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What is environmental sustainability? Optimal environmental policy as a targeting regime

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Abstract

We define and model environmental sustainability within a General-Equilibrium framework. The focus in on "environmental fiscal policy" that pursues environmental sustainability, and the optimal sustainability strategy. We compare and contrast the exogenous fiscal-policy case with the optimal (Ramsey) fiscal policy cases. We find that: (i) returning to 100 percent clean environment is not optimal, and thus not a good target, and (ii) optimal environmental policy constitutes trying to manage environmental quality within pre-specified bands, and is thus akin to inflation targeting in the monetary economics literature; we call this environmental quality targeting, which is a novel quantitative criterion to measure environmental sustainability in a dynamic context. This is the first place such an analogy has been established, and where the contribution of this note lies.

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1 Introduction and Motivation

In this brief note, we define and model environmental sustainability within a General-Equilibrium framework.[1] Our work extends Vasilev (2019b), who takes a simple static model with pollution and environmental quality.[2] The work here also uses a simplified model from Vasilev (2018), and Vasilev (2019a), where the latter characterized optimal fiscal policy in the presence of pollution, and evaluated it relative to the observed one in Bulgaria.[3] However, we do not aim to provide a thorough review of the literature, but rather provide some new results. More specifically, the novelty of this comment paper falls on a new aspect from previous research, namely the unexplored aspects of the *environmental fiscal policy*, which the environmental fiscal authority pursues in order to achieve so-called "environmental sustainability," and the optimal sustainability strategy needed to achieve that objective. We find that: (i) returning to 100 percent clean environment is not optimal, and thus not a good target, and (ii) optimal environmental policy constitutes trying to manage environmental quality within pre-specified bands, and is thus akin to inflation targeting in the monetary economics literature; we call this *environmental quality targeting*, which is a novel quantitative criterion to measure environmental sustainability in a dynamic context. This is the first place such an analogy has been established, and where the contribution of this note lies. We hope this new approach would spur some new research that would explore the synergy between several different fields within macroeconomics. The paper aims to start a new discussion, and expand the stock of knowledge, rather than being the final word on the topic covered in this note. We argue, among other things, that macroeconomists focusing on the real side of environmental dimensions could benefit from learning about developments in monetary economics starting from the late 1990s.[4]

There are also some important differences between the optimal environmental fiscal policy, as described in this paper, and the monetary policy literature (more specifically, the

[1]For other studies on the issue, the reader is referred to Golosov et al. (2014), and Vasilev (2018, 2019a, 2019b), for the case of Bulgaria in particular, as well as the references therein.

[2]Vasilev (2019b) shows pollution 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.

[3]To this end, a dynamic general-equilibrium model is calibrated to Bulgarian data. The main findings are: (i) The optimal steady-state income tax rate is zero; (ii) the benevolent Ramsey planner provides 20 % higher utility-enhancing environmental quality; (iii) the optimal level of carbon taxes is almost three times higher, and the optimal level of abatement spending is six times higher; (iv) the optimal steady-state consumption tax is twice lower.

[4]For some of the classical studies, the interested reader is referred to Bernanke and Mishkin (1997), Taylor (1993), Svensson (1999a, 1999b), Gali (2015), Walsh (2017), Romer (2019), and the references therein.

inflation targeting literature) as well. In particular, in the presence of a committment device, such as a rule in place, there is no inflation-bias equivalent, as there is no benefit (no seigniorage) for the government from producing, or allowing for surprise pollution. In the model setup, pollution is a result of dirty production, so there is no equivalent of setting pollution expectations low ex ante, and then providing an unexpectedly high level of pollution ex post. What is there from the monetary policy literature, is the aim to stabilize the level of pollution, and in turn, the level of environmental quality, while also taking into consideration the real economy. We discuss this in the optimal fiscal policy section. This representation, which is based on a second-order expansion of the utility function around the steady-state a la Woodford (2003), is reminiscent of the central bank's minimizing a weighted average of output and inflation variation, while here the environmental fiscal authority is doing so with variance of consumption and environmental quality. In the dynamic context, which is beyond the scope of the current paper, the policy will be forward-looking, as in Vasilev (2019a),[5] and in addition, would correspond to a flexible inflation targeting regime, with respect to the environmental quality, where the government uses environmental fiscal policy like an interest-rate rule a la Taylor (1993) to achieve its environmental objective.

