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Three Lectures on the Theory of Money and Financial Institutions: Lecture 1: A Nontechnical Overview

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LECTURE 1: A NONTECHNICAL OVERVIEW

By

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Three Lectures on the Theory of Money and Financial Institutions

Lecture 1: A Nontechnical Overview*

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Abstract

This is a nontechnical, retrospective paper on a game theoretic approach to the theory of money and financial institutions. The stress is on process models and the reconciliation of general equilibrium with Keynes and Schumpeter's approaches to non-equilibrium dynamics.

Keywords: bankruptcy, innovation, growth, competition, price-formation

JEL codes: C7, E12

Preamble

This is the first of three essays on a primarily game theoretic approach to the theory of money and financial institutions. I wish to cover 68 years of work that can be broken conveniently into four overlapping parts: 1948-1961 when I was working primarily with games in coalitional form and with oligopoly theory using games in strategic or extensive form when I first became concerned with the essentially unsatisfactory state of both micro- and macro-economics in their treatment of economic dynamics. 1961-1971 when I had decided that the apparently intractable problem that I wished to pursue was the development of a decent strategic microeconomic theory of money. During this period I spent a great deal of time building highly unsatisfactory models

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that I ended up destroying having made no progress. The period 1971-2016 was when I finally managed to get through `The Looking Glass' that permitted me to see the parallel worlds of the physical world of production and consumption and the financially guided economy. This began with my basic insight on how to recast the general equilibrium exchange economy as a playable game in strategic form (that I named `a strategic market game') and how to solve it for its noncooperative equilibria (NCE) not because I liked this solution, but because it provided a way to show how the competitive equilibria (CE) of the general equilibrium system (GE) could be related with the NCE of a process model. The fourth period has been in parallel with the third, but it was started far later. The fourth period has been from 2001-2016 and the work was much influenced by my interaction with colleagues at the Santa Fe Institute. It was around 2001 that I started to perceive that even at a high level of abstraction finding the appropriate process models to match the general equilibrium class of models was not enough. Government, default and innovation had to be covered and the distinction between principal and fiduciary behavior had to be stressed along with the shift in emphasis from the tight equations of equilibrium to the inequalities that limit the domain of dynamics but do not specify the equations of motion. I began a close collaboration with Eric Smith a physicist at the Santa Fe Institute interested deeply in physics, biology, finance and economics

Dynamics of any sort requires institutions or organisms as the carriers of process, be it behavioral, strategic or merely random. A static description of efficient price allocation for many goods and services can be presented with what appears to be a highly abstract and beautiful mathematical structure that does not need or consider either money or disequilibrium. My guess was that the necessity for money and financial institutions to carry economic process could be shown at the same level of axiomatic treatment as general equilibrium. A skeptic might ask why it is even worth doing. The answer is that although there are some underlying invariant properties in political economy that are amenable to a highly abstract description and analysis, there is an intermediate stage between this theory and its applications. It involves investigation of minimal process models. The concept of minimal institution can be defined and this enables us to construct minimally complex process models that resolve the debate about the existence of both competitive and planned price systems. Furthermore although there are several minimal price formation mechanisms associated with any exchange economy the numbers are not large and they are amenable exhaustive analysis. However as soon as the game model involves two periods or more and encompasses general information conditions the handful of strategic games explodes in a hyper-astronomical number of cases each of which requires detailed specification before it is amenable to analysis.

The underlying abstraction of general equilibrium theory tells us a great deal about the power of the price system in the structure of an exchange economy; but it tells us very little operationally about behavior as it does not deal in process. Even the simplest process model shows that there are several different minimal structures that will carry process. If information is absolutely minimal in a one move game there are very few behavioral distinctions that can be made. As soon as there are two periods or more the whole Pandora's Box of institutional models explodes and any model that one wishes to analyze calls for considerable specification of both the institutional structure to lay out the feasible set of outcomes from any process and the behavioral assumptions needed to specify equations of motion. These conditions indicate that in application there is no substitute for knowing your business but it may still be consistent with general equilibrium.

