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Introduction to the Symposium: The discipline of applied general equilibrium*

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Summary. The use of general equilibrium models in applied research imposes a discipline in which model structures can easily be compared and contrasted and model results can be interpreted using a well understood and rigorously developed theoretical framework. These features allow researchers to compare results across modeling efforts and to build on the experience of others in deriving results and formulating questions. This paper first presents a brief critical history of applied general equilibrium analysis. It then summarizes the contributions of eight other papers in this issue.

1. Introduction

Schumpeter (1954) judged the Walrasian general equilibrium model to be the "the only work by an economist that will stand comparison with the achievements of theoretical physics." Since Schumpeter's time, economic researchers have made considered scientific progress not only on the theory of general equilibrium but on its applications. This issue contains eight papers that illustrate the power of applied general equilibrium (GE) as applied science.

Applied general equilibrium analysis here is defined to be the numerical implementation of general equilibrium models calibrated to data: An applied GE model is a computer representation of a national economy or a group of national economies, each of which consists of consumers, producers, and possibly a government. The model's people make many of the same sorts of transactions as do their counterparts in the world. Consumers, for example, purchase goods from producers, supply factors of production, save, and pay taxes to and receive transfer from the govern-

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ment. Theory and measurement, often in the form of statistical estimates, are used to select a parametric class of GE models. In most cases, data are then used to calibrate the model so that it mimics the world as closely as possibly along a limited, but clearly specified, number of dimensions. The researcher can then perform experiments with the applied GE model to derive quantitative answers to well-posed questions. These questions can involve the use of theory – for example, What are the welfare effects of a policy change? These questions can also involve tests of theory – for example, Are the results generated by a model economy consistent with observations?

The use of GE models imposes on researchers a discipline in which model structures can easily be compared and contrasted and model results can be interpreted using a well understood and rigorously developed theoretical framework that matches well the way the economic data are collected and reported. These features allow researchers to compare results across modeling efforts and to build on the experience of others in deriving results and formulating questions. Although these features are important for regarding applied GE as scientific research, there is another feature that is sometimes even more essential: in applied GE experiments, failure is not only possible but often contributes as much as success; a gross inconsistency between the results of an experiment and observations from the world creates a paradox that can only be resolved by further developments in the theory underlying the model.

This paper first presents a brief critical history of applied GE analysis and then summarizes the contributions of the papers in this issue. One paper (Mercenier) deals with the possibility of multiplicity of equilibria in a popular class of applied GE models. Another (Rogerson, Rupert, and Wright) provides an independent measure of a crucial parameter in an applied GE model that has been successful in matching business cycle observations. Two papers (Gravelle and Kotlikoff and Imrohoroglu, Imrohoroglu, and Joines) perform welfare analysis of government policy. Another three (Cooley, Hansen, and Perscott; Kehoe, Polo, and Sancho; and Ljungqvist and Sargent) report results of experiments where the theory performs well in matching observations. Yet another (Cho and Cooley) reports the results of an experiment where a plausible innovation in the theory fails to match observations from the world.

Taken as a whole, these eight illustrate the diversity of approaches encompassed by applied GE analysis. Applied GE is a set of principles for doing economic research, not a particular model. In answering a specific question, the researcher still must decide what abstraction is most useful for that question: whether, for example, to use a static or a dynamic model, what assumptions to make about industrial organization within the model economy, and so on.

2. History

Although applied GE can trace its roots back to the input-output analysis of Leontief (1941, 1953), numerical applications of general equilibrium narrowly defined began with the work of Harberger (1962) and Johansen (1960). Harberger used a model with two production sectors, one corporate and the other noncorporate, calibrated to U.S. data from the 1950s, to calculate the incidence of the corporate income tax. Johansen used a model with 19 production sectors, calibrated to Norweigian data from 1950, to identify the sources of economic growth in Norway over the period 1948–53.

Work on applied GE models received a crucial stimulus from the research of Scarf (1967, 1973) on the computation of economic equilibria. Scarf developed an algorithm for calculating an equilibrium of a multisectoral GE model. Refinements of this algorithm are still used by some modelers. Probably the most significant consequences of Scarf's work, however, were to establish a close connection between applied GE research and the theoretical research of such economists as Arrow and Debreu (1954) and McKenzie (1951) on the existence of equilibrium in very general models and to inspire a generation of Yale graduate students to enter the applied GE field. (Arrow and Kehoe (1994) discuss Scarf's contributions to applied GE modeling.)

