

Environmental Levies, Distortionary Taxation and Increasing Returns

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In this note, we introduce increasing returns to Bovenberg and Mooij's (1994) model as generalised in Fullerton (1997) and use an example to show that (1) even with a distortionary labor tax, the optimal environmental levy is greater than the Pigouvian rate; (2) the difference between tax on the “dirty” good and the “clean” good is also greater than the Pigouvian tax; (3) under certain circumstances, the government can optimally use the environmental levy to both meet its revenue requirement and subsidize the “clean” goods with increasing returns.

Key Words: Environmental levies, Distortionary taxation, Increasing returns.

JEL Classification Numbers: H21, H23.

1. INTRODUCTION

In a well-cited paper, Bovenberg and De Mooij (1994) develop a two-sector model with a pollution-generating “dirty” good and a “clean” good. They demonstrate that in the presence of a government revenue requirement and a distortionary tax on labor income, an environmental levy on the dirty good tends to exacerbate rather than alleviate the preexisting tax distortions even if the revenues are used to cut the preexisting distortionary labor tax. The reason for this is that an environmental levy lowers after-tax real wages thereby reducing people's incentives to work. Due to its negative impact on employment, the optimal environmental levy is lower than the Pigouvian level. Fullerton (1997) offers a different perspective based on a generalised model of Bovenberg and De Mooij's (1994). He notes that since a tax on labor is equivalent to a tax on both the “dirty” and “clean” goods, the environmental levy (on top of the labor tax and in the absence of a separate tax on the clean good) may be lower than the

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Pigouvian level. However, if the clean good is also taxed to help meet the government's revenue requirement, then the tax on the "dirty" good can exceed the Pigovian rate. It is the difference between the tax on the dirty good and the tax on the clean good, not the environmental levy itself that is less than the Pigovian rate.

The results of Bovenberg and De Mooij (1994) and Fullerton (1997) are obtained on the basis of constant return technologies. Casual observation suggests that the development of clean technologies requires considerable fixed costs, which gives rise to increasing returns to scale. Thus it is worthwhile asking how their results change in the context of increasing return technologies.

In this note, we introduce increasing returns to Bovenberg and De Mooij's model as generalised by Fullerton (1997) and ask the following questions. First, in the presence of externality from pollution, increasing returns in the "clean" industry, and a government revenue requirement, what is the optimal tax structure? Second, how does the optimal tax on "dirty" goods compare to the Pigovian rate? We use a version of Dixit and Stiglitz's (1977) monopolistic competition model to characterize production in the "clean" industry because competition among different varieties of clean technologies (and goods produced with different clean technologies) is intense, which is characteristic of what happens in a monopolistically competitive market.

Since monopolistically competitive firms with increasing returns price at average cost rather than marginal cost, there is under-production which provides scope for public policy intervention (Ng and Zhang, 2007). If an economy has both negative externality from pollution and increasing returns in the "clean" industry in an economy, "clean" goods would be doubly underprovided by markets (Jaffe, Newell and Stavins, 2005). Thus intuitively, the optimal tax structure would need to address the over-production in the "dirty" industry due to the externality of pollution, the under-production in the "clean" industry due to increasing returns as well as meeting the government's revenue requirement. It is likely then that the optimal environmental levy will exceed the Pigouvian rate in Bovenberg and De Mooij's (1994) model setting of a distortionary labor and zero tax on the clean good. This is indeed what our model shows.

2. MODEL

Consider an economy with N consumers who derive utility from good X , a set of differentiated goods Y , a public good G , leisure V , and environmental quality E . The production of good X uses a "dirty" technology such that for each unit of good X produced a unit of pollutants is emitted, which lowers environmental quality. Specifically, $E = (Nx)^{-1}$, where x is

the quantity of good X produced. Goods Y are produced using “clean” technologies with zero emissions. Public good G is provided by the government in a fixed quantity and is financed by taxes. The government can tax labor and all commodities.

The representative consumer has one unit of time for both labor and leisure. His utility function is:

$$U = u(x, y, v, G, E), \quad y = \left(\sum_{i=1}^n y_i^\rho \right)^{\frac{1}{\rho}} \quad (1)$$

where n is the number of varieties of the clean good.

Assuming a large N , the representative consumer considers the environmental damage associated with his own consumption of good X to be negligible, therefore he takes E (and G , which is assumed to be fixed,) as given, and maximizes utility subject to the budget constraint:

$$p_x x + \sum_{i=1}^n p_{y_i} y_i = (1 - t_L)(1 - v) \quad (2)$$

where p_x and p_{y_i} are the prices of goods X and the i^{th} variety of good Y ; w is the wage rate normalized to be 1; v is leisure ($v = 1 - l$), and t_L is the tax rate on labor income.

