Leigh Tesfatsion
Last Udated: 9/14/03

WALRASIAN EQUILIBRIUM: A CRITIQUE

Key Questions:

- What is a "Walrasian equilibrium"?
- Is Walrasian equilibrium an appropriate benchmark of coordination success? What does coordination success mean?
- How should an individual person's "welfare" be measured?
- How should "social welfare" be measured for an economy?
- In what sense is social welfare "optimized" in a Walrasian equilibrium?
- How robust is the concept of Walrasian equilibrium to various weakenings of its assumptions?

1. Introduction

As detailed in Katzner [4], the Walrasian general equilibrium model represents a precisely formulated set of conditions under which feasible allocations of goods and services can be supported by price systems in decentralized market economies characterized by price-taking consumers and firms and the private ownership of capital and labor. The standard textbook version of the Walrasian general equilibrium model incorporates nine basic assumptions, as follows:

A1: There is a fixed finite number of distinct consumption good and capital good types. Each good is *private* in the sense that it is both excludable and rival, where *excludable* means that people can be excluded from consuming the good and *rival* means that one person's consumption of the good reduces the amount available for consumption by others. Note: For capital goods, consumption = depreciation (used up portion) of the capital good.

A2: There is a fixed finite number of agents, called consumers, who have preferences over different bundles of consumption goods and who own nonnegative initial endowments of capital goods and labor.

A3: The preferences of each consumer can be represented by a utility function.

A4: There is a fixed finite number of agents, called firms, who produce consumption goods for sale to consumers using labor services and capital services purchased from consumers as inputs to production. Consumers are the ultimate owners of firms; profits are distributed back to consumers as dividends in proportion to their ownership shares.

A5: The income of consumers comes from dividends and from the sale of capital services and labor services.

A6: Markets for services and consumption goods are *complete*. This means that, for each valued service and consumption good, there is a market price at which it can be bought or sold.

A7: Consumers, taking expected goods prices, wages, rental rates, and dividends as given, choose demands for consumption goods and supplies of capital and labor services to maximize their utility subject to a budget constraint (expenditure less than or equal to expected income) and physical feasibility conditions (nonnegativity and endowment constraints).

A8: Firms, taking expected goods prices, wages, and rental rates as given, choose supplies of goods and demands for capital and labor services to maximize expected profits subject to technological feasibility conditions (nonnegativity constraints, and production relations associating inputs with possible outputs).

A9: All purchase and sale agreements are costlessly enforced.

Under assumptions A1-A9, then, the world is viewed as highly orderly. Property rights are well established and costlessly enforced. Potentially disruptive behavior such as incorrect expectations, the breaking of contracts, theft, power struggles, and status competition is not permitted. Within this orderly world, researchers have established additional restrictions on utility functions and production relations guaranteeing the existence of a unique *Walrasian equilibrium*, that is, a unique set of relative prices and corresponding demand and supply quantities at which, assuming fulfilled expectations, all consumers are maximizing their utility, all firms are maximizing their profits, and all markets clear.

2. A Simple Illustrative Walrasian General Equilibrium Model

Consider, for concreteness, the following illustrative Walrasian general equilibrium model over a time period $T = [t^0, t^1]$. The economy at time t^0 consists of n utility-maximizing never-satiated consumers, $i = 1, \ldots, n$, and two profit-maximizing firms, X and Y. Each consumer is endowed with labor, capital, an ownership share in firm X, and an ownership share in firm Y. During period T the firms X and Y produce distinct consumption goods x and y, respectively, using labor services and capital services purchased from consumers at the beginning of period T. The consumption goods are sold to the consumers at the end of period T, and all profits are distributed back to the consumers as dividends in proportion to their ownership shares. The structure of this economy is schematically depicted in Figure 1.