Early static models

Two of Scarf's most prominent students are Shoven and Whalley (1972), who developed a calibrated, multisectoral general equilibrium framework to analyze the welfare impact of government tax policy. Shoven and Whalley (1984, 1992) provide surveys of this work and the large literature that has followed it. Early models in the Shoven-Whalley tradition were explicitly static, studying the determination of equilibrium in a single period. Later models studied the evolution of capital stocks over time in a framework where the people in the model either solve static problems (as in Johansen's model) or, what is almost the same, where people have myopic expectations, that is, they expect current relative prices to persist in the future; see Fullerton, Shoven, and Whalley (1983) for an example of the latter approach. Ballard and Goulder (1985) developed a perfect foresight version of the Fullerton-Shoven-Whalley model and showed that it predicts a substantially lower impact of switching from income taxes to consumption tax in the United States than does the version with myopic expectations.

Researchers working in the Shoven-Whalley tradition have stressed developing theoretical underpinnings for applied GE models and producing results that are meant to be compared with those of simpler theoretical frameworks. They have spent little effort in comparing their results with outcomes of policy changes in the world. Whalley (1986, 1988), for example, contends that these models are not intended to forecast the values of economic variables, but rather to provide useful insights that may help policymakers to undertake more informed, and presumably more desirable, policy actions. This line of thought has led to Whalley to suggest that the concept of positive economics should be perhaps altogether abandoned in appplied GE modeling. Subsequent developments, however, illustrated by some of the papers in this issue, have shown applied GE to be a valuable tool in positive economics.

Further development in static models

Several other groups of researchers began using static applied GE models to do policy analysis after Shoven and Whalley (1972). One such group centered around the World Bank and focused on developing countries; a survey of its work is presented by Dervis, de Melo, and Robinson (1982). Another group has come to prominence doing policy analysis in Australia; a summary of early work by this group is given by Dixon, Parmenter, Sutton, and Vincent (1982); a more recent survey is presented by Dixon, Parameter, Powell, and Wilcoxen (1992).

There is a large and expanding literature on multisectoral applied GE models. A recent search of the EconLit database produced references to more than 200 books and journal articles on this subject. Prominent contributors – besides those mentioned above – include Ginsburgh and Waelbroeck (1981), Jorgenson (1984), and Manne (1985). There have also been numerous collected volumes of papers on this subject: Scarf and Shoven (1984); Piggott and Whalley (1985, 1991); Srinivasan and Whalley (1986); Bergman, Jorgenson, and Zalai (1990); Taylor (1990); Don, van de Klundent, and van Sinderen (1991); and Mercenier and Srinivasan (1994).

In contrast to work in the Shoven-Whalley tradition, some other applied GE models have attempted to address policy issues in areas where rigorous theory has not been developed. The World Bank group in particular has been criticized for spending little effort in building the theoretical foundations of their models. Srinivasan (1983), for example, characterizes their work as being "full of examples of less than complete understanding of even elementary aspects of general equilibrium theory."

Over the past decade, many researchers have begun to incorporate dynamics into their multisectoral applied GE models. Before discussing these models, however, we should mention another significant innovation to static multisectoral applied GE models: the addition of increasing returns to scale and imperfect competition. The pioneering contribution to this area was provided by Harris (1984), who showed that incorporating these phenomena into a static model of the Canadian economy could lead to predicted gains from trade liberalization that are substantially higher than those found in models with constant returns to scale and perfect competition. Later researchers, such as Brown and Stern (1989), have extended this approach and have tied it to theoretical developments in the theory of monopolist competition of Dixit and Stiglitz (1977) and to the new trade theory surveyed by Helpman and Krugman (1985); Kehoe and Kehoe (1994) provide an overview of these sorts of models. Such models have received public attention in recent discussions of the economic impact of the North American Free Trade Agreement; see Francois and Shiells (1994).

Although they have been used to analyze a number of important policy issues, current applied GE models with increasing returns and imperfect competition force uneasy marriages between partial equilibrium models of monopolistic competition and the general equilibrium framework. Ginsburgh (1994), for example, has pointed out the sensitivity of model results to the seemly arbitrary choice of numeraire in firms' profit maximization problems and has called for more work on the theory underlying these models.