When I finally appreciated the implications of what I called Mathematical Institutional Economics I realized that there was an enormous task ahead to lay out the models containing the logic for the invention of the institutions and instruments and then start to analyze these many disparate but related models. The construction of a viable theory of money and financial institutions calls for the assembly of a vast jigsaw puzzle of interrelated aspects of the physical economy and its financial control by synthetic legal persons known as corporations acting as fiduciaries for their ultimate owners, the legal natural persons. As the key concern is dynamics a natural way to think of all models constructed is that each should be a playable experimental game. As anyone who has debugged an experimental game knows, this condition imposes a completeness and consistency test on every model.

A Little History and Context

Over the course of the last 43 years I have given several lectures on my game theoretic approach to the theory of money and there are still in the audience a few who at Cowles have heard parts of a much told tale. This contains my wrap up comments. I have planned three essays, one essentially non-technical giving an overview with some personal commentary, while the other two will provide a moderately technical sketch of the structure and many of the pieces that had to be fitted together. My last technical book (joint with Eric Smith, 2016) is about to appear

I graduated from High School with a scholarship to the University of Toronto in general proficiency stressing History and English I was interested in politics and was concerned with bettering the world. I contemplated going into Political Science or Economics. On further reflection I decided that although I was probably a mediocre or poor mathematician, if I went into Mathematics and Physics, I might acquire some techniques and knowledge that would help analytical thought. I was convinced that at the undergraduate level, the Social Sciences in the 1940s were rudimentary. If I were to go into politics, I thought that I needed some form of economics or political science, but I felt that this could be obtained later at graduate school or possibly law school or I could read the basic books myself.

I registered in Mathematics and Physics suspecting that I risked failure, but I managed to crawl through with a distinctly mediocre performance. However it did what I wanted. I simultaneously realized that I was never going to be a mathematician, but that I had an appreciation of good mathematicians and I began to understand the aesthetics of good mathematics and the concept of a careful experiment in elementary physics. On graduating I registered in Political Economy for an MA where I simultaneously admired the scholarship and distrusted the scientific objectivity of Harold Innis. He nevertheless taught me how to read material such as Locke, Mackinder, Weber, Hume and other social science greats. Economic theory did not seem to be very deep.

While browsing in the library in 1948, I picked up in the new purchases section, The Theory of Games and Economic Behavior. I took it out, read it with much excitement and little understanding and decided to do a review of it for my class in Economic Theory. The mathematics was unfamiliar and the approach was far different from anything I had seen, but it seemed to provide the right approach to a serious mathematization of economic statics. I decided to apply to Princeton saying that I wanted to study the theory of games.

I received a small scholarship and went to Princeton in the fall of 1949 and was swept into the excitement. The contrast there between the Economics and Mathematics Departments was enormous. In the Economics Department there appeared to me to contain three faculty members of serious interest, they were Morgenstern, Viner and Baumol (who came as an assistant professor). In comparison to the Mathematics Department it was minor. In the Mathematics Department almost every faculty member had major stature. I sat in on lectures from Feller, Artin, Tukey and Tucker.

It is my belief that graduate students learn not only from their mentors, but from their fellow students. Furthermore the learning is not merely academic. In the Economics Department the students who impressed me intellectually were Tom Whitin, Otto Eckstein, Gary Becker and few others. There were, however no students to talk with about game theory in the Economics Department. In the Mathematics Department matters were considerably different, the students I knew and with whom I interacted were Marvin Minsky, John McCarthy, John Nash, Lloyd Shapley and later, to a lesser extent Herbert Scarf and Ralph Gomory. Among the others slightly more senior who I met who impressed me were Richard Bellman, Sam Karlin, Alan Hoffman and Harlan Mills.