– Insert Figure 1 About Here –

Each consumer i maximizes his period T utility subject to physical feasibility constraints and a budget constraint, conditional on an expected dividend and on expected prices (i.e., goods prices, a wage rate, and a capital rental rate). Supressing dependence on exogenously specified endowments and tastes (utility functions), the solutions to these consumer utility maximization problems give the demands and supplies for consumers as a function of expected dividends and expected prices. Each firm X and Y maximizes its period T expected profits subject to nonnegativity and technology constraints, conditional on expected prices. Supressing dependence on the exogenously specified technology, the solution to these profit maximization problems give the demands and supplies of firms as a function of expected prices.

DEFINITION: A specific vector e^* comprising consumer supplies and demands for services and consumption goods, firm demands and supplies for services and consumption goods, prices, expected prices, and expected dividends is said to be a *Walrasian equilibrium* if the following three conditions hold:

(a)Individual Optimality: At e^*, each consumer i is maximizing his utility, conditional on expected prices and expected dividends, and each firm X and Y is maximizing its profits conditional on expected prices.

(b) Fulfilled Expectations: At e^*, expected prices coincide with actual prices and expected dividends coincide with actual dividends calculated as consumer shares of firm profits.

(c) Market Clearing: At e^*, excess supply is greater than or equal to zero in each market for each service and consumption good.

Remark on Walras' Law: Given conditions (a) and (b), it follows directly from a summation of all consumer budget constraints (with fulfilled expectations) that the economy satisfies a weak form of Walras' Law at e^*, i.e., the total value of excess supply is nonnegative. Consequently, the assumed non-satiation of consumers — which implies that consumers satisfy their budget constraints as equalities — suffices to guarantee that Walras' Law holds at e^* in the stronger sense that the total value of excess supply is zero. Condition (c) then yields the further implication that any service or consumption good in excess supply at e^* must have a zero price.

3. Pareto Efficiency and the First Welfare Theorem

How should a person's welfare be measured? Under what circumstances is it appropriate to say that one person is better off than another?

Political philosophers addressing this question generally focus on political rights (including property rights) as well as on economic standards of living. For example, the famous political philosopher John Rawls [8] has attempted to construct welfare measurements in terms of a "primary good" index, where by primary goods he means goods which are generalized means for the attainment of a decent quality of life. Thus, primary goods include political goods (liberties such as freedom of speech, freedom of religion, etc.) as well as basic economic goods (shelter, food, clothing, etc.).

Economists, on the other hand, have primarily devised welfare criteria which focus on non-wastage of resources, where resources are interpreted in two different but related ways: non-wastage of *physical resources* ("productive efficiency," or just "efficiency") and non-wastage of *utility* ("Pareto-efficiency"). Political rights are considered to be part of the given background context. In particular, property ownership is generally taken as given; and the discussion of welfare focuses primarily on the possible benefits of a redistribution of income (i.e., of the payments received by the owners of human and physical capital) rather than on a redistribution of property ownership per se.

Consider first the concept of (productive) efficiency, as defined in standard economic texts:

DEFINITION: An economy is said to exhibit *(productive) efficiency* if, within the limitations of technology and resources, there is no feasible way to increase the amount of produced output, holding fixed the current amount of inputs to production, or to decrease the amount of inputs to production, holding fixed the current amount of produced output.

In contrast, the concept of Pareto efficiency considers whether utility is being wasted. The general definition of Pareto efficiency is as follows:

DEFINITION: A feasible allocation of goods and services for an economy is said to be *Pareto efficient* if there does not exist any other feasible allocation of goods and services for the economy under which the utility of each person in the economy is at least as great and the utility of at least one person is strictly greater.

Assuming nonsatiation (positive marginal utility for consumable goods and services and postive marginal productivity for inputs), efficiency in the sense of nonwastage of physical resources is a necessary but not sufficient condition for Pareto efficiency. It is now possible to state what is widely perceived to be the most important implication of Walrasian equilibrium, the First Welfare Theorem. For a proof of this theorem, see for example Takayama [13, Section C, pp. 185–204], especially Theorem 2.C.1 on page 192.

THE FIRST WELFARE THEOREM: Let a Walrasian economy be given, as outlined in sections 1 and 2. Suppose the utility function of each consumer is strictly increasing with respect to each of its arguments, implying that no consumer is ever satiated with respect to consumption and hence each consumer entirely exhausts his budget in equilibrium. Then, any Walrasian equilibrium for this Walrasian economy is Pareto efficient, in the sense that the allocation of goods and services resulting from this equilibrium is a Pareto efficient allocation.