Labor is the only factor of production in the economy. The production technologies for goods X and the public good G exhibit constant returns to scale. We define their units such that their unit cost is one:

$$X = L_x, \quad G = L_G \quad (3)$$

Each firm in the Y industry produces a differentiated product Y_i , and engages in monopolistic competition. The production of good Y_i involves a fixed cost (f_i) such that:

$$Y_i = L_{y_i} - f_i \quad (4)$$

The existence of a fixed cost means that the production of Y_i exhibits increasing returns.

The decision problem for the X producing firm is:

$$\max \pi_x = (p_x - t_x)X - L_x \quad \text{subject to } X = L_x \quad (5)$$

Assuming symmetry in the production of all varieties of good Y , we have the decision problem of the firm producing good Y_i as:

$$\max \pi_{y_i} = (p_{y_i}(Y_i) - t_y)Y_i - L_{y_i} \quad \text{subject to } Y_i = L_{y_i} - f_i \quad (6)$$

where t_x and t_y are unit tax rates on good X and Y respectively.

In equilibrium, the labor market clears:

$$Nx + G + N \sum_{i=1}^n y_i + \sum_{i=1}^n f_i = N(1 - v) \quad (7)$$

Solving the consumers' and producers' decision problem and using the labor market clearing condition, we can obtain the equilibrium consumer utility. The optimal tax structure is the set of tax rates chosen by the government that maximizes consumer utility:

$$U = u(t_L, t_x, t_y) = u(x^*, y_i^*, n^*, v^*, G, E^*) \quad (8)$$

Subject to the budget constraint: $G = t_L N(1 - v) + t_x X + t_y n Y_i$

In contrast to the case with constant returns, models with increasing returns usually have to rely on specific functional forms to obtain definite results¹. We derive the optimal tax structure for the model outlined above, assuming a Cobb-Douglas utility function:

$$U = u(x, y, v, G, E) = x^\alpha y^\beta v^{1-\alpha-\beta} G E^\theta, \quad (9)$$

where $y \equiv (\sum_{i=1}^n y_i^\rho)^{\frac{1}{\rho}}$; $E = (Nx)^{-1}$. The equilibrium solutions are:

$$\begin{aligned} x &= \frac{\alpha(1-t_L)}{1+t_x}; & y_i &= \frac{\beta(1-t_L)}{n^{\frac{1+t_y}{\rho}}} = \frac{\rho f}{N(1-\rho)(1+t_y)}; & v &= 1 - \alpha - \beta; \\ n &= \frac{(1-t_L)N\beta(1-\rho)}{f}; & \lambda &= \frac{U}{1-t_L} \end{aligned} \quad (10)$$

where λ is the marginal utility of income.

The Pigouvian tax (τ) is equal to the dollar cost of the environmental damage caused by the marginal unit of the dirty good (Fullerton, 1997), that is

$$\tau = - \frac{\partial U}{\partial E} \frac{de}{d(Nx)} \frac{N}{\lambda} \quad (11)$$

Substituting (10) into (11), we obtain the Pigouvian tax rate in our model:

$$\tau = \frac{\theta(1+t_x)}{\alpha} \quad (12)$$

¹Most papers following the work of Dixit and Stiglitz (1977) resort to specific functional forms, see for instance, Krugman (1983).

To obtain the optimal tax structure, we substitute results (10) into the government's decision problem (8). The optimal tax structure consists of:

$$t_L = \frac{\frac{G}{N} - \rho(\alpha - \theta) - \alpha}{\beta - \rho(\alpha - \theta)}; \quad t_x = \frac{\alpha - \rho(\alpha - \theta)}{\rho(\alpha - \theta)}; \quad t_y = 0 \quad (13)$$

That is, in our model, it is optimal for the government to meet its revenue requirement from labor tax and environmental levy. This structure coincides with Bovenberg and De Mooij's (1994) setup with positive labor tax and zero tax on the clean good. However, contrary to their conclusion that the environmental levy should be lower than the Pigouvian tax, in our model, the environmental levy is greater than the Pigouvian rate:

$$t_x = \frac{\alpha - \rho(\alpha - \theta)}{\rho(\alpha - \theta)} > \tau = \frac{\theta}{\rho(\alpha - \theta)}. \quad (14)$$

Now we follow Fullerton (1997) and look into the case where there is no distortionary labor tax, and both the dirty and the clean goods are taxed to meet the government revenue requirement. In this case, the government's decision problem (8) is constrained by $t_L = 0$. Solving the government's decision problem gives us the optimal tax rate:

$$t_x = \frac{[\alpha - (\alpha - \theta)\rho]\beta + (\alpha - \theta)\frac{G}{H}}{(\alpha - \theta)(\alpha + \rho\beta - \frac{G}{N})}; \quad t_y = \frac{\rho(\alpha - \theta) - \alpha + \frac{G}{N}}{(\alpha + \rho\beta - \frac{G}{N})} \quad (15)$$