My relationship with Oscar Morgenstern was strange in several ways. I grew to be enormously fond of him and admired him greatly. He was an individual who appeared to be distant and formal until one got to know him. At which point he was charming with a good sense of humor and very supportive of his students. His mathematics was probably worse than mine; but rather than accepting it as a reality, this bothered him. In some ways he was a social snob.
Although he was *persona non grata* in the Economics Department, he protected and fostered the careers of the handful of graduate students who worked in his group.

I learned my game theory primarily from the seminar in the mathematics department and from conversations with Shapely, Nash and some others. Morgenstern provided protection and encouragement and taught me, to some extent the importance of asking good questions and persisting in trying to understand phenomena that others took for granted. In particular he sensitized me to problems with the concept of perfect foresight.

When Nash beat Shapley and me in the production of a variable threat two person fair division model, I suggested to John that we apply it to a duopoly model and contrast it with the Cournot-Nash solution (Mayberry, Nash and Shubik, 1952). When Shapley and I discussed, what was to be eventually called the core solution I suggested that, in essence Edgeworth's discussion of the shrinkage of the contract curve could be regarded as the convergence of the core under replication.

From the start of my interest in game theory, I found that the description of the amount of information required in well defining a game and knowledge of the rules of the game was often unreasonable. I noted this in an early article on information and competition (Shubik, 1952). Nevertheless, with cooperative games one could safely abstract out information and organization conditions and still be left with many phenomena worth studying.

I embarked on a long term collaboration with Lloyd Shapley, primarily on cooperative game theory. Early I developed great respect for Lloyd's pioneer work on both the core and the value as different solution concepts for an n-person game in coalitional form. In particular I felt that the application of the value to voting offered considerable insights into voting structures and we were both surprised and delighted at the speed with which our article on a power index was published (Shapley and Shubik, 1954).

The information structure and the details of the rules of the game appeared to matter considerably for the study of games in strategic and extensive forms. As I had become interested in oligopolistic competition and this seemed to be a natural theory to use in the study of oligopolistic competition, I decided to use noncooperative theory for my thesis (which eventually become a book: *Market Structure and Behavior*, Shubik, 1959). It was while working on my thesis that four questions occurred to me. The first concerned the number of competitors in a market. The second concerned the role of institutions. The third involved the treatment of economic dynamics and the fourth involved the goals of the firm, bankruptcy and contingent outcomes.

I believe that I derived the idea of the replication of a market from my reading of both Cournot and Edgeworth. My mathematics was weak, I could handle any finite replication, but I did not know precisely how to handle a countable infinity of equations, in full generality. I felt that a fully satisfactory mathematization of the idea of pure competition called for a continuum of agents, but I knew no measure theory. Shapley had already been thinking about a continuum of agents for oceanic voting games, but although I proposed it I was unable to interest him in this problem. Some years later Bob Aumann (Aumann, 1964) did this completely independently. I do not recollect ever having talked to him about this.

From an economic point of view a key feature in considering the replication of players in a market was that a *quantitative difference could cause a qualitative difference.* In particular with only few players the noncooperative equilibrium analysis seemed to depend heavily on information and threats. With many players the noncooperative equilibrium became a better model of reality as communication and organization costs made the anonymous market model a better representation of actuality as numbers increased. I believe that the simple Cournot model of duopoly is a poor representation of duopolistic competition. However with even ten, twenty or thirty individuals and easy entry on both sides of the market the Cournot-Nash equilibrium provides a good approximation, close to that of the competitive market model. This encouraged me in the late 1950s to run experimental games at the SDC Corporation varying the number of competitors.

My next two concerns were that in economic dynamics, institutions mattered, the economics institutions are the carriers of economic process. At least in the short run, they can be regarded by the firms as given by the rules of the game. These thoughts led me to coin the term **`Mathematical Institutional Economics.'** Some felt this to be an oxymoron, a contradiction in terms, but to me it meant that in considering process one needed to clothe abstraction with the richness and relevance of institutional detail.

