PART I

Philosophical and methodological implications of complexity and evolution in economic systems

CHAPTER 1

Toward a generalized Coase theorem: a theory of the emergence of social and institutional structures under imperfect information

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Present-day mainstream neoclassical economic theory is built on the perfect competition paradigm. It can be shown that, when the paradigm and its underlying assumptions are satisfied, an economy ends up in general equilibrium that represents the highest possible state of welfare. To reach this state, three assumptions must be satisfied. First, perfectly competitive markets must exist, including perfect information for all agents operating on these markets. Second, there must be two exogenous sets of fixed parameters, consumer preferences and production technology. Third, all agents must adopt utility maximization as their behavioral motive. Equilibrium is reached when all pairs of marginal costs and benefit ratios are equalized. At that point entropy is maximized and economic activity – agents making choices – must necessarily cease because no agent can further improve his or her position. At best, economic activity goes on in the reproductive mode, whereby agents eternally exchange the same mix of goods and services at the same prices. In the absence of external impulses, the economic system dies an entropy death.

From a systems theory point of view, the neoclassical perfect competition paradigm is incomplete because it has no entropy-decreasing mechanism and is not self-sustainable. In the case of economic systems, a competition-reducing force is required to keep it going. That is precisely the role of innovation. In terms of the neoclassical model, innovation can be introduced only through modification of exogenous behavioral parameters, consumer preferences, and production technology. In ordinary language, this is called inventions and the introduction of new consumer ideas.

To make innovation a regular feature of the economic model, these exogenous parameter modifications need to be endogenized in the system. This was attempted in the 1980s by two major schools of thought: endogenous growth theory (Romer 1986, Lucas 1988) and the neo-Schumpeterians (Nelson and Winter 1982). The endogenous growth school, by and large, remained within the confines of the neoclassical perfect competition paradigm. However, Romer (1990a, 1994) has shown that innovation-based endogenous growth theory basically conflicts with the neoclassical model because it violates the convexity requirement that is needed to reach equilibrium. The neo-Schumpeterian school has never tried to remain within the neoclassical paradigm.

Whichever of the two schools of thought one prefers to follow, mainstream economic theory clearly needs to switch to a new model and indeed a new paradigm that covers not only competitive optimizing behavior but also innovation as a means to escape from competition and entropy death. An attempt is made here to develop an outline of such a model. Although it maintains competition and optimizing behavior as key features, it constitutes a departure from the neoclassical model to the extent that it assumes that individual behavior is based on imperfect or incomplete information. The model is not driven by individual utility or profit maximization but by making optimal use of limited individual information-processing capacity. It is shown how this results, at the level of individual agents, in the emergence of rule-based rather than permanent optimizing behavior and, at the level of social interaction, in the emergence of norms, rules, and institutions. The proposed approach not only endogenizes innovation but also institutional developments. In fact, the two cannot be separated. It makes extensive use of Coase's (1937, 1960) ideas on the role of transaction costs in the emergence of firms and the settlement of externalities. For this reason, the model in this paper could be considered as a generalized version of the well-known Coase theorem.

First Romer's argument on the conflict between neoclassical production theory and innovative producer behavior is retraced. The same arguments are transplanted to consumer behavior, a domain neglected both by endogenous growth theory and the neo-Schumpeterian innovation school. The (narrative) outlines of a new model that focuses on uncertainty reduction as a behavioral motive are presented in Section 3. It is shown how this approach is not only consistent with findings in evolutionary biology but also explains the emergence of trade itself, as well as social rules of behavior and institutions. Finally, it is demonstrated how this cognitive model can be derived from a generalized formulation of the Coase theorem.

1 Innovative producer behavior

Since the early 1950s, mainstream economics' treatment of production and economic growth has been almost entirely based on the neoclassical Solow model (Solow 1956). The production process is a technological black box that transforms factor inputs (capital goods and labor) into outputs (production). Transformation ratios between factor inputs and outputs (factor productivity) are considered exogenous to the economic process. Empirical estimation of these transformation ratios, by Solow (1957) himself and others, showed, however, that its capacity to explain output growth was limited. An important growth residual that could not be explained in terms of changes in factor inputs remained: the so-called Solow residual. It can be explained only in terms of productivity growth or technological progress inside the production black box, which the neoclassical model considers to be exogenous to the economic system.

