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Is Pollution a Giffen Good? General-Equilibrium Analysis and Some Policy Implications

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Abstract:

This paper takes a simple model with pollution and environmental quality and derives some novel results. In particular, pollution is shown to be a Giffen good. This is a very important finding with clear policy implications, namely that carbon taxes (and pollution permits) are counter-productive, as they lead to increase in pollution, and instead governments should administratively set emission caps.

Keywords: pollution; carbon tax; Giffen good.

JEL Classification: Q2; Q4; Q54; Q58.

Introduction

This paper utilizes a static general-equilibrium model, augmented with preference for clean air and investigates the effect of environmental quality consideration for the aggregate economic activity. The analysis performed provides important insights with direct relevance for public policy and dispels some of the myths in the literature. In particular, the model suggests that when pollution is a Giffen good, carbon taxes become sun productive, as they generate further increase in pollution. In order to achieve pollution abatement, emission caps are more effective in this aspect.

1. Model Setup

The model setup is a simplified and static version of Vasilev (2018). In particular, there is a representative household in the model economy, which derives utility out of consumption and environmental quality. On the production side, there is a stand-in firm, which produces a homogeneous final good, and pollution as a by product, which in turn lowers the level of environmental quality. The government imposes a carbon tax on output, and in addition can spend on pollution abatement activities. The government also has access to consumption and income taxation and returns the surplus revenue back to the household in a lump-sum fashion. The final good could be used for either consumption or government pollution abatement spending.

2. Household

The representative one-member household values consumption and environmental quality:

$$\ln c + \ln q, \tag{1}$$

where c denotes household's consumption, and q is its preference for clean environment ("environment quality"). As in Vasilev (2018), we define the last term as a "good" (or absence of pollution, hence "more is better"), and not as a "bad" (stock of pollution). This is done to preserve the positive monotonicity in household's preferences. In addition, environmental quality will possess all the features of a public good.

For simplicity, there will be no physical capital. The household owns the firm in the economy, and has a legal claim on the firm's profit, π . In addition to profit income, each household can generate labor income by working in the representative firm. The hourly wage rate is w ; given that the household does not value leisure, it will supply all its time endowment (normalized to unity). The household's budget constraint is as follows:

$$(1 + \tau^c)c = (1 - \tau^y)[w + \pi] + g^t, \quad (2)$$

where τ^c, τ^y denote the consumption and income tax rates, respectively, and g^t denote government transfers.

The household takes environmental quality, wages, profit, and fiscal policy variables described above as given, and chooses consumption and labour supply to maximize Eq. (1) s.t. (2)-(3). The first-order condition for consumption is

$$\frac{1}{c} = \lambda(1 + \tau^c) \quad (3)$$

The interpretation of the condition above is that in equilibrium, the household equates the marginal benefit from an additional unit of consumption and the shadow price of wealth, adjusted for the consumption tax rate. In equilibrium, $c = [(1 - \tau^y)w + g^t]/(1 + \tau^c)$. Since labour supply is a degenerate decision ($=1$), there is no optimality condition for hours.

3. Pollution and Environmental Quality

There is a representative firm in the economy, which produces a homogeneous product. Total production value y is taxed at a rate τ^E (carbon tax). The price of output is normalized to unity. The production technology $f(\cdot)$ uses labor hours h to maximize profit

$$\pi = (1 - \tau^E)f(h) - wh, \text{ where } f' > 0, f'' < 0. \quad (4)$$

In equilibrium, profit is zero, and with inelastic labor supply

$$w = (1 - \tau^E)f(1). \quad (5)$$

In this paper, the stock of environmental quality is equivalent to "absence of pollution." The environmental quality evolves according to the following law of motion:

$$q' = (1 - \delta)\bar{q} + \delta q - p + g^E, \quad (6)$$

where $\bar{q} > 0$ denotes the steady-state stock of environmental quality, $0 < \delta < 1$ is the per-sistence parameter of environment quality. p denotes the level of emitted pollution, which decreases environmental quality. To offset the effect of pollution, government can spend resources on pollution abatement (clean-up policy).