4. Robustness of the Walrasian General Equilibrium Model

The Walrasian general equilibrium model outlined in sections 1 and 2 can be enhanced with more explicit analytical details and more sophisticated features. As Figure 1 makes clear, however, its defining *structural* characteristic is that direct agent-agent interactions do not take place. Rather, all agent-agent interactions are mediated by an implicit clearinghouse colorfully referred to as the "Walrasian Auctioneer."[1]

More precisely, *strategic interaction* is said to occur between two agents if the choice of a decision for at least one of the agents depends upon what he perceives or expects the decision of the other agent to be. The Walrasian general equilibrium model reflects the view that, in decentralized market economies, price systems reduce or even eliminate the need for economic agents to interact strategically.

As Illustrated in Figure 1, the key observation here is that values for prices and dividend payments constitute the only information conveyed to consumers and firms in the Walrasian general equilibrium model. Since prices and dividend payments are treated as parameters by these agents in their decision problems, these decision problems reduce to "control" problems. That is, the decision problem for each agent only includes decision variables fully under the agent's own control; the decision variables for other agents do not appear, implying there is no strategic interaction. In systems science parlance, the global allocation problem has been decomposed into a collection of individual agent allocation problems by the introduction of linking variables (prices and dividends).

The equilibrium values for the linking variables are determined by calculations performed by the fictitious Walrasian Auctioneer; they do not arise from any actions of the consumers or firms within the model. For example, the Walrasian Auctioneer might be presumed to use the following tatonnement (iterative solution) process to discover equilibrium prices and dividend payments: The Auctioneer starts by "calling out" arbitrary positive prices for goods and services to firms and consumers as well as nonnegative dividend payments for consumers, requiring that the consumers and firms in turn report back to the Auctioneer their optimal demand and supply quantity responses. If these quantity responses imply, in aggregate, that

[1] This terminology appears to have been introduced by Leijonhufvud [5].

a good or service is in excess demand (supply), the Auctioneer then calls out a slightly higher (lower) price for this good or service as well as revised dividend payments for consumers. The Walrasian Auctioneer stops calling out new prices and dividend payments only when all markets for goods and services are in equilibrium in the following sense: (a) There is no excess demand in any market; (b) any good or service in excess supply has had a zero price called out for it; and (c) the dividend payments called out by the Auctioneer equal the actual dividends that would be paid out by the firms, given the final called-out prices.

The robustness of the Walrasian general equilibrium model to changes in its pricing structure can be tested by considering three basic questions.

Question 1: How might strategic interaction become important if firms set prices for their inputs and outputs?

Firms' actions become strategically linked together if they understand and exploit the fact that the demand for their outputs and the distribution of labor and capital rental services across firms depend on the prices they set as well as on the prices set by other firms. For example, firm X might be able to bid away labor services from firm Y by offering a higher wage than the wage set by firm Y; and similarly with regard to attracting an increased supply of capital services and an increased output demand. Consequently, the attraction and retention of service suppliers and customers now involves a careful consideration of the pricing strategies of other firms.

Question 2: How might expectations and learning rules become important if firms set prices for their inputs and outputs?

Realistically, firms would not have costless access to complete and correct information regarding the supply and demand functions they face for inputs and outputs, information that is critical for the price-setting process. In this case, firms would face a "dual control" problem at each point in time in the sense that each firm would have two potentially conflicting objectives:

> *Information exploitation*: Set prices in an attempt to ensure that total profits are as high as possible, conditional on the firm's current information regarding the supply and demand functions it faces.

Information exploration: Set prices in an attempt to learn more about the supply and demand functions faced by the firm, so that *future* profits can be increased even if these learning efforts lead to lower current profits.

The situation is further complicated by the fact that the supplies and demands for a firm's inputs and outputs depend not only on its own prices but also on the prices set by other firms. Indeed, past prices will also affect the firm's current supplies and demands to the extent that these past prices affect current consumer budget constraints and search behavior.