In the 1980s, two different gateways were explored to endogenize technological progress in the economic system. The first started from the microeconomic evolutionary approach of Nelson and Winter (1982) to economic change that builds the foundations for most of the recent wave of neo-Schumpeterian entrepreneurial innovation models. The second gateway was situated at a more macroeconomic level, in which Romer (1986, 1987, 1990b) and Lucas (1988) transformed Arrow's (1962) learning-by-doing model into an endogenous growth model.

Nelson and Winter and the neo-Schumpeterian school have sought inspiration in genetic adaptation models in biology to explain innovative producer behavior.[1] Production processes are described as algorithms. As with genes in biology, they consist of a set of behavioral instructions to be performed on a set of inputs in order to arrive at a specific (set of) output(s). Competitiveness is treated as an evolutionary problem: Producers must adapt or perish. Adaptation means changes in production algorithms. The market position or relative monopoly power and profit margin of individual firms continually changes because of innovations by competitors. Successful innovators become price setters rather than price takers in markets.

In line with Darwinian evolutionary theory, neo-Schumpeterian models basically treat changes in production algorithms as random processes. Investments in research and development yield innovations through a stochastic mechanism.[2] These innovations are then linked to a standard firm-level production model in which they improve the quality of output and/or increase productivity in the production process. Quality improvements are reflected in price increases as consumers are willing to pay a higher price for "better" products. Productivity improvements result in production cost savings. Both improvements are coupled to time patterns of diffusion of innovation and to the

[1] The exclusive focus on the firm as the locus of innovation allows us to classify the neo-Schumpeterians as evolutionary supply siders. Their own models explain how this supply-side bias has been caused by historical path dependency (David 1993) on Schumpeter's (1934) initial firm- and entrepreneur-focused approach.

[2] A good overview with recent examples is presented in the September 1994 issue of the *Journal of Evolutionary Economics*, including articles by Dosi and Nelson (1994), Ulph and Owen (1994), etc. Aghion and Howitt (1993) have developed a micro–macro model in which economic growth, including business cycles, is driven by innovation and creative destruction.

evolution of relative monopoly power in the market. Although the replication of ideas can normally be done at virtually zero marginal cost, the diffusion of ideas is protected in practice by legal patents, secrecy, and time-consuming learning processes to acquire the ideas.

Endogenous growth models are more conservative in their approach. They attempt to explain the Solow productivity residual at a macroeconomic level by building in explanatory mechanisms for productivity growth. Clearly learning plays an essential role here. Learning or knowledge has to be embodied, either in goods or in persons, before it can be used. Arrow (1962) embodies new knowledge, accumulated through learning by doing in production processes, in a new generation of capital good outputs. Human capital models embody learning in labor or in a new production factor, knowledge (Becker and Murphy 1992, Tamura 1991). A core issue here concerns the nature of knowledge. In the neoclassical tradition, knowledge, like any other information, is a pure (nonrival and nonexcludable) public good, freely available to everybody. This excludes monopolistic market situations caused by innovation. However, more realistic approaches assume that knowledge is a nonrival but at least partially excludable good, thereby permitting the emergence of monopolistic product and factor markets. In the latter interpretation, all innovation-based models, including the neo-Schumpeterian, violate fundamental neoclassical principles.

First, they introduce imperfect competition in product markets as the driving force for innovation. Innovation allows producers to increase product prices above prevailing market prices for standard (noninnovative) products and indeed above the marginal cost. General competitive equilibrium analysis does not hold anymore.[3] In neo-Schumpeterian models, for example, prices are typically determined through markup procedures, completed by market share allocation mechanisms among producers, without taking into account changes in consumer demand.

Second, they result in imperfect competition in factor markets. Contrary to ordinary goods, ideas are nonrival goods. They can be used by many users at the same time without loss of benefits or additional costs for any of them, despite the fact that the material carrier of the idea (paper, diskettes, video, any communication media) is a rival good. Romer (1990a) has demonstrated that nonrival goods result in production functions that have a degree of homogeneity higher than 1. Consequently, Euler's theorem on the allocation of factor income according to marginal productivity is not valid anymore and factors are not remunerated according to their marginal productivity. Classic production functions, for instance those of the Cobb–Douglas type, can, in principle, not be used anymore because they become meaningless for the allocation of factor

[3] Dixit and Stiglitz (1977) have presented a new approach to imperfect product markets that may still result, in some situations, in a Pareto-optimal equilibrium.

income. Some models try to solve this problem by splitting the economy into two sectors, one that produces nonrival innovation and a second that produces ordinary rival goods (with bought innovation inputs) that remains subject to the classical production functions (see, for example, Aghion and Howitt 1993). But this does not solve the problem of the first sector's incompatibility with neoclassical welfare optimization.