The paper is structured as follows: Section 2 presents the model, Section 3 defines the competitive equilibrium, Section 4 discussed the exogenous-policy solution, and Section 5 presents the optimal (Ramsey) policy solution. Section 6 concludes.

2 The Model

The model is populated by a representative household, a representative firm, and a government. The setup is static, and without physical capital, which allows us to focus on the environmental issues as hand.

2.1 Representative Household

The representative household in this model economy, which, similar to the case in Vasilev (2019b), maximizes the following utility function:

$$\max_{\{c,h\}} \left\{ \ln(c) + \ln(q) \right\}, \tag{1}$$

[5]It could be also hybrid, akin to the hybrid New Phillips curve, e.g., in Gali (2015); after all, past pollution matters for the level of the future pollution.

where c and q denote private consumption, and environment quality (or, alternatively, absence of pollution), respectively.

The household owns the firm, so all the profit is received as dividend income (π). In addition, the household can generate labor income, by supplying h hours from its time endowment, here normalized to unity, at the going hourly wage of w. Thus, the budget constraint faced by the household is

$$c = wh + \pi. \tag{2}$$

In addition, given the environmental concerns, there will be also a *sustainability* constraint:

$$q \geq \underline{q} > 0, \tag{3}$$

where $\underline{q}$ is some minimum acceptable level of environmental quality (or the level beyond which the environmental quality is irrecoverable). Note that the household does not choose q, it takes it as given; however, household's actions may affect q', i.e., next-period environment quality.

The household problem is then to maximize (1) s.t (2)-(3), and taking w, π as given. The first-order optimality conditions (FOCs) are as follows:

$$c : \frac{1}{c} = \lambda, \tag{4}$$

or in other words, the marginal utility of consumption equals the marginal utility of wealth. Note that there is no first-order optimality condition (FOC) for h, as in equilibrium the household will choose a corner solution, $h = 1$, for hours, due to the fact that leisure is not valued. Optimal consumption is then $c = w + \pi$.

2.2 Representative Firm

There is a representative firm, which rents labor from the household to produce output (y), where $y = f(h)$, where $f' > 0$, $f'' < 0$. Production is dirty, and pollution (p) is produced as a by-product in the amount of $p = \phi f(h)$, where $0 < \phi < 1$. In order to decrease pollution, the government taxes the firm as follows: Firm's revenues are subject to an environmental tax, which is modelled as a tax on output. The problem then faced by the firm is to maximize

$$\pi = (1 - \tau^E)f(h) - wh, \tag{5}$$

From the consumer problem we obtained that $h = 1$, hence

$$\pi = (1 - \tau^E) f(1) - w. \tag{6}$$

Assuming free entry, or $\pi = 0$ in equilibrium, this solves for the wage rate

$$w = (1 - \tau^E) f(1), \tag{7}$$

and pollution:

$$p = \phi f(1), \tag{8}$$

where we have used that output is

$$y = f(1). \tag{9}$$

Clearly, there is a negative externality in this model, as the firm does internalize for the generation of pollution. The firm only maximized profit.[6]

2.3 Government

The government raises environmental tax revenue, and spends on pollution abatement activities. In other words,

$$\tau^E y = g^E, \tag{10}$$

or

$$g^E = \tau^E f(1)$$

Thus, spending on abatement is conditional on the tax revenue raised. However, given that taxation is distortionary, taxation to finance abatement has the negative aspect of discouraging production.

2.4 Evolution of environmental quality

Starting from 100 percent clean environment ($\bar{q}$), over time the quality decreases - this is captured by the depreciation rate δ, where $0 < \delta < 1$. In this paper we are not going to

[6]Note that in the first-best case, the government will want to set the tax at the Pigou rate, so that all eternal effects are internalized, or $1 - \tau^E = \frac{1}{1+\phi}$, or $\tau^E = \frac{\phi}{1+\phi}$. In the optimal policy case, we will assume that the first-best outcome is unattainable.

