

Can Rebate of Revenue Make Environmental Taxes Progressive?



Don Fullerton

The University of Illinois at Urbana-Champaign

Holly Monti

The University of Texas at Austin



Motivation

- Important to know not only costs and benefits of environmental policies, but also the effects they will have on different people
- Distribution of costs depends of what is done with any policy-driven revenue (taxes or auctioned permits)
- Research done on the distribution of costs of pollution policies mostly uses partial equilibrium models, focusing only on output prices and ignoring the sources side of income
 - environmental taxes are regressive



Motivation

- Pollution policy can affect individuals through other means (wage rates)
- Returning tax revenue through lower taxes on low income workers may raise net wage of the low-income group, but it is important to know conditions under which this effect is enough to offset higher prices



Related Literature

- Double dividend literature has focused on efficiency considerations.
- Metcalf (1999, 2009), Dinan and Rogers (2002), and West and Williams (2004) empirically estimate incidence of environmental tax swap, focusing on the uses side of income.



Research Question

- What are the distributional effects of a pollution tax on both the uses and sources side of income when there is revenue-neutral pollution tax?



Contribution

- Analytical general equilibrium model that analyzes distributional effects on the uses side and sources side of a revenue-neutral pollution tax, where tax revenue used to lower pre-existing labor tax
- Find closed-form solutions for change in the real unskilled wage and skilled wage to show general conditions under which relative real wages rise or fall



The Model

- Analytical general equilibrium model similar to Fullerton and Heutel (2007)
- This model is used to solve for changes in prices and quantities as the result of an increase in a pollution tax.
- Competitive two sector economy that uses two factors of production (skilled and unskilled labor), and pollution is also used as in input for the “dirty” sector.



The Model

CRTS production functions :

$$X = X(H_X, L_X)$$

$$Y = Y(H_Y, L_Y, Z)$$

where X is the "clean" good, Y is the "dirty" good,
 H is high - skilled labor, and L is low - skilled labor.

resource constraints :

$$H_X + H_Y = \bar{H}$$

$$L_X + L_Y = \bar{L}$$

differentiate constraints :

$$\frac{dH_X}{\bar{H}} + \frac{dH_Y}{\bar{H}} = \frac{d\bar{H}}{\bar{H}} = 0$$

$$\frac{dH_X}{\bar{H}} \frac{H_X}{H_X} + \frac{dH_Y}{\bar{H}} \frac{H_Y}{H_Y} = 0$$

$$(1) \hat{H}_X \lambda_{HX} + \hat{H}_Y \lambda_{HY} = 0 \text{ where } \hat{H}_X = \frac{dH_X}{H_X} \text{ and } \lambda_{HX} = \frac{H_X}{\bar{H}}$$

similarly,

$$(2) \hat{L}_X \lambda_{LX} + \hat{L}_Y \lambda_{LY} = 0$$

- Government budget constraint:

$$G = \tau_Z Z + h\tau_H \bar{H} + w\tau_L \bar{L} + p_y \tau_y Y + p_x \tau_x X$$

$$p_L = w(1 + \tau_L), p_H = h(1 + \tau_H)$$

- Assume that $d\tau_H = d\tau_X = d\tau_Y = dG = 0$

- Producers of X can substitute between skilled and unskilled labor in response to changes in prices:

$$(4) \hat{H}_X - \hat{L}_X = \sigma_X (\hat{p}_L - \hat{p}_H)$$

where $\hat{p}_L = \hat{w} + \hat{\tau}_L$, $\hat{p}_H = \hat{h}$, and σ_X is the elasticity of substitution in production

- e_{ij} is the Allen elasticity of substitution between inputs i and j
 - $e_{ij} > 0$ for substitutes and $e_{ij} < 0$ for complements
- θ_{Yj} is the share of sales revenue from Y that is used to purchase factor j

- Differentiate input demand functions (input demands are functions of prices p_L , p_H , and p_Z):

$$(5) \hat{H}_Y - \hat{Z} = \theta_{YH}(e_{HH} - e_{ZH})\hat{h} + \theta_{YL}(e_{HL} - e_{ZL})(\hat{w} + \hat{\tau}_L) + \theta_{YZ}(e_{HZ} - e_{ZZ})\hat{\tau}_Z$$

$$(6) \hat{L}_Y - \hat{Z} = \theta_{YH}(e_{LH} - e_{ZH})\hat{h} + \theta_{YL}(e_{LL} - e_{ZL})(\hat{w} + \hat{\tau}_L) + \theta_{YZ}(e_{LZ} - e_{ZZ})\hat{\tau}_Z$$

- Perfect competition and CRTS imply that sales revenue in each sector equals the sum of payments to factors of productions.