Because of the very nature of knowledge, innovation-driven models violate neoclassical principles. The neo-Schumpeterians have never claimed to be, or wanting to be, consistent with the neoclassical paradigm. On the contrary, they thrive on imperfect competition, which they claim – rather successfully – to be closer to reality. Indeed, the objective of business managers is not to operate on a perfect level playing field with their competitors but rather to differentiate their products through price and nonprice strategies. But it is a far cry from neoclassical general equilibrium theory.

2 Innovative consumer behavior

A fundamental problem with the introduction of innovation in production processes is that new goods are likely to appear that were previously unknown to the consumer. When the number of produced goods changes from n to $n + 1$, the number of arguments in a consumer's utility function should also increase from n to $n + 1$ and may upset all existing utility preferences. Somehow, a method has to be found to account for the emergence *ex nihilo* of preference arguments for such new goods. Lancaster (1966b) has already noted that this is one of the toughest nuts to crack in a neoclassical consumer framework. Both endogenous growth theory and the neo-Schumpeterian approach to innovation have neglected the consumer side of the innovation story.

Clearly, preferences must be at least partially endogenized to make an innovation-based model work. Very few authors seem to be aware of this problem. Among them, Ulph and Owen (1994) augment consumer preferences by the amount of quality improvement as reflected in product price increases. This merely shifts the problem from exogenous preferences to exogenous quality parameters.

By far the strongest statement in defense of the neoclassical assumption of exogenous consumer preferences has been made by Becker and Stigler (1976), although Becker (1991) seems to have somewhat softened his views. Pollak (1976a, 1976b, 1977, 1978) has weakened the neoclassical stance and allowed for various sources of endogenous influences on consumer preferences: habit formation or own past preference, social influences or preferences of other consumers, and price-dependent preferences. Since Pollak's seminal work on this issue, an endless series of variations on this theme has been developed. Bikchandani et al. (1992) introduce a theory of fads, fashion, and customs, based on "information cascades": Consumers can save on information costs by simply copying consumer behavior from others. Ditmar (1994) erodes consumer sovereignty to the bone. Empirical socioeconomic investigations lead to the conclusion that consumer behavior is largely dependent on norms and values within peer groups. A substantial body of psychoeconomic literature has developed around the theme of socialization of consumers from early childhood onward (see, for instance, Lea 1990). In short, the sovereign neoclassical consumer, who maximizes utility solely in the function of personal ex ante exogenous preferences, does not exist anymore in present-day economic theory (if this consumer had ever existed in reality, then the vast amounts spend on marketing campaigns would never have made sense).

Lancaster (1966a) replaces the traditional approach to consumer demand, whereby goods are the direct objects of utility, with the view that utility is derived from specific properties or characteristics of goods. For example, different color characteristics of a car result in different preferences: The utility derived from a red car is not the same as that from a gray car. Similarly, different design characteristics of clothing: This season's fashion design yields higher utility than that of last seasons. He assumes that characteristics are nonnegative quantities, "universally recognizable" and "objectively measurable." Whereas in the neoclassical approach a one-to-one link is assumed among a good, its characteristics, and consumer preferences for it, Lancaster's approach allows for consumer preferences for an entire set of characteristics that are reflected in a set of goods.

This enables him to define a new good – an innovation – as the addition of one or more choices to a bundle of goods within a given set of characteristics. When we know the new good's characteristics, through its "objective" and "universal" characteristics matrix, we can situate it in the bundle of available goods for a particular set of preferred characteristics. A new or innovative good will be preferred if its total characteristics vector yields a higher level of consumer satisfaction for the same budget outlay. If a consumer would get less of all preferred characteristics for the same budget outlay, then the new good is unlikely to succeed in the market.

Innovative goods are thus treated as substitutes for existing one. They are new only to the extent that they provide an original (re)combination of preferred characteristics. They are not totally new in the sense that they embody characteristics that were previously totally unknown. There is no demand for unknown characteristics, and such goods would simply fail in the market. Innovation thus builds on existing preferences for characteristics and provides only an original or enhanced (re)combination of a bundle of characteristics.