make a stance how much of this depreciation is due to natural causes, and what part if man-made. In addition, pollution lowers the environmental quality, but spending on abatement can compensate for that, or

$$
\begin{aligned}
q' &= (1-\delta)\bar{q} + \delta q - p + g^E \\
q' &= (1-\delta)\bar{q} + \delta q - \phi f(1) + \tau^E f(1) \\
q' &= (1-\delta)\bar{q} + \delta q + (\tau^E - \phi) f(1) \geq \underline{q} > 0
\end{aligned}
$$

3 Competitive Equilibrium(CE)

Given the prices $\{w, \pi\}$, the production function $f(.)$, the environmental tax rate $\{\tau^E\}$, and the environmental quality level $\{q\}$, the CE is a list $\{c, h, y, p, g^E, q'\}$, s.t.: (i) the household chooses $\{c, h\}$ to maximize utility, (ii) the firm chooses h to maximize profit, (iii) the government chooses $\{g^E\}$ st. keeping the budget balanced; (iv) all markets clear, i.e. $h = 1$, $c + g^E = (1-\tau^E)f(1) + \tau^E f(1) = y = f(1)$.

4 Model Solution and Discussion

This model is very simple to solve algebraically (i.e., symbolically). The main parameters are $\phi, \tau^E, \bar{q}, \underline{q}, \delta$, which can be calibrated from data, see Vasilev (2018, 2019a).

In particular, $c = w = (1-\tau^E)f(1)$, $h = 1$, $y = f(1)$, $p = \phi f(1)$, $g = \tau^E f(1)$. However, the environmental quality solution, or the "environmental fiscal policy" as we call it, is the interesting and novel result in the paper, as its dynamics is constrained by the interval $[\bar{q}, \underline{q}]$, which are the upper and lower bar, respectively. The optimal rule for environmental fiscal policy is reminiscent of an "inflation targeting" in the monetary economics literature.footnoteOther parallels are the (s-S) rules of price adjustment, or the "crawling peg in a band" in the exchange rate literature. More specifically, the government has an instrument at its disposal g^E (as τ^E is just a method to raise funds for abatement spending) to offset the effect of pollution.[7] in order to achieve a single objective - to preserve q within the bands.[8′9]

[7] In reality, those two would be just two elements of the overall public finance structure. The simplified structure is used to focus on the issue at hand. Obviously the problem is much more complicated when navigating environmental quality is done within the overall public finance situation.

[8] This is reminiscent also of the s-S rule in inventory management (economics of inaction, impulse control), or the sticky price literature with time/state-dependent pricing, with the bounds are taken to be exogenous.

[9] Here for simplicity, the lower band is taken as exogenous, but it might be endogenous, e.g optimally chosen by some democratic means. Similarly, by regulations, δ could also be lowered.

One interesting question that arises in this framework is whether going back to $\bar{q}$, say, 100 percent clean environment is feasible/optimal. Maybe it is simply too costly to choose rates of τ^E and level of g^E sufficient to push q' back to $\bar{q}$? After all, the household cares about private consumption (and by proxy, private production) as well. We answer this question briefly below.

In particular, simple calculations show that the highest effect on keeping environmental quality q' as high as possible, is when $\tau^E = 1$, but then $y = 0$, $p = 0$, but $c = 0$, and total utility is the lowest. Alternatively, the highest effect on (consumption) utility is when $\tau^E = 0$, but then $g^E = 0$, and thus q' is the lowest across all fiscal regimes. Clearly, there is some (intra- and inter-temporal) trade-off between c and q; Therefore, we need to solve the Ramsey problem to determine optimal "environmental fiscal policy". We do this in the next section.[10]

5 Ramsey problem (Optimal environmental fiscal policy with full commitment)

In this section we assume that there is a benevolent government, which chooses τ^E and g^E to maximize the utility function of the household (i.e., choose c for the household), s.t. all the constraints from the CE above.