Also, firms can now offer different wage rates to observationally equivalent workers and different goods prices to observationally distinct consumers for units of the same type of good. Consequently, it is highly unrealistic to assume that consumers can costlessly acquire complete and correct information regarding the wage rates and goods prices they face. Rather, consumers would presumably have to undertake some form of sequential search to learn about the current distribution of wage rates and goods prices.

Presumably, however, this search would involve opportunity costs for consumers in terms of delayed consumption and foregone wages. Consequently, consumers might decide to sample only a small fraction of the available wage offers and goods prices and then to accept the highest wage offer and lowest goods prices found to date instead of carrying out a complete global search of all possibilities. The rule by which a consumer decides to stop sequential sampling is called a *sequential stopping rule* in the statistical decision theory literature. When consumers use stopping rules, a nondegenerate distribution of wage rates can exist in "equilibrium" for a single type of labor, and a nondegenerate distribution of prices can exist in "equilibrium" for a single type of good. Moreover, consumers deciding to supply labor to or buy goods from a firm in some time period may simply decide to stick with this firm in future time periods without engaging in more search (habit, brand effects,...). These considerations can further complicate the strategic price-setting rivalry among firms.

Question 3: How might bankruptcy rules, rationing rules, and inventory management become important if firms set prices for their inputs and outputs?

Markets are no longer guaranteed to clear at the levels of *planned* supplies and demands, since wage rates and goods prices might be "wrong." Some type of formally or informally established rationing rule is needed to determine who gets what if the planned demand for a good happens to exceed its supply. If this situation arises frequently, a firm might want to institute an inventory plan so that excess demand can be satisfied out of inventory.

In the reverse case of supply exceeding demand, unintended inventories arise, and the firm would presumably want to take this possibility into consideration when making its price and quantity decisions. Even with an inventory plan, the possibility of bankruptcy arises for a firm if it cannot sell all it produces; for the firm might then be unable to fulfill its obligations with respect to wage and capital rental payments. If bankruptcy occurs, some type of formally or informally established rule is needed to determine how the assets that the firm still possesses get divided among its various creditors.

5. Illustrative Example with Price-Setting Firms

As suggested by the discussion in the previous section, the removal of the Walrasian Auctioneer from the Walrasian general equilibrium model is most definitely *not* a small perturbation of the model. Once firms and/or consumers are permitted to set prices and/or wages, strategic interaction naturally arises among agents who must now compete directly with rivals in their attempts to maximize utility and profits. In this section a simple example is presented that illustrates how strategic interaction arises between two price-setting profit-maximizing firms who are competing for the scarce dollars of a budget-constrained consumer.

Consider an economy that consists of two price-setting profit-maximizing firms, each producing a distinct consumption good at constant marginal cost, and a utility-maximizing consumer who obtains utility from the consumption of these two goods. Suppose that the profit obtained by Firm i from the sale of good i, $i = 1, 2$, is given by

$$p_i q_i - c_i q_i \quad , \tag{1}$$

where p_i denotes the price of good i, q_i denotes the amount sold of good i, and the constant marginal cost c_i is positive.

Suppose the consumer has a utility function of the form

$$U(q_1, q_2) \quad = \quad log(q_1 - b_1) + log(q_2 - b_2) \quad , \tag{2}$$

where b_1 and b_2 are given nonnegative constants. Suppose, also, that the income I of the consumer is a positive exogenously-given constant. The utility maximization problem faced by the consumer then takes the following form: Given goods prices p_1 and p_2, solve

$$\max_{q_1,q_2} U(q_1, q_2) \tag{3}$$

subject to the budget and feasibility constraints

$$p_1q_1 \ + \ p_2q_2 \ = \ I \ ; \tag{4}$$

$$q_1, q_2 \geq 0 \ . \tag{5}$$

The solution to the utility maximization problem (3) yields the following demand functions for q_1 and q_2:

