The CGE Approach to the Analysis of Sustainable Development: Some Remarks

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1. Introduction

- Originally, the CGE approach was popular in studies such as calculating tax incidences.
- In recent years, many environmental economists have applied the CGE approach to study the welfare impact of various emission or pollution regulations.
- Although it is difficult to draw a line between environmental economics and sustainable development, it is safe to say that the latter refers to more global, longer-run, ecology-related topics. We shall argue here that, as we apply the CGE analysis to topics on a global and long-run scale, several directions of extension are worth exploring.

2. The Benchmark CGE Framework

- A general equilibrium system is composed of *n* market clearance conditions. On the household side we assume that consumers have the following indirect utility function: $V(p,\alpha,\theta)$, where p is an *n*-vector of prices, α is a vector of structural parameters, and θ is a policy instrument in question. We can derive *n* demand functions for all commodities:

  $D_i(p, \alpha,\theta), \ i = 1, \ldots, n.$
- On the firm side, we can write down a profit function for the representative firm in industry *i*: $\pi_i\ (p,\beta,\theta)$, where β is the structural parameter for firms. We can derive *n* net commodity supply functions:

  $S_i(p, \beta,\theta), \ i = 1, \ldots, n$

2. The Benchmark CGE Framework

- Equating the *n* demand and supply functions, we have the following conditions for a general equilibrium:

  $D_i(p,\alpha,\theta) = S_i(p, \beta, \theta), \ i = 1, \ldots, n.$

  from which the equilibrium price vector p can be calculated.
- Given a set of (α,β) values, p is solved for the current θ_0 and for a targeted θ_1, respectively denoted p_0 and p_1. Let the corresponding expenditure function be $E(p, \alpha,\theta)$. The compensation variation, or equivalence variation, or the exact social benefit, in monetary terms, of an assumed change in θ, characterized by $E(p_1,\alpha,\theta_1) - E(p_0,\alpha,\theta_0)$, can then be calculated.

2. The Benchmark CGE Framework

- In the past three decades, considerable contributions have been made to modify or extend the CGE approach. These include the introduction of the econometric approach [Jorgenson and Wilcoxen (1990)], adding a functional specification concerning the speed of technical change [Bergman (1990)], considering imperfect markets [Mercenier (1995)], allowing market disequilibrium, especially in the labor sector [Conrad and Schmidt (1997b)], and embodying international trade. However, for the analysis of development sustainability, several problems remain.

3. Structural Nonconvexity in CGE Models

- According to Swanson (1996), the development of agriculture has a network effect. Once a particular technology is used, the related market widens, and the R&D aimed at improving such a popular technology will be more intensive, resulting in even more efficiency and more acceptance of this technology. Thus, an obvious *network economy* is involved. which causes what Pearce (1999 p.489) called "the homogenization" of the production process, which is indeed a major reason of environmental damage.
- Structural nonconvexity arising from the network effect exists not only in agriculture, but also in other industrial production technologies. Many examples can be found in Arthur (1989).

3. Structural Nonconvexity in CGE Models

- An implication of such a network externality is the existence of multiple equilibrium, and the possible inefficiency and lock-in effect involved.
- On the one hand, the lock-in effect implies that if a particular technology or method of production has been used by many economic agents, it is very difficult to have a large number of adopters to switch. On the other hand, the lock-in effect and the multiple equilibria together also suggest that a sizeable change in policy instruments may cause a drastic jump in equilibrium. In ecological issues, indeed we need to consider drastic policies in order to reverse the negative outcomes we have already achieved.

3. Structural Nonconvexity in CGE Models

- Another type of nonconvexity is the one that will *arise* from significant changes in policy instruments. If a significantly high tax on *CO*2 emission is levied on the production of a particular good, then it is likely that a new industry specialized in dealing with such an emission-abatement will arise, which solves the problem of internal inefficiency in each firm's emission control. The emergence of this new industry will disturb the original *n*-equation equilibrium system in a discontinuous way, and therefore the traditional CGE comparative analysis, be it analytical or numerical, does not work out right.

3. Structural Nonconvexity in CGE Models

- If there are multiple equilibria, then the stable set of each equilibrium needs to be characterized, at least roughly, so that the switching point of the dynamics can be identified, and corresponding calculation algorithms can be explicitly embodied. To achieve this, more theoretical (instead of empirical) work is necessary. The mathematically work involved is similar to the *inframarginal analysis* proposed by Yang and Ng (1993) and some analysis along this line is needed.