We know that q is taken as given, and $c = (1-\tau^E)f(1)$, and $g^E = \tau^E f(1)$. So the Ramsey government/planner needs to set the environmental tax to maximize

$$\ln[(1-\tau^E)f(1)] = \ln(1-\tau^E) + \ln f(1)$$

or, equivalently, to

$$\max_{\tau^E} \ln(1-\tau^E) \tag{11}$$

s.t.

$$q' = (1-\delta)\bar{q} + \delta q + (\tau^E - \phi)f(1), \tag{12}$$

[10]Within the current setup, there are some "exogenous" government policies, e.g., the government may try to implement other "green" policies, which will decrease ϕ directly, and result in cleaner production, thus bringing down p; Similarly, other such policies, e.g., recycling, may decrease δ itself. However, since those are policies affecting exogenous parameters, those are not really interesting as they do not affect the incentives of the agents in the model.

where we have already substituted all the contraints from the CE. The frst-order condition is

$$\tau^E: \quad \frac{-1}{1-\tau^E} + \mu f(1) = 0$$
$$\frac{1}{(1-\tau^E)f(1)} = \mu$$

This balances MU of consumption, with μ, which is the shadow price on the evolution of environmental quality, so it is like a price of clean environment. But from the CE, we know MU of consumption is λ, so it follows $\lambda = \mu$. In other words, now the benevolent planner will equate the marginal utilities of consumption and environmental quality, a margin that was missing from the CE. Now we need to check if the critical value for the environmental tax rate is indeed maximizing welfare, or the second-order condition:

$$\tau^E: -\frac{1}{(1-\tau^E)^2} < 0. \tag{13}$$

Indeed, there is a global max, when $\tau^E \in [0,1]$. Furthermore, the optimal environmental tax then equals

$$\tau^E = \frac{1-\delta f(1)}{\delta f(1)} \in (0,1). \tag{14}$$

Therefore, returning to $\bar{q}$ does not constitute an optimal sustainable strategy.[11].

Note that when the problem is extended to a dynamic setting, as in Vasilev (2019), the setup looks like

$$\min_{(c,q)} var(c) + \gamma var(q), \tag{15}$$

which is a well-known problem from the monetary policy literature, e.g. Woodford (2003), Gali (2015), Walsh (2017), among others, and where $\gamma > 0$ captures the relative preference attached to the variation in environmental quality element of the objective function. However, solving explicitly for the dynamic cases is left for future research.[12] Still, the same trade-offs already outlined in the static case will show up in the dynamic setting as well.

[11]In addition, using the calibration for Bulgaria in Vasilev (2019a), this yields $\tau^E = 11\%$, which is not far from the actual "green energy tax", as it is called in Bulgaria. These results are consistent with Golosov et al. (2014), while at the same time the model here is cleaner and more tractable.

[12]And would require to be solved by a 2nd-order approximation around the steady-state.

6 Conclusions

We define and model environmental sustainability within a General-Equilibrium framework. The focus in on Environmental Fiscal Policy that achieves/preserves environmental sustainability, and the optimal sustainability strategy.Tthe novelty of this comment paper falls on a new aspect from previous research, namely the unexplored aspects of the *environmental fiscal policy*, which the environmental fiscal authority pursues in order to achieve so-called "environmental sustainability," and the optimal sustainability strategy needed to achieve that objective. We find that: (i) returning to 100 percent clean environment is not optimal, and thus not a good target, and (ii) optimal environmental policy constitutes trying to manage environmental quality within pre-specified bands, and is thus akin to inflation targeting in the monetary economics literature. In particular, the "environmental fiscal authority" is trying to manage environmental quality within pre-specified bands, while at the same time responding to the developments in the real economy. This is the first place such an analogy has been established, and where the contribution of this note lies, and coining the term *environmental quality targeting*, which is a novel quantitative criterion for environmental sustainability.

As a possible venue for future work, it would be interesting to investigate, given the absence of inflation bias (and thus no dynamic inconsistency in the optimal dynamic plan of the government), whether the so-called "divine coincidence" would occur in the case of environmental targeting, i.e. if by focusing on environmental stability alone, the variation in output will be minimized. The answer might depend on whether there is a strong commitment device to bind the rules of the environmental fiscal authority, otherwise there could be a delayed stabilization, postponing the spending on abatement, thus having to increase the environmental tax much more in the future, which in turn violates the tax-smooting motive that we see present in the public finance literature. This, however, is an extension that is left for future research.

Another interesting point is the operation of environmental fiscal policy within the framework of overall fiscal policy, which is akin to the literature on the interaction between monetary and fiscal policy in the macroeconomic literature, with the important difference that the Environmental Minister is usually subservient to the Minister of Finance, and the environmental budget is a subset of the overall budget. Those issues, however, are left for future research.

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