國立臺灣大學
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Advanced Public Finance
107, Semester 2
Documentation

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This essay contains 1314 words.
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1. Introduction

The purpose of this project is intended to find the optimal tax to reduce the negative production externality; and at the same time, we want to maximize producers' profit and consumers' utility. We will try to achieve this objective simulating an economic model with Python.

An economic model is a simplified representation of the relationship between different variables that explain how the economy operates or a particular phenomenon of it.

Our real case is based on two factories that produce different goods: the first factory paper boxes and the second reusable plastic boxes. We only have one consumer that would use paper boxes or reusable plastic boxes depending the moment.
The two factories, by the simple fact of producing, generate waste that contaminates a river. This contamination is what we will understand as a negative externality of production.
In order to avoid that the companies don't take into account this negative externality and try to take care of the world, the government applies a tax to the producers.

2. Economic Model

2.1. Producer Externality

Externalities are defined as production, consumption and investment decisions made by individuals or companies that affect third parties that do not participate directly in those transactions. Sometimes, those indirect effects are minuscule, but if they are large, they can be problematic; that's why externalities are one of the main reasons that lead governments to intervene in the economy.

The externalities can be positive or negative.
When the externalities are negative, the social costs are superior to the private costs. These indirect costs (which do not fall on either the producer or the user) may include, for example, the deterioration of life quality, the increase in the cost of health care or the loss of production opportunities.
On the other hand, if the externalities are positive, private profitability is lower than social profitability. For example, research and development activities are widely considered to generate positive effects considered to generate positive effects that transcend the producer (usually the company that finances them).

The reason is that research and development enrich general knowledge, which contributes to other discoveries and advances.

Production externality refers to a side effect from an industrial operation; they are usually unintended, and their impacts are typically unrelated to and unsolicited by anyone. They can have economic, social or environmental side effects.
In the case of negative externalities, the government can use the taxes to compensate the damage to third parties; this tax would produce the market result that would have occurred if the polluters had properly internalized all the costs. Following the same logic, governments should subsidize those who generate positive externalities in the same proportion as others benefit.

2.2. Agents of the model

In this economic model we can find two producers and one consumer.

2.2.1. Producers

The goal in the part of the producer is to maximize the profit taking into account the technology used and the negative externality that appears when producing.
The production function will help us to find the quantity supply and the labour demand.

$$Production\ Function = (A \cdot Factor^{\alpha}) \cdot (\frac{1}{goods_{supply} \cdot externality})$$

2.2.2. Consumer

In the case of the consumer, considering the prices of the factors and the goods and the money that the consumer can spend (constraints), we want to maximize his utility.

$$Utility\ Function = Good1^{\psi} + Good2^{\psi} - \beta \cdot Factor^{\delta}$$

2.2.3. Economy

After defining all the variable incurred, say, price, wage and tax rate, to get the maximized profits for producers and maximized utility for consumers, we now have to find the approach channelling two sides to equilibrium. That is, in the economy will the price (same for wage and tax rate) iterate itself until find the proper value to make,

Q1 supplied = Q1 demanded
Q2 supplied = Q2 demanded
Labour demanded = Labour supplied

which stand for the equilibrium for the entire society.

3. Code

3.1. Producer Class

3.1.1. Variables

The instance variables of the producer class are defined as:

· pr: number of producers (each producer produces only 1 type of good)

· cr: number of consumers (each consumer provides only 1 type of factor)

· *dict* is the collection of all the parameters

· A: technology

· *alpha*, *theta*, and *omega* are the production parameters

3.1.2. prodftn(self)

In this function, taking the parameter *self* and including the production function, we will get an array of the goods supply.

3.1.3. profit(self, p, w, t)

This function uses the parameters *self, price, wage* and *tax* and calculates the earnings of the sales of the goods and the earnings of the factor provided. Once it has done all the above, calculate the total profit obtained by the producer.

3.1.4. maximize(self, p, w, t)

This function uses the same parameters as the one before (self, price, wage and tax) to maximize the profit of the producers. The objective is to find out the quantity supply of the goods and the labour demanded by the firms.

3.2. Consumer Class

3.2.1. Variables

The instance variables of the consumer class are defined as:

- ngp: number of types of good produced by each producer
- lc: types of labour provided by the consumer
- kc: types of capital provided by the consumer
- p: random input a price list for each good
- *psi*, *beta*, and *delta* are the consumer parameters

3.2.2. utility(self, general_list)

This function includes the parameters *self* and *general_list*. Appending each consumer's utility from both goods it will return the total utility that is the sum of the good utility minus the labour utility.

3.2.3. constraint(self, general_list, pi, p, w)

The constraint function has the parameters *self, general_list, pi, p, w,* and *t* and models the constraints of the consumer. To satisfy the budget restriction, the result of the equation has to be zero.

3.2.4. MaxUtility(self, p, w)

The MaxUtility function wants to find out the maximization of the quantity demanded by the consumers and the labour supplied. The arguments used are price, wage and tax.

3.3. Economy Class

3.3.1. Variables

The variables here include the quantity supplied for goods and labour demanded from supplied sides under maximized profits conditions; in addition, quantity demanded for goods and labour supplied derived from the consumers who maximize their utility. Markedly, all the variables here are in terms of p, w and t which need to be iterated in the economy class.

3.3.2. objective(self)

Unfortunately, it is complicated for us to introduce loops or gradient way directly; instead, we use excess demands (excess supplied as the two sides on the same coin):

(ex_post_array_pro[0] - ex_post_array_con[0]) : excess demanded on good 1

(ex_post_array_pro[1] - ex_post_array_con[1]) : excess demanded on good 2

(ex_post_array_pro[2] + ex_post_array_pro[3]) - ex_post_array_con[2]: excess demanded on labour

as the minimized objects to reach equilibrium once they all down to zero.

3.3.3. equilibrium(self)

What introduced here is scipy.minimize approach, and the objective is the square on all excess demanded values (to recoil from the negative number) without constraint. From initial guess = 100, the code would eventually via “Nelder- Mead” method to return equilibrium price, wage and tax rate.

3.4. Simulation

In the simulation is where the code asks the user to enter the number of producers and consumers and then run the economy to find the optimal tax, price and wage for the externality.

4. Conclusion

The simulation from this python is supposed to help the government determine what is the optimal tax rate to impose on the producer so that the producer can internalise the externality that they impose on the other producers. In this simulation we have several limitations such that parameters (wage, tax, prices) are fixed and the codes are restricted to only 2 producers and 1 consumer. Therefore, to allow for the python codes to reflect that of the real world, we need to find and determine the magnitude of the parameters instead of fixing them. Also, we will have to generalise the codes of this simulation to take in variable numbers of producers and consumers.