Deterministic dynamic models

Some of the earliest static applied GE models dealt with phenomena that are best handled in a dynamic framework; Johansen (1960) dealt with the determinants of growth, and Harberger (1962) and Shoven and Whalley (1972) dealt with the incidence of the tax on corporate capital income. Over the past decade researchers have begun to construct applied GE models that are fully dynamic in the sense that the people in the model solve intertemporal maximization problems with foreword looking behavior. In some of these models there are people who live as long as the model (often infinitely); examples include Lipton and Sachs (1983); Manne and Preckel (1985); Jorgenson and Yun (1986); Erlich, Ginsburgh, and van der Heyden (1987); and Goulder and Summers (1989). In other models there are overlapping generations; examples include Summers (1981) and Auerbach and Kotlikoff (1987).

Early dynamic applied GE models faced severe computational limits because they needed to simultaneously compute equilibria in a number of periods, and so were highly aggregated in terms of the number of production sectors and/or consumers. As computer hardware and computational algorithms have improved, computational limits have become much less important and models have become more disaggregated; Kehoe (1991) presents a survey of algorithms used to compute the equilibria of deterministic applied GE models.

In contrast to static models whose comparative advantage is analyzing issues that involve different sectors of an economy, the comparative advantage of deterministic dynamic models is analyzing issues that involve such phenomena as capital accumulation and growth. Yet sectoral disaggregation is also important for addressing some dynamic issues. Echevarria (1992), for example, has shown that incorporating sectoral disaggregation into the neoclassical growth model can significantly improve the model's ability to match growth and development observations.

Business cycle models

The current approach to analyzing business cycle phenomena incorporates aggregate uncertainty as well as dynamics. This approach was initiated by Kydland and Prescott (1982); Cooley (1995) provides a recent survey of the large amount of work that has followed. Applied GE business cycle models are often highly aggregated, but they need not be: Recent work by Hornstein and Praschnik (1994) shows how a GE business cycle model can be used to capture the comovements across sectors observed in the data. Rios-Rull (1995) presents a survey of applied GE business cycle models with heterogeneous consumers.

There are two stages to an applied GE business cycle experiment: The researcher begins by computing the equilibrium behavior of the people in the model economy, that is, their decision rules. He or she then feeds a series of random shocks into the model and compares properties of the generated time series data with properties of data from the world. The Kydland and Prescott (1982) model, for example, did a good job of matching many of the variances and covariances in data from the United States. An important finding of their experiment was that the theory resulted in a variance in hours work that differed significantly from that in the data. This finding led Hansen (1985) to modify the Kydland-Prescott formulation, in which workers were homogeneous, using Rogerson's (1988) theory of labor indivisibility: rather than all workers working a little less during a period with a negative technology shock, some workers became unemployed. Actually, the Hansen model overaccounted for the variance in hours. Yet a further development by Kydland and Prescott (1989) allows for variations in both the number of workers and in the number of hours per worker. This model is more successful than either the original Kydland-Prescott model or the Hansen model in matching the variance in hours found in the data.

This sort of interplay between theory and measurement is frequent in GE business cycle modeling: because failures of a model to match the data are easily interpreted within the context of a well understood theory: they point to obvious directions for future research. This characteristic represents a significant advantage of the applied GE approach over the alternative of "accepting" or "rejecting" models based on formal statistical tests, at least as they are usually employed. Even Gottfries (1991), defending the use of formal statistical theory against Summer's (1991) charge of its irrelevance in macroeconomics, admits that the results of applied GE models are easier to understand than the results of statistical hypothesis tests.

3. Using theory

A number of the papers in this issue illustrate the ability of applied GE models to analyze policy. Kehoe, Polo, and Sancho, for example, present an applied GE model of the Spanish economy, constructed in the Shoven-Whalley tradition, that had previously been used to predict the impact of the changes in fiscal and trade policy enacted in Spain in connection with its 1986 entry into the European Community. The model is static and focuses on movements in relative prices and resource allocation across 12 different industrial sectors. The Kehoe-Polo-Sancho model had predicted that the changes in fiscal policy in Spain in 1986 would result in a substantially higher indirect tax burden and significant changes in relative prices across sectors. Subsequent experience has shown these predictions to be fairly accurate.

