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OPTIMAL TAX INCENTIVE FOR THE CARBON-CAPTURE-AND-STORAGE TECHNOLOGY

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CCS is a green technology that enables the green growth or 2DS with the dominantly used fossil fuel. Pigouvian taxation on the non-CCS equipped sectors is one way to achieve the goal. In this research, through the dynamic programming of the optimal growth model, effective Pigouvian tax rate is obtained. The calibrated Pigouvian tax rate by simulation would be useful to the policy for 2DS.

"What is the effective Pigouvian tax rate on the non-CCS equipped utility or industry sectors?"

CCS and the Pigouvian Taxation

1. Research Motivation

- Fossil fuel has been the most dominant energy and it is expected to be so in the future.
- CCS is an imperative call for the green growth or 2DS due to the dominant use of fossil fuels. However, the development and improvement is on progress. Thus, it is not enough to be applied and equipped to the utility or industry sectors.
- There are wide spectrum of polices that can promote the CCS technology. The Pigouvian taxation on non-CCS sectors is an financial and economical approach of supporting the development of the CCS technology.

2. Research Goal

- This research aims to calculate the effective Pigouvian tax rate on the non-CCS sectors.

3. Research Contributions

1) Theoretical Contribution:
- Through a modification of the dynamical programming, this research introduces a model incorporating environmental factors which enables the discussions of the environmental policies.

2) Empirical Contribution:
- The calibrated Pigouvian tax rate possess policy implication. The effective Pigouvian tax rate can be compared with the other environmental tax rate so that a complete set of environmental policy can be obtained.

Approach

1. Setting up a Model

- Key Assumptions
  1) The baseline model is optimal growth model using the dynamic programming, e.g. Solow-Swan model
  2) Every consumption is reduced to the consumption of energy; we need shadow price of energy.
  3) Pigouvian taxation on non-CCS equipped sector is enacted in every period.
  4) The reserve of fossil fuel and the price of energy in each period follows certain stochastic process.
  5) A Pigouvian tax rate is called an effective tax rate when it achieves 2DS in 2050.

2. Solving for the Equilibrium via Dynamic Programming

- Shadow Price of Energy Consumption
  The price is obtained in econometric methodology which is estimating the regression coefficients of energy on GNP or GNI. Panel data composed with the GDP or GNI of each country and energy consumption in each time is required. Adjustment of energy efficiency of each country needs to be considered.
  e.g. Fama-Macbeth regression : $GDP_{i,t} = \alpha_t + \pi_{CCS,t}E^i_{CCS,t} + \pi_{N,t}E^i_{N,t} + \epsilon_{i,t}$
- Tax Revenue from the Pigouvian Taxation
  The tax revenue is only used for CCS technology improvement as follows:
  1) Reducing the cost of running CCS systems
  2) Improving Enhanced-Oil-Recovery (EOR) technology
  3) Reducing the emission of CO2

3. Simulation and Calibration of the Pigouvian Tax Rate

- Data from IEA (energy data), OECD (national account) is used for the calibration of the effective tax rate.

The Model

- Social Planner's Problem
  The social planner follows the Permanent Income Hypothesis of Friedman. There are two types of models. The first model is the basic model without CCS settings. The second one is the extended model with CCS settings.

Functions and Model Parameter	Description
$u(\cdot)$	Utility function
$\eta(\cdot)$	Disutility function by the CO2 emission
ϵ	CO2 emission per energy consumption unit
B	Disutility factor; negative number

State Variable of time-t	Description	Type
R_t	Reserve of fossil fuel	exogenous
π_t	Price of energy per consumption unit	exogenous
K_t	Capital Stock	endogenous

Choice Variable of time-t	Description
E_t	Energy consumption
K_{t+1}	Capital accumulation
Y_t	Production; Cobb-Douglass form
I_t	Investment

1) Basic model

$$\max_{\{E_t\}_{t=0}^{\infty}} \left[\sum_{t=0}^{\infty} \beta^t \{u(E_t) + B\eta(E_t\epsilon)\} \right]$$

subject to

$$E_t \le R_t$$
$$E_t\pi_t + I_t \le Y_t = \alpha(K_t)^\alpha$$
$$K_{t+1} = I_t + (1-\delta)K_t$$

The goal is 2DS in 2050 i.e. $t = 0$ (2015) to $t = 35$(2050) and $T(E_0, \dots, E_{35}) \le 2$

2) CCS model

$$\max_{\{E_t\}_{t=0}^{\infty}} \left[\sum_{t=0}^{\infty} \beta^t \{u(E_{CCS,t} + E_{N,t}) + B\eta(E_{CCS,t}\epsilon_{CCS}(z_t(\xi_t)) + E_{N,t}\epsilon)\} \right]$$

subject to

$$E_{CCS,t}\pi_{CCS,t} + E_{N,t}\pi_{N,t} + I_t \le Y_t = \alpha(K_t)^\alpha$$
$$E_{CCS,t} + E_{N,t} \le R_t$$
$$R_t = r_t + \rho(z_t(\xi_t))$$
$$I_t = i_t + \xi_t$$
$$\xi_t = t_{CCS}\pi_{N,t-1}E_{N,t-1}$$
$$K_{t+1} = i_t + (1-\delta)K_t$$

Introducing of CCS technology and Pigouvian tax revenue which enhanced the CCS technology level makes difference with the basic model as follows:

- $E_{CCS,t}$ and $E_{N,t}$: Energy consumption whether from CCS sectors or not.
- $\xi_t = t_{CCS}\pi_{N,t-1}E_{N,t-1}$: Investment to CCS technology from the Pigouvian tax revenue from $t-1$.
- $z_t(\xi_t)$: CCS technology level by the investment ξ_t.
- $\epsilon_{CCS}(z_t(\xi_t))$: CCS CO2 emission when technology level is z_t.
- t_{CCS} : Pigouvian tax rate on non-CCS sectors.
- $\rho_t(z_t(\xi_t))$: Enhanced Oil Recovery by the improvement of CCR technology.
- $\pi_{CCS,t} = \pi_t + \phi(z_t(\xi_t))$: price of energy consumption of CCS where $\phi(z_t(\xi_t))$ is cost of equipping CCS represented on the price.

The goal is 2DS in 2050 i.e. $t = 0$ (2015) to $t = 35$(2050) and $T(E_0, \dots, E_{35}) \le 2$. We call t^E_{CSS} as an effective tax rate that is the minimum tax rate satisfying the goal.

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