# Can Rebate of Revenue Make Environmental Taxes Progressive?

Don Fullerton
*The University of Illinois at Urbana-Champagne*

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 contraints:

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

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

differentiate constraints:

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

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

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

similarly,

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

- Government budget constraint:

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

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

- 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 $\sigma_X$ 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

- $\theta_{Yj}$ 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

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

- 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* $\sigma_U$ 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 $\hat{h}, \hat{w}, \hat{p}_Y, \hat{Z}, \text{and } \hat{\tau}_L$
- 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

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

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

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

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

# 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 $\hat{p}_Y, \hat{h}, \text{and } \hat{w}$ 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 $\alpha_L$ 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 $\alpha$ 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!