The paper by Gravelle and Kotlikoff develops an overlapping generations model in which the representative consumer in each generation lives for 55 (year long) periods and there are 11 production sectors. Some production sectors include both corporate and noncorporate firms. There are three factors of production in every period – capital, labor, and managerial input. Gravelle and Kotlikoff use this model to estimate the welfare gains of the 1986 Tax Reform Act in the United States. They find gains resulting from the reduction in the corporate income tax contained in this legislation that are four times as large as those found by static models that follow the Harberger (1962) and Shoven and Whalley (1972) approach. Their findings, Gravelle and Kotlikoff explain, are dependent on both the ability to identify intertemporal distortions and the ability to model shifts between corporate and noncorporate production in some industries. They have, therefore, chosen to use a model that incorporates both dynamic and sectoral detail.

Another paper in this issue that uses a deterministic dynamic applied GE model, by Imrohoroglu, Imrohoroglu, and Joines, analyzes the impact on welfare of potential reforms to the social security system in the United States. Like Gravelle and Kotlikoff, these researchers employ an overlapping generations model. Unlike

Gravelle and Kotlikoff, they choose to abstract away from heterogeneity across production sectors but not heterogeneity across consumers: there is a single production sector, but each generation consists of a continuum of consumers who can live for up to 65 periods and face individual risk with respect to both income and mortality. Because there is no aggregate uncertainty, the equilibrium of the model is deterministic but it requires specifying distributions of consumer types in each generation. Since the Imrohoroglu-Imrohoroglu-Joines model does not include annuity markets, social security provides insurance against living too long. In addition, that social security reduces the capital stock may even be beneficial because there is potential for capital overaccumulation. Imrohoroglu, Imrohoroglu, and Joines find that, although a calibrated version of the current social security system leads to underaccumulation of capital in their model, eliminating social security entirely would lead to overaccumulation. The optimal system would not provide annual benefits to retirees equal to 60 percent of their average lifetime employement income, as does the current system, nor would it provide no benefits; rather, the optimal replacement ratio in their model is 30 percent.

Another paper in this issue that abstracts away from aggregate, but not individual uncertainty, is that of Ljungqvist and Sargent. In the Ljungqvist-Sargent model there is a continuum of infinitely lived consumer/workers who face uncertainty about wages and job security while on the job and uncertainty about wage offers while looking for a job. The authors embed a job search model in a very simple applied GE framework. They are able to resolve the apparent puzzle of why for may years Sweden had a low unemployment rate at the same time that it had a generous unemployment system. They find the anwer in Sweden's high marginal income tax rates: high tax rates reduce workers' incentives to switch jobs in response to changes economic opportunities.

The different papers in this issue that use applied GE models to do policy analysis choose different abstractions because they ask different questions. As a group these papers illustrate the flexibility of applied GE models and its ability to address a wide range of policy questions.

4. Testing theory

Some of the papers in this issue show how applied GE models can be used to test current theory. The tests take a variety of forms: Some papers test whether the results of an applied GE experiment are consistent with observations from the world. Others test whether the results are robust to changes in the structure of the model economy used in the experiment.

In a sense, whether or not we can develop an innovation in the theory to resolve an apparent puzzle in the data is a test of the applied GE methodology. The paper by Ljungqvist and Sargent in this issue and many of the papers in the equity premium puzzle literature inspired by the work of Mehra and Prescott (1985) fall into this category. This issue also includes papers that explicitly test established theory by comparing the results generated by applied GE models with data.

The first of these is the paper by Kehoe, Polo, and Sancho. These authors stress that the value of an applied GE model constructed to do policy analysis lies in its ability to do conditional prediction: What would be the impact of a given policy on a particular set of variables, everthing else being equal? They test the results of their model constructed to analyze the impact of the policy reforms that accompanied Spain's entry into the European Community in 1986 by comparing its results with the changes in relative prices and resource allocation that took place in Spain during the period 1985–87. They find that, at least when the effects of two major exogenous shocks are included, the model does a remarkably good job in tracking these changes. Kehoe, Polo, and Sancho also examine the sensitivity of their results to alternative specifications of the behavior of the government and foreign sector, which are exogenous in their model, and to alternative specifications of labor market behavior. The arbitrainess of these alternative specifications, usually referred to as closure rules, is one of the main sources of Whalley's (1988) worries about comparing results with data. Kehoe, Polo, and Sancho find that their results are robust to these alternative specifications. Their work should encourage other researchers to do similar testing of their applied GE models. Shortcomings in conditional predictions of a model would then provide motivation for further theoretical development and further testing.