$$q_1^* \ = \ b_1/2 + [I - b_2p_2]/2p_1 \ = \ D_1(p_1, p_2) \ ; \tag{6}$$

$$q_2^* \ = \ b_2/2 + [I - b_1p_1]/2p_2 \ = \ D_2(p_1, p_2) \ , \tag{7}$$

where dependence on the exogenous variables b_1, b_2, and I has been notationally supressed for expositional simplicity. Note that q_1^* is independent of p_2 in (6) if and only if $b_2 = 0$, and that q_2^* is independent of p_1 in (7) if and only if $b_1 = 0$. This illustrates the general rule of thumb that the optimal consumer demand for any one good will depend on the prices of all goods. This dependence arises because the demands of a consumer for goods in any one period are simultaneously and jointly constrained by a single budget constraint that requires total expenditures for all goods to equal total income (possibly modified by borrowing or lending). An exception to this rule arises for the special case of an additive and purely logarithmic utility function, e.g., the utility function in (2) with $b_1 = 0$ and $b_2 = 0$; in this case, as seen in (6) and (7), the demand for each good reduces to being a fixed proportion of income with a proportionality factor that depends only on own price.

Suppose the market protocol governing market behavior in this economy is as follows: Firm 1 and Firm 2 simultaneously announce prices p_1 and p_2, promising to meet any forthcoming demands for their goods from the consumer as long as this can be done with nonnegative profits. A strategic interaction problem then arises for each profit-maximizing firm, because the profits of each firm depend on the price set by the other firm. Specifically, the profit function of Firm 1 takes the form

$$\pi_1(p_1, p_2) \ = \ [p_1 - c_1]D_1(p_1, p_2) \ , \tag{8}$$

and the profit function of Firm 2 takes the form

$$\pi_2(p_1,p_2) \quad = \quad [p_2 - c_2]D_2(p_1,p_2) \quad . \tag{9}$$

Suppose the values taken on by the parameters appearing in the above-described model economy are as follows:

$$b_1 = 1/2;\ b_2 = 1;\ I = 1;\ c_1 = 0;\ c_2 = 0 \quad . \tag{10}$$

In this case, the consumer demand functions (6) and (7) reduce to the following particular forms:

$$q_1^* \quad = \quad 1/4 + [1 - p_2]/2p_1 \quad = \quad D_1(p_1,p_2) \quad ; \tag{11}$$

$$q_2^* \quad = \quad 1/2 + [2 - p_1]/4p_2 \quad = \quad D_2(p_1,p_2) \quad . \tag{12}$$

Suppose, also, that each firm can set its goods price at only one of two possible values, low L or high H, where

$$L \quad = \quad 1/2 \ \text{ and } \ H \quad = \quad 3/4 \quad . \tag{13}$$

In this case, the demands $D_1(p_1,p_2)$ faced by Firm 1 for all possible settings of the prices p_1 and p_2 are as follows:

$$\begin{aligned} D_1(L,L) &= 3/4 \ ; \\ D_1(L,H) &= 1/2 \ ; \\ D_1(H,L) &= 7/12 \ ; \\ D_1(H,H) &= 5/12 \ . \end{aligned}$$

Similarly, the demands $D_2(p_1,p_2)$ faced by Firm 2 for all possible settings of the prices p_1 and p_2 are as follows:

$$\begin{aligned} D_2(L,L) &= 5/4 \ ; \\ D_2(L,H) &= 1 \ ; \\ D_2(H,L) &= 9/8 \ ; \\ D_2(H,H) &= 11/12 \ . \end{aligned}$$

			Firm 2	
			L	H
Firm 1	L		(18,30)	(12,36)
	H		(21,27)	(15,33)

Table 1: Profit Payoff Matrix

Using (8) and (9), the profit payoff matrix faced by the two firms then takes the form depicted in Table 1. (For clarity, each profit level has been multiplied by 48 so that profits are represented as whole number rather than as fractions.) The first number in each reported payoff pairing denotes the profit for Firm 1 and the second number denotes the profit for Firm 2.

