Single-stage regulation of global pollutants from multi-stage production: Policies based on lifecycle emissions

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1 Motivation

In designing regulations for greenhouse gases (GHG) policy makers should take into consideration two differences with respect to past experience. Previous regulations have largely targeted local pollutants[4]. Also past regulations have targeted emissions occuring merely at the regulated site and not emissions associated with the production of inputs used by the regulated site i.e, they have been single point regulation[5]. However GHGs emissions are ubiqutous (i.e., accompany most industrial, commercial and agriculture activities), distributed across the production chain and not concentrated within one stage. They accompany multiple-stages of production.

The most efficient policy for limiting GHG pollution is a pigouvian tax on GHG emitting activities. However for immediate practical purposes we can assume the first best policy is infeasible and that regulators need to design second-best policies such as standards on emissions and mandates for clean products. Furthermore in the absence of GHG regulation of input producing industries, the emissions associated with the production of inputs need to be take into account in determining the optimal level of policy at the final stage. One type of policy is an emission standard for end-producers based

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[4] An exception is regulation of ozone-depleting Chloro-Fluro-Carbons (CFC) whose impacts are felt at a global level. However unlike GHGs CFC emissions are not ubiquitous and emissions are concentrated within one stage of the lifecycle, namely, end-use and not distributed across the lifecycle

[5] This is not to be confused with point or non-point source regulation. By single point regulation we mean although emissions occur at multiple stages of the production chain, only one stage is regulated (and this often happens to be the final stage)

on lifecycle emissions, i.e, including associated upstream emissions . The State of California's Low Carbon Fuel Standard is an example of one of the first such policy to be implemented shortly. A policy that allocates pollution quotas (with or without emission trading) can also be designed based on lifecycle emissions. Finally, while a economy wide GHG tax may be unlikely, a GHG tax on an industry such as electricity generation and oil refining may be less unrealistic. Therefore another option is a GHG tax which penalizes the producers for lifecycle emissions. Policies that target reduction of lifecycle emissions provide incentives to reduce emissions arising not only at the regulated site but also emissions associated with the production and use of intermediate inputs.

Designing policies to reduce lifecycle emissions and ex-ante impact assessment is a major challenge. In this paper we compare the efficiency and other impacts(such as output and pollution) lifecycle based regulations to an optimal carbon tax. We also show how heterogeneity among producers would affect patterns of adoption at each stage. Although our discussion is the context GHG emissions of biofuel production, the framework is generic and be extended to single-point regulation of GHG gases from any multi-stage production.

2 Model

Our aim is to illustrate how single-point regulation of GHG gases from any multi-stage production process affects the pattern of production within a geographical region. We assume low transportation costs (normalized to zero) within this region. This is assumed to be a small region, and therefore all prices (including consumer prices), except the price of the crops purchased by the biorefineries, is given. Consider a two stage production process which yields biofuel as the final product(this can be extended to an arbitrary number of stages or to any other commodity).

In the first stage, farmers choose from two different crops[6]. One crop can be used for both food and energy (say, corn) while the other is an energy crop (say, switch grass or Miscanthus)[7]. The crops are grown using a variable input(fertilizer)[8]. Farms are heterogeneous with respect to land quality,

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[6] Alternatively we can also consider one crop grown with farmers choosing between two different technologies for growing the crop

[7] Although switch grass is a perennial crop, for simplicity we assume it is grown as an annual crop just like corn

[8] The other input is land. However we perform all calculation per unit of land and hence we do not represent the quantity of land explicitly

which affects the amount of input necessary to produce a unit of output. For instance, quantity of fertilizers depends on soil quality; soils of better quality demand less fertilizers. We assume hedonic prices which are composed of two parts: the price for the physical good, and a premium for environmental quality.

In the second stage, biorefineries convert crops produced in the first stage into biofuel, which is a homogenous product. The conversion process requires energy and biorefineries choose from two different energy sources, one more polluting (say, coal) and other less polluting (say, natural gas)[9]. We assume that production in the second stage is fixed proportion. Biorefineries are heterogeneous with respect to conversion efficiency, which affects the amount of crop required to produce a unit of biofuel[10].

Pollution accompanies production at each stage. In the first stage, pollution arises from the use of input (fertilizer) and the quantity of input used is a function of land quality. In the second stage, pollution from any given biorefinery depends on the choice of energy source and quantity of energy used which is a function of the conversion efficiency. Pollution accumulates over time and reduces social welfare.

3 Results

We assume that there exists a social planner who maximizes the present discounted value of producer surplus from every stage while taking into the social loss from pollution at each stage. We first derive the socially optimal outcome under a tax. Next we evaluate different regulatory regimes and here we consider a standard based on lifecycle emissions and an emission tax based on lifecycle emissions. We show how a lifecycle emission tax on the second stage compares to an optimal carbon tax at stage. We also show how a lifecycle based standard on the second stage compares to a lifecycle emission tax on stage. We find that under certain restrictive conditions a lifecycle emission based tax on second stage can replicate optimal tax. We also expect to find that regulation that places an upper bound on emissions may lead to outcomes that lead to no improvement from the status quo. We will perform a numerical simulation of the model for ethanol production in the US using data from the GREET model. This model is widely used in

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[9] Alternatively this can be a model in which producers use a common energy source but choose between two different conversion technologies

[10] Biorefineries can also be heterogenous with respect to energy efficiency which affects the amount of energy required to produce a unit of biofuel

calculation of emissions from different methods of production of ethanol[11]. The contribution of this paper to the literature is in expanding the literature on the choice of policy tools for regulation of emissions from multistage processes.

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[11] http://www.epa.gov/OMS/renewablefuels/420f07035.htm