The other paper that tests a theory by comparing experiment results with observations from the world is that of Cho and Cooley, which builds money and rigid nominal contracts into a GE business cycle model. (This sort of exercise shows the terminology "real business cycle model" to be unfortunate.) As Kydland and Prescott (1989) have found, technology shocks can account for about 70 percent of aggregate fluctuations in the postwar U.S. economy. Economists like Fischer (1977) and Taylor (1980) have stressed monetary shocks acting through the propagation mechanism of nominal contracts as a source of business cycle movements. Cho and Cooley use a carefully constructed and calibrated GE model to see whether monetary shocks acting through nominal contracts can result in business cycle fluctuations that match those in the data. They find that they are able to choose the length of a nominal contract in the model so that the fluctuations in output in the model have the same magnitude as those in the data. Unfortunately, the comovements among such variables as output and real wages, and productivity and hours worked in the model economy are completely at odds with their counterparts in the data. Cho and Cooley conclude that the theory of monetary shocks propagated by nominal wage contracts fails as a theory of business cycles, although it may be useful in explaining some of the fluctuations not accounted for by technology shocks.

Another paper in which we learn from the failure of an applied GE experiment is that of Cooley, Hansen, and Prescott. In their model capital, like labor in the Hansen (1985) model, can be unemployed. Given that idle capacity, like unemployed labor, is a feature of the world not found in simple GE business cycle models, it is tempting to hypothesize that incorporating idle capacity into the model will significantly improve the match with the data. The results of this paper are negative in that Cooley, Hansen, and Prescott conclude that incorporating idle capacity has very little effect on the properties of aggregate variables in their model. In fact, however, these results can be interpreted in a positive light: the standard GE business cycles model is tested for robustness to the incorporation of idle capacity, and its principal features are found to be remarkably robust.

The paper by Mercenier involves a different test of robustness. Mercenier presents a static, calibrated GE model with increasing returns and imperfect competition that has been constructed to analyze the impact of the single market reforms instituted by the European Community in 1992. He shows that, if he assumes there is free entry and exit of firms in the model, then there are multiple equilibria, but if the number of firms in an industry is fixed, there is a unique equilibrium. Multiplicity of equilibria makes policy analysis and conditional prediction problematical, and it is disturbing to find multiplicity tied to a fairly arbitrary assumption about market structure. Mercenier interprets his findings as indicating the need for more theoretical work on applied GE analysis with increasing returns and imperfect competition.

5. Measurement

The seven papers discussed in the previous two sections represent final products in that they present the results of applied GE experiments that either use or test the theory. The paper by Rogerson, Rupert, and Wright, in contrast, represents an intermediate input in applied GE analysis. The authors measure an important elasticity parameter of the preference structure in GE business cycle model that allows for household production as well as market production.

In an earlier paper, McGrattan, Rogerson, and Wright (1993) have found that, for suitable values of the parameters of their preference structure, this model matches the data better than, and has different policy implications from, the corresponding model without household production. That the model matches the business cycle data well does not provide a very informative test, however, because the parameters of the model have been fitted to this data using a maximum likelihood method. A more informative test of their structure is to compare these fitted parameters with ones obtained from other data. They do this in the case of a key parameter, the elasticity of substitution between home production and market production, using statistical techniques applied to household panel data. The measure of the elasticity that they obtain is reassuringly close to that they had found by fitting the parameters of their model to aggregate time series data.

References

Arrow, K. J., Debreu, G.: Existence of equilibrium for a competitive economy. Econometrica **22**, 265–90 (1954)

Arrow, K. J., Kehoe, T. J.: Distinguished fellow: Herbert Scarf's contributions to economics. J Econ. Perspect. **8**, 161–81 (1994)

Auerbach, A. J., Kotlikoff, L. J.: Dynamic fiscal policy. Cambridge: Cambridge University Press (1987)

Ballard, C. L., Goulder, L. H.: Consumption taxes, foresight, and welfare: A computable general equilibrium analysis. In: Piggott J., Whalley, J. (eds.) New developments in applied general equilibrium analysis, pp. 253–282. Cambridge: Cambridge University Press (1985)

Bergman, L., Jorgenson, D., Zalai, E.: General equilibrium modeling and economic policy analysis. Oxford: Basil Blackwell (1990)

Brown, D. K., Stern, R. M.: U.S.-Canada bilateral tariff elimination: The role of product differentiation and market structure. In: Feenstra, R. C. (ed.) Trade Policies for international competitiveness. pp. 217–45. Chicago: University of Chicago Press (1989)