Many years later I was able to build the appropriate models stressing the idea of a "minimal institution" as the simplest mechanism required to be identified with a specific economic function. The relevant abstractions required much hand tailoring and the best approach was to build special models which met the standards required for a playable game (Shubik, 1973, Shapley and Shubik, 1977, Dubey and Shubik, 1978) and generalize later over classes of such models (Dubey, MasColell and Shubik, 1980, Dubey Sahi and Shubik, 1993).

The last point that concerned me then and even now was how to account for default and bankruptcy. The firm had to decide how to trade off the worth of profits against the probability of going bankrupt. The basic problem that faces any financial intermediary is selecting the reserves deemed adequate to fulfill its fiduciary responsibilities to at least three different constituencies. They are its employees, its customers and its stockholders.

In 1961, I started to worry about the lack of a decent theory of money in microeconomics. I told Oskar Morgenstern that I had found my problem. He expressed enthusiasm over the problem and doubt that anyone would make much headway in the next decades. I played around to some extent trying to graft money onto a von Neumann growth model, but did not succeed. I felt that there had to be some new twist that would make money appear naturally in the economic model, but I did not have it. After butchering many models I gave up. I did continue, however to work on what had developed into a major intellectual interest by then. This was to show how many different solution concepts would provide an approach to the emergence of the price system. The Arrow-Debreu approach seemed to me to be not only pre-institutional and non-dynamic. It provided no indication as to how an efficient price system could come into existence. It could come about by a central socialist government announcing the correct set of prices, or it could have emerged from individual competitive behavior. I observed that two completely different playable games could lead to efficient prices.

A basic theme in in my work through the 1960s and into the 1970s was to understand the price system from a game theoretic point of view. The convergence of the core and value cooperative solutions applied to market games indicated that the price system was called for by more considerations than pure competition.

In December 1970 I reviewed the various game theoretic solutions which would converge under replication towards the price system and brooded over why I had not been able to obtain a model for the noncooperative equilibrium.

I also reconsidered my work on the theory of money where I had wasted some ten years trying to get a decent model incorporating money. I made a conscious decision to abandon looking for a theory of money. I argued that I was already forty four and I was probably too old to try to generate the new idea that was needed. I decided that I should devote all of my time to completing the work with Shapley on game theory solutions that converged to an efficient price system. The major missing item was the Cournot-Nash non-cooperative model. That required concentrating on a model of exchange as a game in strategic form in which the players were intrinsically symmetric and then studying the noncooperative equilibria. In 1967 in a joint paper with Shapley entitled Concepts and Theories of Pure Competition (Shapley and Shubik, 1967) we had succeeded in embedding a one-sided noncooperative game where one group of players was strategic, but the other merely accepted a price as though they faced a competitive market. We showed convergence as the number of players increased. Independently Gabszewicz and Vial (1972) obtained a similar model. Neither model treated all agents symmetrically, but a fully satisfactory model should have been able to do so, or include an explanation as to why symmetry was violated.

Having abandoned my efforts on a theory of money I went back to trying to build the symmetric closed economy Cournot model. I had recently taken another glance at Mrs. Robinson's Monopolistic Competition and had observed that her chapter entitled "A World of Monopolies" contained an ill-defined model. However, the title of the chapter gave me an idea. I decided to try to build an n-person symmetric game with n commodities where each player would be a monopolist holding only one good. All players would have a utility function for all goods. I soon observed that there were difficulties with the model. There had to be n independent strategy sets, but there were only n-1 independent prices. If one insisted that all players were to denominate prices in terms of a specific commodity, then the player whose commodity is selected plays a nonsymmetrical role. I overcame this difficulty by considering a somewhat different game with n monopolists trading in an n+ 1st commodity where each monopolist held one unit of his special good and a supply of the n+1st good. I set the price of the n+1st good equal to one and had all strategies denominated in terms of the n+1st good. I realized that I had a choice of using either a personal bid price or quantity as the strategic variable. At this point, purely for mathematical convenience, in order to keep continuity in the relationship between payoffs and strategy variation I decided to switch to a quantity strategy model rather than a price strategy model. I nevertheless kept the n+ 1 commodity and had each individual offer some amount of his good for sale and attempt to purchase the other goods by offering quantities of the n+1st commodity. I then tried this out on a specific model and considered the replication of the model with k players of each type and let k become large. The example was tractable; I could calculate a specific noncooperative equilibrium and show that it moved toward the Pareto optimal surface ask became large. I took my preliminary model to Shapley who constructively tore it to bits in many different ways. After each tearing up it was possible to rebuild and strengthen it. In particular Lloyd was quick in pointing out that if no one offered a commodity for sale, but the n+1st commodity had been bid for it, as price was defined as a ratio of two quantities, there would be a division by zero. The specialist's role on the New York exchange requires that she make an `orderly market,' i.e., that she has a small inventory available for sale. This can be treated mathematically by defining an epsilon-related game to the game under consideration where some small amount epsilon is available in each market.