A *Nash equilibrium* for Firm 1 and Firm 2 is any pair (p_1^*,p_2^*) of pricing strategies such that, given p_1^*, Firm 2 has no incentive to deviate from p_2^*, and given p_2^*, Firm 1 has no incentive to deviate from p_1^*. As seen in Table 1, there exists a unique Nash equilibrium for the model economy at hand: namely, the pricing strategy pair (H,H). In fact, an even stronger property holds for (H,H). The pricing strategy H constitutes a *dominant* pricing strategy for each firm in the sense that H is the best price for each firm to set in response to *any* price set by its rival. Morever, (H,H) is also Pareto efficient, meaning there is no other feasible pricing strategy pair under which both agents would be at least as well off and at least one would be better off.

Note that Firm 1 would actually prefer the profit payoff it obtains under the pricing strategy pair (L,L) to the profit payoff it obtains under the pricing strategy pair (H,H), but it has no power to enforce this outcome. Even if Firm 1 were to announce that it plans to choose price L, it would still be best for Firm 2 to choose price H; and the profit payoff for Firm 1 under (L,H) is worse than the profit payoff for Firm 1 under (H,H).

Various open questions remain. For example, is (H,H) *always* a dominant (hence Nash) pricing strategy pair for the game at hand, regardless of the particular parameter values? Is there always a Nash equilibrium (even if not a dominant pricing strategy pair), regardless of parameter values? If so, is this Nash equilibrium always Pareto efficient? Could there be a Nash equilibrium which is Pareto dominated, for example, in the sense that there is another feasible pricing strategy pair that yields at least as much profit for both firms and strictly more profit for at least one? And what about the welfare of the consumer in all of this? And the sensitivity of the conclusions to the form of the utility function?

6. Concluding Remarks

In conclusion, the Walrasian general equilibrium model demonstrates how price systems are capable, in principle, of coordinating the supplies and demands of private agents in models of decentralized market economies that assume all agents are price *takers*. However, the Walrasian general equilibrium model is incomplete as a model of real-world decentralized market economies, since many private agents in such markets are price *setters*. When price setting by private agents is introduced into the standard Walrasian general equilibrium model, it simply breaks down.

Although a definitive *theory* regarding the working of decentralized market economies with price-setting agents is currently lacking, we do have some analytical, experimental, and natural data evidence that bears on this question.

For example, some researchers have attempted to introduce price setting into appropriately modified general equilibrium models; see, for example, Fisher [1], Pingle and Tesfatsion [6, 7], and Shubik [10, Chapter 14]. The relationship between these attempts and the now rather extensive partial-equilibrium literature in industrial organization on sequential bargaining games with price-setting agents nevertheless remains unsettled; see, for example, Fudenberg and Tirole [2, Chapter 10].

In the human-subject market experiments conducted by Charles Plott, Vernon Smith and others in which the market structure is kept fairly simple — e.g., a single market with a unique market clearing point — various auction mechanisms in which buyers and sellers sequentially make bids and offers for units of good have been regularly observed to result in convergence to a market clearing outcome. See, for example, Kagel and Roth [3] and Smith [11, 12]. Thus, the Walrasian general equilibrium model does have predictive content in certain experimental settings even when its behavioral assumptions (in particular, price taking) are known to be false.

Also, various researchers have constructed relatively simple computational models of decentralized market economies with imperfectly informed but price-*taking* agents – see, for example, Sargent [9, Chapter 5]. The experiments conducted for these economies suggest that convergence to a market clearing equilibrium can sometimes be ensured if the learning algorithms used by agents to update their price expectations are suitably restricted by the modeller. On the other hand, in "bottom up" agent-based computational economics (ACE) studies of decentralized market economies in which consumers and firms are modelled as autonomous interacting price-*setting* agents who evolve their behavior over time, experiments indicate that multiple persistent configurations ("attractors") can exist for each specification of the initial structural conditions if interaction effects are sufficiently strong, as in labor markets. See, for example, Tesfatsion [14, 15].