- Consumption of the two goods is divided between both types of laborers and government so that

$$X = X_L + X_H + X_G \quad \text{and} \quad Y = Y_L + Y_H + Y_G$$

- Consumer demand response to a change in prices is given by

$$(13) \hat{X}_L - \hat{Y}_L = \sigma_U (\hat{p}_Y - \hat{p}_X)$$

$$(14) \hat{X}_H - \hat{Y}_H = \sigma_U (\hat{p}_Y - \hat{p}_X)$$

where σ_U is the elasticity of substitution in utility

- Assuming government has same elasticity of substitution,

$$(15) \hat{X}_G - \hat{Y}_G = \sigma_U (\hat{p}_Y - \hat{p}_X)$$

- Government and skilled labor budget constraints are

$$G = p_X(1 + \tau_X)X_G + p_Y(1 + \tau_Y)Y_G$$

$$p_X(1 + \tau_X)X_H + p_Y(1 + \tau_Y)Y_H = h(H_X + H_Y)$$

- Revenue neutrality condition: $dG = 0$



Results

- Solve 17 equations through successive substitution
- Variables of interest are \hat{h} , \hat{w} , \hat{p}_Y , \hat{Z} , and $\hat{\tau}_L$
- 2 main effects:
 - Output effect - higher pollution tax reduces demand for intensively used factor in production of Y
 - Substitution effect - higher pollution tax helps high-skilled labor ($\hat{h} > 0$) whenever $e_{HZ} > e_{LZ}$

Case 1: Equal Factor Intensities

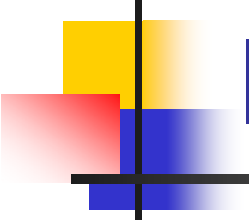
- Means that $\frac{H_Y}{H_X} = \frac{L_Y}{L_X} = \gamma$
- Eliminates output effect
- Solutions are

$$(19a) \quad \hat{p}_Y = \theta_{YZ} \hat{\tau}_Z$$

$$(19b) \quad \hat{w} = \frac{-\theta_{XH} \theta_{YZ} \gamma (e_{HZ} - e_{LZ})}{D_1} \hat{\tau}_Z - \hat{\tau}_L$$

$$(19c) \quad \hat{h} = \frac{\theta_{XL} \theta_{YZ} \gamma (e_{HZ} - e_{LZ})}{D_1} \hat{\tau}_Z$$

where $D_1 = (\sigma_X - \theta_{XL} \theta_{YH} \gamma e_{HH} - \theta_{XH} \theta_{YL} \gamma e_{LL}) + \gamma (\theta_{XL} \theta_{YH} + \theta_{XH} \theta_{YL}) e_{HL}$



Case 2: Equal Factor Intensities and $e_{HZ} = e_{LZ}$

- Special version of Case 1 where low-skilled and high-skilled labor are equally substitutable for pollution (no substitution effects)

- Solutions are

$$(20a) \quad \hat{p}_Y = \theta_{YZ} \hat{\tau}_Z$$

$$(20b) \quad \hat{w} = -\hat{\tau}_L$$

$$(20c) \quad \hat{h} = 0$$

Case 3: Fixed Input Proportions ($e_{ij}=0$)