Some weeks after Shapley and I had agreed that this was the appropriate model that provided an intrinsically symmetric game in strategic form that could show the convergence of some noncooperative equilibria formed by Cournot quantity strategies to competitive equilibria it dawned on me that it was sufficient to obtain the symmetry of the player strategy sets by introducing the extra good in a way that it was in adequate supply and well distributed among the agents; furthermore the extra commodity could be interpreted as a money. This construction had imposed a set of constraints on the optimization that was not present in the general equilibrium model which had only wealth constraints. This model had cash flow constraints as well as the wealth constraints. I had been looking at the solution to my second most important problem, the Cournot convergence and it provided the key insight into the study of money, the problem I had decided to abandon. To this day, I cannot understand how I could have worked for so long without even considering the connection.

The extra commodity that enabled me to treat the agents symmetrically did so utilizing the minimal number of markets. It was a store of value or a good like any other good, but it was distinguished strategically. Logically there could be many monies but not with fewer markets. Many years later we investigated strategic market games with any number of monies (Amir, Sahi, Shubik and Yao, 1990).

I realized this model provided the key to the development of a theory of money and financial institutions. When I saw the connection I said to my wife, "I have managed to go through the Looking Glass. This result is the key to the development of a theory of money." I added that I thought that it would take years to develop and that I might not be bright enough or live long enough to carry it out. It almost did not matter because finally, at least for me, the general map was there.

The work I have been pursuing at one level is related with Bewely (1980), Grandmont (1982), Stokey and Lucas (1989), Kiyotaki and Wright (1993), and others, but differs in its stress on closed fully defined process models, on bankruptcy, conservation laws and on the detailed distinction between money and various forms of credit.

A satisfactory theory of money and financial institutions requires as necessary (but not sufficient conditions) the following:

1. A completely well-defined process model must be built. A good test of this is that the model can be simulated or played as a game.

2. Money and different forms of credit and credit issuers have to be carefully defined and distinguished. The rules concerning the creation and destruction of both money and the different forms of credit must be completely specified. This is tantamount to specifying the rules of conservation and construction and specifying or why and how conservation is violated. Only a few different instruments need be regarded as basic elements, their rules for transmutation through time must be specified.

3. Bankruptcy, insolvency and reorganization must be accounted for in a fully dynamic context. Even if one believed in some form of an economic equilibrium solution, this equilibrium must often involve some percentage of the population going bankrupt and being reorganized. Equilibrium and bankruptcy are not incompatible. They can be modeled as a stationary birth-death process where entry and reorganization provide the means for birth and rebirth. By 2,000 at the Santa Fe Institute I started to realize that the bankruptcy laws were related to mutation in an evolutionary system.

4. The noncooperative equilibrium solution is not adequate for the next steps in our understanding. Learning models and a serious study of the formation of expectations are called for. But fortunately considerable understanding of money and financial institutions can be obtained with equilibrium analysis if the models are full process models and are well defined out of equilibrium as well as at the points of equilibrium.