Cooley, T. F.: Frontiers of business cycle research. Princeton: Princeton University Press (1995)

Dervis, K., de Melo, J., Robinson, S.: General equilibrium models for development policy. Cambridge: Cambridge University Press (1982)

Dixit, A., Stiglitz, J. E.: Monopolistic competition and optimum product diversity. Amer. Econ. Rev. **67**, 297–308 (1977)

Dixon, P. B., Parmenter, B. R., Powell, A. A., Wilcoxen, P. J.: Notes and problems in applied general equilibrium economics. Amsterdam: North-Holland (1992)

Dixon, P. B., Parmenter, B. R., Sutton, J., Vincent, D. P.: ORANI A multisectoral model of the Australian economy. Amsterdam: North-Holland (1982)

Don, H., van de Klundert, T, and van Sinderen, J.: Applied general equilibrium modeling. Dordrecht: Kluwer Academic Publishers (1991)

Echevarria, C.: Sectoral composition and its relation to development. Unpublished Ph.D. dissertation. University of Minnesota (1992)

Erlich, S., Ginsburgh, V., van der Heyden, L.: Where do real wage decreases lead Belgium? A general equilibrium analysis. Eur. Econ. Rev. **31**, 369–83 (1987)

Fischer, S.: Long-term contracts, rational expectations, and the optimal money supply rule. J. Polit. Econ. **85**, 191–205 (1977)

Francois, J. F. Shiells, C. R. Modeling trade policy: Applied general equilibrium assessments of North American free trade. Cambridge University Press (1994)

Fullerton, D., Shoven, J. B., Whalley, J.: Replacing the U. S. income tax with a progressive consumption tax: A sequenced general equilibrium approach. J. Publ. Econ. **20**, 3–23 (1983)

Ginsburgh, V.: In the Cournot-Walras general equilibrium model, there may be "more to gain" by changing the numéraire than by eliminating imperfections: A two-good economy example. In Mercenier, J, Srinivasan, T. N. (eds.), Applied general equilibrium and economic development pp. 217–24. Ann Arbor: University of Michigan Press (1994)

Ginsburgh, V. A., Waelbroeck, J. L.; Activity analysis and general equilibrium modeling. Amsterdam: North-Holland (1981)

Gottfries, N.: Comment on L. H. Summers, "The scientific illusion in empirical macroeconomics." Scand. J. Econ. **93**, 149–54 (1991)

Goulder, L. H. Summers, L. H.: Tax policy, asset prices, and growth: A general equilibrium analysis. J Publ. Econ. **38**, 265–96 (1989)

Hansen, G. D.: Individual labor and the business cycle. J. Monet. Econ. **16**, 309–27 (1985)

Harberger, A. C.: The incidence of the corporate income tax. J. Polit. Econ. **70**, 215–40 (1962)

Harris, R.: Applied general equilibrium analysis of small open economies with scale economies and imperfect competition. Amer. Econ. Rev. **74**, 1016–32 (1984)

Helpman, E., Krugman, P. R.: Market structure and foreign trade: Increasing returns, imperfect competition, and international economy. Cambridge, Mass.: MIT Press (1985)

Hornstein, A., Praschnik, J.: Intermediate inputs and sectoral comovement in the business cycle. Unpublished manuscript. University of Western Ontario (1994)

Johansen, L.: A multi-sectoral study of economic growth. Amsterdam: North-Holland (1960)

Jorgenson, D. W.: Econometric methods for applied general equilibrium analysis. In: Scarf, H. E., Shoven, J. B., (ed.) Applied general equilibrium analysis, pp. 139–203. Cambridge: Cambridge University Press (1984)

Jorgenson, D. W., Yun, K. Y.: The efficiency of capital allocation. Scan. J. Econ. **88**, 85–107 (1986)

Kehoe, P. J., Kehoe, T. J.: A primer on static applied general equilibrium models. Fed. Res. Bank Minn. Q. Rev. **18**, 2–16 (1994)

Kehoe, T. J.: Computation and multiplicity of equilibria. In: Hildenbrand, W., Sonnenschein, H. (ed.), Handbook of mathematical economics IV, pp. 2049–2143. Amsterdam: North-Holland (1991)

