OPTIMAL TIMING OF PHASING OUT FOSSIL FUEL PRODUCER SUBSIDIES

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Overview

Fossil fuel subsidies include producer subsidies and consumer subsidies, as well as general services (OECD, 2015). While fossil fuel subsidies to consumer has received a considerable amount of study, subsidies to fossil fuel production are rarely discussed and are often hidden by both governments and companies. A difficulty in studying producer subsidies is that many of the subsidies are indirect, related to national fiscal system, which cannot get global benchmark. Support for fossil fuel production not only entails fiscal burden, but also adds to the risks of ‘carbon lock-in’, which means once carbon and capital-intensive fossil fuel dependence are made, and the carbon emissions can become ‘locked in’, the transition to climate-compatible pathways becomes much more difficult, because of the long time horizon over which the investments operate (Erickson, 2015).Without government support for exploration and development, especially under today’s low price, large fossil fuel development would be unprofitable. These resources in place will become un-burnable carbon, and their investments will become ‘stranded’. Therefore, G20, OECD, Overseas Development Institute (ODI) etc. claimed to phase out producer subsidies to meet the target of limiting global temperature increases to no more than 2℃.

Because there are uncertainties and irreversibilities in such environment problems, related policy design can involve important problems of timing. Optimal timing problems are an important class of stochastic control problem (Pindyck, 2002). This problem can be displayed as: at what point should governments adopt a policy to phase out fossil fuel producer subsidies? Since there is always uncertainty over the future costs and benefits of adopting a policy, this paper we present the real option model and calculate solutions for different combinations of parameter values to show how ecological uncertainties affect the optimal timing of phasing out producer subsidies.

Methods

The uncertainties and irreversibilities make the timing problems feasible to delay action and wait for new information (Pindyck, 2002). We adopt the real option model to assess the value of policy adoption. The objective of policy adoption by governments is to maximize the discounted present value of social welfare, which includes consumer surplus, producer surplus (firm profits), government revenue (removal subsidies) and social costs (environmental pollution losses).

$$SW(t) = u + \pi + S(t) - \int_0^{\infty} B(M(t), \theta) e^{-rt}$$

Where $SW(t)$ means the social welfare; u is consumer surplus; π means the producer profits; $S(t)$ denotes the revenue of removal subsidy; $B(M(t), \theta)$ is environmental losses, in which $M(t)$ means the environmental stock variable representing the average level of the atmospheric carbon concentration at time t, and where θ is social cost per pollution stock.

Fossil fuel is depletable resources, which has limited stock in the ground. It is now assumed a firm with a fixed stock at the initial period, $R(0)$. The resource extraction rate at time t is represented by $q(t)$, and the resource stock at time t is denoted by $R(t)$. The total cost of extraction is $C[Q(t)]$, where it is assumed that $C(0)=0$, $C'(Q)>0$ for all $Q>0$. The problem facing the firm is to choose the optimal extraction path achieving the maximum discounted profits. Here we assume a positive constant discount rate is denoted as r.

$$\pi = \max \int_{t=0}^{\infty} [P(t)Q(1\text{-}S) - C(Q(t), S)] e^{-rt} dt$$

subject to $\dot{R}(t) = -Q(t)$, $R(0)=0$

Firms go for profits, so this is a standard optimization control problem. $R(t)$ is the state variable representing the reserves remaining at time t; S denotes the subsidies for producer.

Assuming fossil fuel price for consumers is exogenous, the consumer surplus u will not change.

Fossil fuel is also polluting resources, and its combustion will produce a large amount of environmental pollutants. There is ecological uncertainty over the evolution of the environment.

$$dM / dt = \beta Q(t) - \delta M(t)$$

Where β denotes the unitary pollutant content of fossil fuel with absence of policy, the pollution flow released into the atmosphere amounts to $\beta Q(t)$. The social cost (environmental pollution losses) is assumed to associate with the stock variable $M(t)$. Here we adopt linear B in M:

$$B(\theta, M_t) = -\theta M_t$$

Let SW_T represents policy is adopted at time t, and SW_0 means policy is adopted now. Therefore, the optimal timing problem can be displayed that it is better to adopt the policy at time t=0 or wait until T comparing SW_0 to SW_T.

$$SW_0 = -\frac{\theta M_0}{r+\delta} - \frac{\theta\beta Q}{r(\delta+r)} - \frac{PQ - C(Q)}{r} + \frac{S}{r}$$

$$SW_T = -\frac{\theta(M_0 + \frac{\beta Q}{r})}{r+\delta} + \frac{\beta Q}{r(r+\delta)} e^{-rT} + \frac{2\theta(\beta Q + M_0\delta)}{\delta(\delta+r)} e^{-(\delta+r)T} + \frac{PQ(1-S) - C(Q,S)}{r}(1-e^{-rT}) + \frac{PQ - C(Q)+S}{r} e^{-rT}$$

So, the optimal timing T is determined by the formula:

$$\arg\max \Delta SW_T = SW_T - SW_0 = \frac{\beta Q}{r(r+\delta)} e^{-rT} + \frac{2\theta(\beta Q + M_0\delta)}{\delta(\delta+r)} e^{-(\delta+r)T} + \frac{PQ(1-S) - C(Q,S)}{r}(1-e^{-rT}) + \frac{PQ - C(Q)+S}{r}(e^{-rT}\text{-}1)$$

Results

By calculating solutions for the optimal T, the real interest rate, absorption parameter, and initial level of emissions we will use the value: r=0.04, β=0.58 (oil), δ=0 [1], θ=\$20/tons/year. We use an oil field as example, its production declines in exponential type, $Q(t)=Q_0e^{-\alpha t}$, α=-0.12, C=100Q. A tax credit is provided, S=0.05PQ. Therefore, we use programming solver for the optimization problem. The calculated optimal time T=3.28 year. We should wait and remove the producer subsidy 3 years later. We also use sensitivity analysis to examine the impacts of changes of parameters on the optimal timing.

Conclusions

The policies are adopted in the face of considerable uncertainties over the flow of costs and benefits that they will generate. We use a two-period model in removing producer subsidies in policy that could be adopted either now or at some fixed time in the future. The “incremental” social welfare is used to judge the optimal timing. The results show that waiting is better than executing immediately, and the optimal timing is calculated. This model is helpful for government to make optimal policy timing.

References

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[1] a reason approximation for GHGs, the actual decay rate has been 0.5 percent or less.