In the real world, decentralized market economies with price-setting agents have evolved an enormous variety of institutions (legal systems, credit systems, social norms, ...) that help to prevent market breakdowns. Given these supporting institutions, it does appear that many decentralized market economies are able to achieve, on average, a rough balancing of supplies and demands for goods and services. More generally, these economies are able to stay approximately coordinated over time, in the sense that inflation and unemployment do not get wildly out of control and a positive GDP growth rate is sustained on average. Consequently, despite our current inability to explain, theoretically, the process by which real-world decentralized market economies accomplish such feats, the fact that such economies do accomplish such feats is incontrovertible evidence that coordination issues remain a key unresolved aspect of macroeconomic theory.

What still needs to be done, then, is to combine the use of theoretical model analysis, market lab experiments, and computational experiments in an attempt to explain actual empirical data on the workings of real-world decentralized market economies with price setting agents. In particular, do such economies in any sense tend to evolve naturally, or are they the result of deliberate top-down planning? To what extent, if any, is their success or failure the result of top-down interventions?

As detailed above, a serious investigation of these issues will require the consideration of various topics that have traditionally been identified with other disciplines:

1. Strategic interaction (Game Theory and Industrial Organization)
2. Dual control (Systems Science)
3. Optimal search/sampling rules (Statistical Decision Theory)
4. Inventory planning (Management Science and Operations Research)
5. Descriptive behavioral characterizations, e.g., of the way in which individuals and groups resolve or account for uncertainty in their decision making (Sociology and Psychology)
6. Descriptive institutional characterizations, e.g., of the customs, rules, and/or laws regarding bankruptcy procedures, rationing, wage contracting, credit contracting, etc. (Business and Law)

The resulting models can be quite complex. Consequently, the analysis, experimental lab study, or computational study of such models will require sophisticated mathematical tools from systems theory, a good knowledge of statistical experimental design, and/or a good working knowledge of a powerful computer programming language such as C++ to succeed.

References

[1] Fisher, F. M., *Disequilibrium Foundations of Equilibrium Economics*, Cambridge University Press, Cambridge, 1986.

[2] Fudenberg, D., and Jean Tirole, *Game Theory*, The MIT Press, 1991.

[3] Kagel, J. H., and A. E. Roth, *Handbook of Experimental Economics*, Princeton University Press, Princeton, N.J., 1995.

[4] Katzner, D., *The Walrasian Vision of the Microeconomy: An Elementary Exposition of the Structure of Modern General Equilibrium Theory*, University of Michigan Press, Ann Arbor, 1989.

[5] Leijonhufvud, A., *On Keynesian Economics and the Economics of Keynes*, Oxford University Press, Oxford, 1968.

[6] Pingle, M., and L. Tesfatsion, "Active Intermediation in a Monetary Overlapping Generations Economy," *Journal of Economic Dynamics and Control* 22 (1998), 1543–1574.

[7] Pingle, M., and L. Tesfatsion, "Active Intermediation in Overlapping Generations Economies with Production and Unsecured Debt," *Macroeconomic Dynamics* 2 (1998), 183–212.

[8] Rawls, J., *A Theory of Justice*, Harvard University Press, 1971.

[9] Sargent, T., *Bounded Rationality in Macroeconomics*, Oxford University Press, Clarendon, 1993.

[10] Shubik, M., *A Game-Theoretic Approach to Political Economy*, The MIT Press, Cambridge, MA, 1991.

[11] Smith, V. L., "Theory, Experiments, and Economics," *Journal of Economic Perspectives* 3 (1989), 151-169.

[12] Smith, V. L., "Economics in the Lab," *Journal of Economic Perspectives* 8 (Winter 1994), 113-131.

[13] Takayama, A., *Mathematical Economics* Cambridge University Press, l985.

[14] Tesfatsion, L., "Agent-Based Computational Economics: An Introduction to the Literature," *Readers' Guide to the Social Sciences*, Volume 1, Fitzroy Dearborn Publishers, London, March 2001.

[15] Tesfatsion, L., "Structure, Behavior, and Market Power in an Evolutionary Labor Market with Adaptive Search," *Journal of Economic Dynamics and Control* 25/3-4 (2001), 419-457.