rho}}\right]^{\frac{\gamma}{\omega}-1} y^{-\omega-1}}\frac{q}{w_n}
\end{aligned}$$