5. Good theory deals with invariant properties of a system. The invariant properties in political economy are in function, not form. The institutions that deliver the functions such as saving or

insurance or division of labor are in constant flux and unlike in physics the predictability of the overlying dynamics is, at best extremely short term and calls for ad hoc macroeconomic models applied to a specific economy for a relatively short time period such as a year or two at most. General equations of motion will never be available, but this neither rules out basic understanding of function, nor valuable advice provided from short term detailed applied models to help provide short term economic guidance

The first published paper containing the new model was *Commodity Money, Oligopoly, Credit and Bankruptcy in a General Equilibrium Model* (Shubik 1973). The collaboration of Lloyd Shapley in generalizing and pushing through the mathematics was critical. Some years later Shapley and I published *Trade using one Commodity as a Means of Payment* (1977). Primarily through Lloyd's ingenuity, we used the Edgeworth Box diagram for the basic exposition of an elementary model. Pradeep Dubey and I, in a paper entitled *The Noncooperative Equilibria of a Closed Trading Economy with Market Supply and Bidding Strategies* (1978) published the basic proof for the existence and convergence of the model where individuals can both buy and sell all commodities. This should have been a three-author paper as a key lemma was supplied by Shapley.

Since the late 1970s I have had the good fortune that there has been a group of mathematical economists working on strategic market games. A substantial coverage of this literature up until 2002 has been presented in a survey by Giraud (2003). Once the basic model had been correctly formulated and analyzed serious drudge work is required to of show the inevitable emergence of financial institutions and instruments as sufficient requirements to provide necessary functions for a complex economy. The comments above have been on an intermixture of autobiography and a program of work. The remainder of this paper is devoted to a brief, possibly cryptic, sketch of many of the items that must be and have been assembled to present an overall understanding of a theory of money and financial institutions. They are broken into several parts that include:

1. Money and markets,
2. Credit,
3. Fiduciary players, controllers and minimal institutions;
4. Innovation, public goods and exogenous risk
5. Solutions, their role and relationship with behavior;
6. Solutions intent and behavior in games with minimal information;
7. The connection between application and theory where all solutions are behavioral.

MONEY AND MARKETS

Anthropology indicates that the organization of markets preceded and set the stage for the emergence of a money.

There are two types of money that need to be considered. They are (1) commodity money which may be regarded as the ultimate decentralized individualistic form of money governed by custom of acceptance and private production; (2) fiat money which is guaranteed by government, law, custom and enforcement has become a dominant financial force since the late 17th century.

Both monies are durable goods. The class of all minimal economic exchange models must involve three time periods that can be described as initial conditions, the period of choice and terminal conditions; or history, now and the future. The existence of a fiat or commodity money and other durables requires that expectations be defined in order to provide a full description of any economy.

Two variants of accounting money can be considered, one of which exists and the other is a limiting ideal. (3) Accounting money which is essentially the bookkeeping credits among a group of individuals who net accounts. (4) The accounting money of a perfect instantaneous universal clearing system; this may be regarded as though all agents were able to generate their personal money and the perfect clearing house balanced accounts (see Sorin 1996, Huber, Shubik and Sunder 2014).

A key characteristic of any economy that uses a money but no credit is that no default is feasible.

CREDIT

As soon as we observe that the execution of a trade involves some finite amount of time the cash flow conditions involving the use of a money become relevant. If these conditions hamper trade an economy devises institutions and instruments to cure this. Even at its simplest there are many ways to do so. One might avoid the need to create credit by speeding up the velocity of payment, but this, while not impossible, is difficult to do and both habit and technology impose an upper bound on velocity.

Most cures involve the invention of near monies or credit. (1) the most prevalent form of credit is often confusingly called bank money; most modern economies evolved some form of a commercial banking system. Bank money is in fact bank debt usually denominated in the official money of the nation (2) there are a host of other lenders that include private individuals, the government itself and other specialized institutions.

All credit instruments have the key feature that for a complete definition of the economic system in which they exist, default conditions must be specified. Unlike a money, when a debt is repaid or defaulted the debt instrument is destroyed.