In the model, pollution p is generated as a by-product of production

$$p = \phi f(h), \quad (7)$$

where $0 < \phi < 1$ is the measure of the pollution technology that maps (say CO₂) emissions as a function of aggregate output. Note that when we solve for the decentralized competitive equilibrium, the firm will maximize profit independently of the level of pollution emitted and would produce a level of output that is larger than the socially optimal amount. In that sense, there will be a negative externality effect in the competitive equilibrium in the model, and the allocations will be inefficient.

4. Government

In the model setup, the government is levying taxes on income, taxes production, as well consumption in order to finance its spending on transfers and pollution decreasing (abatement) activities. The government budget constraint is as follows:

$$g^t + g^E = \tau^c c + \tau^E y + \tau^y w \quad (8)$$

Government spending on abatement-to-output ratio would be chosen to match the average share in data, and government transfers would be determined residually so that the government budget is balanced. Without loss of generality, transfers may be held fixed, and abatement spending could be the free variable.

5. Decentralized Competitive Equilibrium (DCE)

For the given values of the technology parameter ϕ , average tax rates τ^c, τ^y, τ^E , initial environmental quality q , the decentralized dynamic competitive equilibrium is a list of consumption and hours allocations for the

household, the level of government purchases and transfers, and a wage rate such that (i) the household maximizes its utility function subject to its budget constraint; (ii) the representative firm maximizes profit; (iii) government budget is balanced in each period; (iv) pollution and environmental quality follow their laws of motion; (v) all markets clear.

6. Discussion: Is Pollution a Giffen Good?

Once we solve the model, we can investigate how changes in the carbon tax τ^E affect pollution in equilibrium. From the firm's profit maximization condition, it follows that

$$(1 - \tau^E)f(h) - wh = 0 \quad (9)$$

Note that we have to allow hours to differ from unity in the general case. Next, totally differentiating w.r.t. the carbon tax and hours, and after some rearrangement yields

$$\frac{dh}{d\tau^E} = \frac{f(h)}{(1-\tau^E)f'(h)-w} > 0, \quad (10)$$

where the result follows from the concavity of the production function and (9). From $f' > 0$, it also follows that $\frac{dy}{d\tau^E} > 0$. Given that pollution is proportional to output, it follows that

$$\frac{dp}{d\tau^E} > 0. \quad (11)$$

Therefore, the carbon tax in a DCE is not a Pigouvian tax, and actually has negative consequences for future environmental quality, as

$$\frac{dq'}{d\tau^E} < 0. \quad (12)$$

This novel result is due to the fact that the demand for labour (and in turn, demand for final output) is upward-sloping. This makes both output and pollution Giffen goods. In that case, using a carbon tax is a bad idea, as it has the unintended consequences above. An alternative interpretation of the results is that once the pollution tax is paid, the firm has an incentive to pollute more, which is a moral hazard issue.

Note that when pollution is a Giffen good, trade in pollution permits is also ineffective. Instead, authorities might resort to emission caps. Note that only in cases when total production is the sum of output and the emitted pollution, i.e. $y + p = (1 + \phi)y$, then $\phi/(1 + \phi) \in (0,1)$ is a Pigouvian tax.

The results obtained above will not change if the carbon tax is imposed in terms of additional costs instead. In that case the firm's optimality condition will be amended to

$$f(h) - w(1 + \tau^E)h = 0 \quad (13)$$

Totally differentiating w.r.t the carbon tax and hours, and after some algebra yields

$$\frac{dh}{d\tau^E} = \frac{wh}{f'(h)-w(1+\tau^E)} > 0, \quad (14)$$

where the result follows from the concavity of the production function and (13). Therefore, our results are immune to the modelling assumption, as there is a clear equivalence between an environmental tax on revenue and a similar tax, expressed in terms of wage costs.

Conclusion

Economic policy should be based on rigorous economic models. Often, disciplined setups are able to dispel myths. This is what was achieved in this paper. Utilizing a micro-founded model with environmental quality, we show that pollution could be a Giffen good, which means that increasing the effective price of pollution via carbon taxes can produce unintended consequences, which lead to a decrease in environmental quality. This is an important and novel policy result, which suggests that instead governments should adopt emission caps to effectively restrain pollution.

References

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