Lancaster's model might tempt us to conclude that innovation can be taken into account without endogenizing consumer preferences. This would be true if all sources of variation in utility would stem from variations in objectively measurable characteristics of goods. However, some may stem from new information received by the consumer, through the appearance of new goods or through publicity campaigns. An advertisement for a fast car can be interpreted as conveying objective information ("these cars are indeed fast") that may or may not fit in with your existing preference for that characteristic. Alternatively, it may convey the message that a fast car is something you should really have, thereby enhancing your preference for that characteristic. The first interpretation is compatible with exogenous consumer preferences; the second is not. With exogenous preferences, consumers get only what they want; with endogenous preferences, they may also want what they get.

Endogenous preferences create a fundamental problem. All neoclassical economic models assume that consumers maximize utility, subject to a given set of preferences and a budget constraint. If both the budget constraint and preferences are endogenized, there is no longer an objective function for maximizing behavior. Economic models become steerless in that case. This question cannot be solved within existing economic frameworks. As in every detective story, we need a motive for behavior. The search for a new motive – beyond consumer preference – is the subject of Section 3. We leave economics for a while, and start roaming around in information and evolution theories, biology, and psychology.

3 Uncertainty-reducing behavior as a response to imperfect information

The neoclassical world view starts from the assumption that economic agents are, at any moment, rational optimizers and that they possess all the necessary information to do so, at zero opportunity cost. Exogenously given consumer preferences and production technology parameters are but a consequence of this perfect information assumption. Perfectly informed agents can be expected to know precisely what they want (preferences) and how to get it (technology). Clearly, these assumptions are unrealistic.

A more realistic set of assumptions, revolving around imperfect information and uncertainty, could be formulated as follows. First, the amount of information available in the universe is, for all practical purposes, virtually infinite. Second, the information-processing capacity of any agent operating in the universe, human or nonhuman, and whatever the agent's intelligence, is necessarily limited. Third, evolutionary selection mechanisms will favor survival of agents who are best at giving appropriate responses to the widest possible range of events in their universe. Consequently, any agent's implicit objective function could be formulated as minimizing uncertainty, subject to an information-processing capacity constraint.

Decision making under uncertainty means choosing the option that is most likely to give an appropriate outcome. To do so, predicting outcomes becomes an important issue. Prediction requires analysis of regularities in incoming information flows. The more and the better an agent can analyze these, the better the agent's chances of survival. Enhancing the chances of survival becomes a question of making more efficient use of limited information-processing capacities. As will be shown in subsequent pages, the fundamental building blocks of the economic universe can be derived from the answers to this optimization question.

It is in response to imperfect information and uncertainty that complex adaptive systems have developed in nature, and recently in laboratories. Gell-Mann (1995) calls them information gathering and utilizing systems (IGUSs). IGUSs sift through the limited amount of available information to identify regularities in an uncertain universe. Regularities separate randomness and uncertainty from order and predictability. Although they are only an imperfect approximation of reality, they enable IGUSs to reduce uncertainty in their environment and consequently to improve their survival probability. Rather than passively awaiting the course of external events and hoping that none of these will be harmful or even lethal, IGUSs can try to predict the course of events and actively devise strategies or algorithms to reduce harm and increase benefits. Agents equipped with IGUSs capacity have a competitive advantage in nature's evolutionary selection process, compared with agents who do not have it. Identifying regularities and devising behavioral algorithms[4] in response to them is called learning. The capacity to store learned algorithms in memory, rather then reconstructing them every time, further enhances the survival probability[5] of IGUSs.

Agents may well have explicit behavioral motives other than uncertainty reduction. However, if they do not minimize uncertainty, they are subject to higher risks and have lower survival chances. Evolutionary selection will work against them. The advantage of the implicit approach is that there is no need to identify teleological behavioral motives such as utility or profit maximization, cooperative behavior, love, paternal or maternal instincts, etc. All these implied motives may well exist in peoples' minds, but they are all behavioral guidelines derived from, and subordinate to, uncertainty reduction. To the extent that they contradict the latter, they constitute a handicap, which may have an evolutionary rationale too (Zahavi 1975, Grafen 1990a) but is not discussed here.

[4] In this paper, the words algorithm, (behavioral) rule, and (behavioral) norms are used interchangeably. They are all defined as a (possibly multidimensional) set of behavioral instructions.

[5] Survival probability maximization should not necessarily be interpreted strictly in the life-or-death sense but should be considered in a context of mostly marginal behavioral adaptations that facilitate life.