4. Difficulties of Impact Measurement

- There is much consensus among environmental economists that ozone depletion, global warming, and biodiversity loss are among the most serious problems of development sustainability. For global warming and ozone depletion, their impact on agricultural production and diseases caused by excessive ultraviolet rays can be assessed (see e.g., Nordhaus 1991 and Pearce 1999).
- For biodiversity preservation, however, the cost benefit assessment is not at all easy. In terms of the general CGE model we presented, the difficulty arises because the marginal impact of θ on consumer's indirect utility $V(p, \alpha, \theta)$ (and hence expenditure function $E(p, \alpha, \theta)$)is unknown, so that the change of benefit cannot be calculated accurately.

4. Difficulties of Impact Measurement

- There are basically two kinds of biodiversity values mentioned in the literature. The first is to treat the species as a library and its genes as books. The value of a species is just like the value of a book to the library. The second one is to assess the value of biodiversity in the macro environment. Much scientific evidence has shown that the “resilience” of a particular equilibrium with respect to outside shocks depends on the biodiversity of the system. The value of biodiversity preservation hinges upon its corresponding influence on system resilience. Although the above-mentioned argument is intuitively persuasive, our willingness to pay for such biodiversity preservation is difficult to assess.

4. Difficulties of Impact Measurement

- The problem of impact measurement is further complicated by the fact that preservation decisions have to be made by the present generation, whereas the beneficiaries may be generations to come. There is always the debate concerning the discount rate we should impose upon our children .

5.The Endogeneity of Technological Changes

- Most existing CGE approaches on technological changes have not yet included the initiatives that influence the characteristics of future (less polluting) capital vintages by investment in research and development. In Jorgenson and Wilcoxen (1990) or McKibbin and Wilcoxen (1992), the effort allows a substitution away from polluting inputs, and takes into account the productivity decline due to this substitution; no explicit R&D effect has been considered.
- Characterizing the relationship between R&D inputs and the appearance of new technologies is necessary, because one important goal of environmental policies is indeed to induce new technologies that better preserve the world. The recent contribution by Aghion and Howitt (1998) has provided us with a well-received and useful way of analyzing problems along this line.

5.The Endogeneity of Technological Changes

- Under some reasonable assumptions, they showed that the Schumpeterian equilibrium relationship between innovation and R&D can be characterized by two equations. The first is an arbitrage equation, and the second is the market clearance equation. In our context, the pollution tax saved is obviously a major item of revenue from an invention of pollution-reduction technology. Thus, the tax item will enter into one side of the arbitrage equation. Along this line of thought, there is no conceptual difficulty in formalizing and implementing such an analysis.
- More importantly, the inclusion of technological innovation and R&D in the CGE model may generate deeper insights for the choice of policy instruments. Huang (2001), for instance, showed that in the case of endogenous technological innovation, the firm's investment in pollution control as well as the optimal policy might be quite different from the traditional case where technological innovation and R&D are ignored.

6. Complications of the Population Factor

- Human beings are the ones committing the emissions of CO_2 and CFC. Similarly, forest has always been chopped down by mankind. Very often, people have deforested an area because they had to; the pressure of insufficient food relative to the large population size forces people in various areas to substitute forest for farmland. As pointed out by Cohen (1995, 1997) and Myers (1995), the population pressure *per se* is a major factor contributing to environmental damage. As such, the factor of population should never be left out in environmental analysis.
- At least for the problem of population size, a target of "reducing 10% of place A's population" is really a complicated issue; a mere quantitative calculation of its impact is not at all meaningful. If we treat population policy as a means of improving development sustainability, then the equilibrium may take decades to converge. In sum, in ecological issues, there are many subtle aspects not explicit enough in the conventional equations of CGE.

7. International Coordination

- Many researchers have contributed to endogenizing the foreign sector into the CGE model. However, this is not the major international aspect for the issue of sustainability.
- For instance, to cure the problem of biodiversity decline due to deforestation, some subsidy to people in tropical countries must be designed for them so as to preserve the forest, for otherwise people in these areas could not even survive. Evidently, such subsidies must come from developed countries that benefit from the improvement of the environmental commons. This is not something we can expect to come up from a market; some form of international coordination is necessary.
- The negotiation outcomes cannot be predicted from the structure of competitive markets, but at least we can substitute in some assumed outcomes and do some calibrations based on these assumptions.

8. Conclusions

- In this paper we briefly introduce five areas which restrict the comprehensiveness of applying the CGE approach. Improvements in some of these areas are within the scope of empirical economists' efforts, whereas some others need the devotion of theoretical economists, ecologists, and demographers. We have to emphasize that these are not negative demonstration of CGE's limitation, but a positive identification of directions toward which we could jointly improve.