- No more substitution effects, only output effect left

$$(21a) \quad \hat{p}_Y = \frac{[C\sigma_X - (\gamma_H - \gamma_L) \frac{1}{C_H} h\bar{H}(\frac{Y_H}{Y_L} - \frac{X_H}{X_L})] \theta_{YZ}}{D_3} \hat{\tau}_Z$$

$$(21b) \quad \hat{w} = \frac{\theta_{XH} \theta_{YZ} (\gamma_H - \gamma_L) (\sigma_U N + J)}{D_3} \hat{\tau}_Z - \hat{\tau}_L$$

$$(21c) \quad \hat{h} = -\frac{\theta_{XL} \theta_{YZ} (\gamma_H - \gamma_L) (\sigma_U N + J)}{D_3} \hat{\tau}_Z$$

$$\text{where } D_3 = C\sigma_X - (\gamma_H - \gamma_L) (\sigma_U N + J) (\theta_{XH} \theta_{YL} - \theta_{XL} \theta_{YH}) - (\gamma_H - \gamma_L) \frac{1}{C_H} h\bar{H}(\frac{Y_H}{Y_L} - \frac{X_H}{X_L})$$



Interpretation

- For $\gamma_H > \gamma_L$ (dirty sector is high-skilled intensive),
 $\hat{p}_Y > 0$
 $\hat{h} < 0$
 $\hat{w} > 0$
- For $\gamma_H < \gamma_L$, signs of \hat{p}_Y , \hat{h} , and \hat{w} can all be positive or negative depending on the relative factor intensities and consumption patterns



Effects on the Uses Side

- Real net wage for unskilled is: $\omega = \frac{w}{p_Q^L}$
where $p_Q^L = \alpha_L p_Y (1 + \tau_Y) + (1 - \alpha_L) p_X (1 + \tau_X)$
and α_L is unskilled labor's share of expenditure on Y
- Real wages increase if $\hat{w} > \alpha_L \hat{p}_Y$ and $\hat{h} > \alpha_H \hat{p}_Y$
- Real net wage unskilled wage may fall if
 - H is a better substitute for pollution than L
 - Dirty sector is low-skilled intensive
 - low-skilled labor spends too disproportionately on dirty good



Numerical Simulation

- Data from EPA's Toxic Release Inventory to define “dirty” sector (includes mining, utilities, chemical manufacturing etc.)
- Data from Occupational Employment Survey (OES) provides factor shares for skilled, unskilled labor
- Use CEX data for α parameters
 - Bottom 3 income quintiles correspond to unskilled laborers (income is \$10,531, \$27,674, and \$46,213) and top 2 quintiles make up skilled labor group
 - Add up spending on natural gas, electricity, fuel oil, and gasoline to approximate spending on the “dirty” good: $\alpha_L = 12\%$, $\alpha_H = 5\%$



Numerical Simulation Results

- Burden of the extra tax is the sum of the losses in real net income for both types of labor

Table 5: Burden shares for unskilled, skilled labor

Row	e_{HZ}	e_{LZ}	B_L^G / B	R_L / B	B_L^N / B	B_H / B
1	1	-0.5	4.51437	3.20094	1.31343	-0.31343
2	0	0	5.38446	5.66081	-0.27635	1.27635
3	0.5	0	3.72446	3.14733	0.57713	0.42287
4	1	0	3.00732	2.06266	0.94467	0.05533
5	-0.5	0.5	4.39101	6.33258	-1.94156	2.94156
6	0	0.5	2.96702	3.23231	-0.26529	1.26529
7	0.5	0.5	2.41545	2.03331	0.38214	0.61786
8	1	0.5	2.12206	1.39694	0.72512	0.27488
9	-0.5	1	2.16087	3.50315	-1.34228	2.34228
10	0	1	1.81286	2.07935	-0.26650	1.26650
11	0.5	1	1.64067	1.37772	0.26294	0.73706
12	1	1	1.53750	0.95987	0.57769	0.42231



Conclusion

- Tax cut for low-skilled workers has a positive impact on the net low-skilled wage, but may not be enough to overcome the pollution tax burden:
 - High-skilled labor better substitute for pollution than low-skilled labor
 - Dirty sector is low-skilled labor intensive
 - Low-income families spend disproportionately on the dirty good
- Numerical analysis showed that nominal low-skilled wage increases for all cases, but low-skilled workers can still bear a disproportionate burden of the tax

Questions or comments?

Thank you!