Kydland, F. E., Prescott, E. C.: Time to build and aggregate fluctuations. Econometrica **50**, 345–70 (1982)

Kydland, F. E., Prescott, E. C.: Hours and employment variation in business cycle theory. Econ. Theory **1**, 63–81 (1991)

Leontief, W. W.: Input-output economics. New York: Oxford University Press (1941)

Leontief, W. W.: Domestic production and foreign trade: the American capital position reexamined. Proc. Amer. Philosoph. Soc. **97**, 332–49 (1953)

Lipton, D., Sachs, J.: Accumulation and growth in a two-country model: A simulation approach. J. Int. Econ. **15**, 135–59 (1983)

Manne, A. S.: Economic equilibrium: Model formulation and solution. Mathematical Programming Study 23. Amsterdam: North-Holland (1985)

Manne, A. S., Preckel, P.: A three-region intertemporal model of energy, international trade and capital flows. In: Manne, A. S. (ed.) Economic equilibrium: Model formulation and solution, pp. 56–74. Mathematical Programming Study 23. Amsterdam: North-Holland (1985)

McGrattan, E., Rogerson, R.: Wright, R.: Household production and taxation in the stochastic growth model. Research Department Staff Report 166. Federal Reserve Bank of Minneapolis (1993)

McKenzie, L.: On the existence of general equilibrium for a competitive market. Econometrica **27**, 54–71 (1959)

Mercenier, J., Srinivasan, T. N.: Applied general equilibrium and economic development. Ann Arbor: University of Michigan Press (1994)

Piggot, J., Whalley, J.: New development in applied general equilibrium analysis. Cambridge: Cambridge University Press (1985)

Piggott, J., Whalley, J.: Applied general equilibrium. Heidelberg: Physica Verlag (1991) Rios-Rull, J. V. Models with heterogeneous agents. In: Cooley, T. F. (ed.) Frontiers of business cycle research, Princeton University Press, forthcoming (1994)

Rios-Rull, J. V.: Models with heterogeneous agents. In: Cooley, T. F. (ed.) Frontiers of business cycle research, pp. 98–125. Princeton: Princeton University Press (1995)

Rogerson, R.: Indiviual labor, lotteries, and equilibrium. J. Mon. Econ. **21**, 3–16 (1988)

Scarf, H. E.: On the computation of equilibrium prices. In: Fellner, W. J. (ed.) Ten economic studies in the tradition of Irving Fischer, pp. 207–30. New York: Wiley (1967)

Scarf, H. E., Hansen, T.: The computation of economic equilibria. New Haven: Yale University Press (1973)

Scarf, H. E., Shoven, J. B.: Applied general equilibrium analysis. Cambridge: Cambridge University Press (1984)

Schumpeter, J. A.: A history of economic analysis. New York: Oxford University Press (1954)

Shoven, J. B., Whalley, J.: A general equilibrium calculation of the effects of taxes on income from capital J. Publ. Econ. **1**, 281–321 (1972)

Shoven, J. B., Whalley, J.: Applied general equilibrium models of taxation and international trade: An introduction and survey. J. Econ. Lit. **22**, 1007–51 (1984)

Shoven, J. B., Whalley, J.: Applying general equilibrium. Cambridge: Cambridge University Press (1992)

Srinivasan, T. N.: Review of "General equilibrium models for development policy." Econ. J. **93**, 441–42 (1983)

Srinivasan, T. N., Whalley, J.: General equilibrium trade policy modeling. Cambridge, Mass.: MIT Press (1986)

Summers, L. H.: Capital taxation and accumulation in a life cycle growth model. Amer. Econ. Rev. **71**, 533–44 (1981)

Summers, L. H.: The scientific illusion in empirical macroeconomics. Scand. J. Econ. **93**, 129–48 (1991)

Taylor, J. B.: Aggregate dynamics and staggered contracts. J. Polit. Econ. **88**, 1–23 (1980)

Taylor, L.: Socially relevant policy analysis: Structuralist computable general equilibrium models for the developing world. Cambridge, Mass.: MIT Press (1990)

Whalley, J.: What have we learned from general equilibrium tax policy models? Working Paper 8625C. University of Western Ontario (1986)

Whalley, J.: Lessons from general equilibrium models. In: Arron, H. J., Galper, H., Pechman, J. A. (ed.) Uneasy compromise: Problems of a hybrid income-consumption tax, pp. 15–50. Washington: Brookings Institute (1988)