The Pigouvian tax is still defined as $\tau \equiv -\frac{\partial U}{\partial E} \frac{de}{d(Nx)} \frac{N}{\lambda}$, which in this case is²:

$$\tau = \frac{\theta(\alpha + \beta - \theta)}{(\alpha - \theta)(\alpha + \rho\beta - \frac{G}{N})} \quad (16)$$

The difference between the tax on the dirty good and the clean good is:

$$t_x - t_y = \frac{[\alpha - (\alpha - \theta)\rho](\alpha + \beta - \theta)}{(\alpha - \theta)(\alpha + \rho\beta - \frac{G}{N})} \quad (17)$$

Comparing equations (17) and (16), we see that

$$t_x - t_y > \tau \quad (18)$$

That is, different from Fullerton's (1997) conclusion, in our model, the difference between the tax on the dirty good and that on the clean good is

²Fullerton (1997) notes the fact that the value of the Pigouvian tax varies depending on at which point it is evaluated.

greater than the Pigouvian rate. Moreover, it is easy to see that:

$$t_y = \frac{\rho(\alpha - \theta) - \alpha + \frac{G}{N}}{(\alpha + \rho\beta - \frac{G}{N})} < 0 \quad \text{if} \quad \frac{G}{N} < \alpha - \rho(\alpha - \theta) \quad (19)$$

In other words, under certain conditions [i.e., $t_L = 0$; and $G/N < \alpha - \rho(\alpha - \theta)$], the government can optimally use the environmental levy to both meet its revenue requirement and subsidize the clean industry. These conditions are more likely to be met when per capita government revenue requirement (G/N) is small; and consumer preference over the dirty good is strong (large α) and the disutility of pollution is high (large θ).

Finally it is worth noting that in our model, the number of clean good varieties is endogenous, and decreases with the labor tax rate; but the quantity of each clean good varieties decreases with the tax rate on the clean goods. Thus if we compare two different policy combinations: one with labor tax and environmental levy ($t_L > 0$ and $t_x > 0$) and another with only taxes on commodities ($t_x > 0$ and $t_y < 0$), then the first policy combination would result in fewer clean good varieties, but a larger quantity produced (and therefore lower price) for each variety.

3. CONCLUSION

In this note, we have introduced increasing returns to Bovenberg and De Mooij's (1994) model and shown that contrary to their results obtained with constant returns technologies, in our model, (1) the optimal environmental levy is greater than the Pigouvian tax; (2) in the absence of distortionary labor tax, the difference between tax on the "dirty" good and the "clean" good is greater than the Pigouvian tax; (3) under certain circumstances, the government can optimally use the pollution tax to both meet its revenue requirement and subsidize the "clean" goods with increasing returns.

The main reason behind our results is that with increasing returns technology, the clean good is priced at average cost (which is higher than marginal cost), its output is lower than the socially optimal; thus there is a *prima facie* case for subsidy. The tax on the dirty good serves to both correct the externality from pollution and direct more resources to the increasing return industry, thus it is higher than the Pigouvian tax. Similarly, when both the dirty and the clean goods are taxed, the difference between the taxes is greater than the Pigouvian rate because the difference includes a subsidy to the clean industry. Finally, if the environmental levy can collect sufficiently large revenue it can be used to both meet the government revenue requirement and subsidize the increasing return industry.

REFERENCES

- Bovenberg, A. L., and R. A. De Mooij, 1994. Environmental Levies and Distortionary Taxation. *The American Economic Review* **84(4)**, 1085-1089.
- Dixit, A., and J. Stiglitz, 1977. Monopolistic Competition and Optimum Product Diversity. *American Economic Review* **67(3)**, 297-308.
- Fullerton, D., 1997. Environmental Levies and Distortionary Taxation: Comment. *American Economic Review* **87(1)**, 245-251.
- Jaffe, A. B., R. G. Newell, and R. N. Stavins, 2005. A Tale of Two Market Failures: Technology and Environmental Policy. *Ecological Economics* **54(2-3)**, 164-174.
- Krugman, P., 1983. New Theories of Trade Among Industrial Countries. *The American Economic Review* **73(2)**, 343-347.
- Ng, Y.-K., and D. Zhang, 2007. Average-Cost Pricing, Increasing Returns, and Optimal Output: Comparing Home and Market Production. *Journal of Economics (Zeitschrift für Nationalökonomie)* **90(2)**, 167-192.