In a society that utilizes a fiat money, the only creator of fiat is the government itself. This can be done with a combination of the manipulation of government debt and taxation

FIDUCIARY PLAYERS, CONTROLLERS AND MINIMAL INSTITUTIONS

The needs of trade even without any consideration of exogenous uncertainty require the existence of money and credit instruments. Consideration of time and many forms of efficiency in information and complexity bring into existence markets (Dubey, Sahi, Shubik 2013). The instruments require institutions and managers to help to deliver their basic services. There are many variations of institutions that are sufficient to provide any major function. The differences may permit specific institutions to provide more detailed functions pertaining to the habits and mores of specific societies.

Common to essentially all of them is that they are organizations whose conscious decision-makers are natural persons. In the evolution of modern societies a body of law recognizes two types of legal persons, natural individuals and organizations. The predominant decision-making in producing and selling the goods and services of an economy is by corporations run by natural persons acting as fiduciaries for the owners who are ultimately natural persons. The importance of this observation is to appreciate that almost all intermediate transactions and most final transactions are made by fiduciaries and whatever their preferences and intent may be a large segment of the behavior is to optimize some form of financial income subject to the constraints imposed by laws, customs and institutional structure on fiduciary responsibility.

INNOVATION, PUBLIC GOODS AND EXOGENOUS RISK

The uses of money and financial institutions involve system properties. The complications from different properties crowd in so fast that it vital to try to break up the many problems into bite size. My strong belief was that the general equilibrium non-process structure presented the appropriate abstraction with which one could start to understand the virtues and problems in appreciating the price system's roles in decentralization and efficiency. The only structure at a comparable level of abstraction that treated dynamics (with even more structural simplification) was the von Neumann expanding economy (von Neumann 1938, 1945). We had shown that the conversion of the general equilibrium structure into a process model called forth the existence of commodity money. The ability of commodity money to overcome the cash flow conditions required enough money, but if it did not exist it might be possible to introduce a fiat money; but this requires a rule of law, a trust in government and appropriate expectations. Without even having to consider economic realities such as costs of organization and administration and the many externalities that exist the monopolistic appropriation of the right to control the supply of fiat money brought a profound change in paradigm.

The existence of an economy utilizing fiat money is enough to be able to assemble many basic models of a monetary control system with one powerful agent controlling the money issuing and taxation mechanism and possibly other financial instruments.

Dynamics calls for money, money problems with the sufficiency of money present a sufficient, but not necessary reason to employ fiat money, and this offers the opportunity for monetary control over a fiat monetary system. The system becomes open to the capturing of real resources by government control but no motivation needs to be attached to government.

All the models discussed so far can exist without public goods other than money. In my original development of a theory of money I was willing to ignore pubic goods, exogenous risk and innovation in order to highlight the differences between general equilibrium non-process and game theory process models. Public Goods and innovation are part of any modern economy and although logically not directly associated with money or financial institutions functions such as financing the legal, law enforcement and national defense systems are minimal requirements for government financing. Furthermore although the work described so far has covered and formalized a financial structure on the Walras, Arrow, Debreu, McKenzie models one must immediately ask how is this connected with the critically relevant work of Keynes and other macroeconomists and to Schumpeter and others who see where innovation and oligopolistic competition dominate price formation in an evolutionary process?

I believe that at the best in the application of economic theory believable equations of motion exist only for short term ad hoc models with a range of probably no more than two years. The application of macroeconomic models to socio-economic reality requires at least parameter updating every few months; otherwise the use of low dimension (in cross-section) formal dynamic models such as the Dynamic Programming models utilized by Robert Lucas (Lucas 1972, Lucas and Stokey 1989) and others or by Karatzas, Shubik and Sudderth (KSS, 1994) and others are essentially parables that can be useful to illustrate some properties or prove negative results but as applied to economic reality are of highly limited direct application.

Examples of results that signal the difficulties in developing dynamic equilibrium models are provided by Brian Arthur et al. (Arthur 1984) who illustrated stochastic increasing returns to scale with outcomes depending on history .They considered competition where the probability of attracting new customers was a function of the visibility of the number of customers being served.

Geanakoplos, Karatzas, Shubik and Sudderth (GKSS 2014) utilizing a stochastic dynamic program were able to show that the equilibrium money rate of interest required to sustain a stationary equilibrium growth in a stochastic economy was not equal to then the optimal growth real rate of interest.

Shubik and Sudderth (2012) utilizing a simple dynamic strategic market game model of innovation were able to show the Schumpeterian breaking of the circular flow of capital and illustrated that with even only one period allowing innovation the length of time required to restore any equilibrium if it exists would be arbitrary.

SOLUTIONS, THEIR ROLE AND RELATIONSHIP WITH BEHAVIOR

When one attempts to apply static economic theory models to economic reality one cannot avoid the guesses of comparative statics or some form of dynamics. In doing so problems concerning coordination, expectations and terminal conditions cannot be avoided. I claim and have claimed for many years (Shubik 1999) that there are three, not two sets of theory that need to be contrasted. There is general equilibrium theory with no process described; process models with only one information set per agent, and process models with many information sets. The first is where Walras lives, as simplified by ADM, the third is where Keynes, Schumpeter and all applications live and the third is the almost universally overlooked link between the two where a full process model has been described, but the information conditions are so minimal that the number of behaviors that can described are limited.

SOLUTIONS INTENT AND BEHAVIOR IN GAMES WITH MINIMAL INFORMATION

The minimal information models provide the one area where one even has a hope of studying a more or less exhaustive set of relevant models where initial conditions and terminal conditions surround a game of strategy with a single simultaneous move by all agents. The mechanism description defines the playing field and the solution theory provides sufficient guidance for an individual to select her move (which for a single information set game is equivalent to a strategy).

THE CONNECTION BETWEEN APPLICATION AND THEORY WHERE ALL SOLUTIONS ARE BEHAVIORAL

The description of the dynamic path traced out in a well-defined multi-period game requires that both the playing field and a solution method that provides the instructions to generate the moves be given. The potential complexities of information and the staggering number of alternatives indicate that space of choice of alternative theories of behavior is so large in dynamic games that there is no natural universal satisfactory general solution. Hopefully we can pick out some solution concept such as rational expectations or optimal response or do nothing or follow the crowd to apply to some set of problems providing an ad hoc justification from institutional and behavioral observations.

A frequent mistake often made by non-game theorists is to believe that somehow or other there is a difference between some mysterious universal super rational game theory solution to dynamics and behavioral theories. All theories are behavioral and are ultimately based on observations and assumptions about individual and group behavior. The behavioral economics theorists are possibly reacting to the followers of the rational expectations solution which can be interpreted to be the same as a trembling hand sub-game perfect noncooperative equilibrium. Even this solution which has the attractive feature of self-consistency in expectations has no general proof that out of equilibrium initial conditions will adjust. Furthermore there are many problems with representative agent modeling (see Shubik and Smith 2016).

In essence, when there is a plethora of alternative behavioral theories this signals that there is no dominant theory. The selection of a behavioral model is ad hoc and should address the problem at hand. This type of problem appears in applied finance where the presumption is that the stockbrokers, insurance agents and savings institutions have skills and perceptions not possessed by most of their cliental

CONCLUSIONS

Money and financial instruments are children of the dynamics of exchange. They are part of the production transformation technology of exchange. Much of this technology has been labeled `transactions costs'. However although the concept of transactions cost as something apart from production may be useful for some purposes it generally obscures the ever increasing importance of the technology of trade. The growth of communication, information and education leads to a greater division of labor. This implies more trade.

A general theory of money and financial institutions, like general equilibrium theory provides a model building technique to build broad laws of models going beyond GE, it is designed to construct process models. By including a description of the full state space of the system it provides the structural background for many types of behavior. The stress is on the mechanisms for the guidance and control of process. The many functions needed to carry process call for the evolution of the institutions and an overall theory shows both the evolution and analysis of the institutions that provide for the many functions and indicates how they relate to form a whole.

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