Commerce, Complexity, and Evolution

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CHAPTER 1

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

Bertin Martens

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.

4 Making more efficient use of limited information-processing capacities

Order-creating IGUSs exist at various levels of complexity, from simple biological structures to complex entities with cognitive capacities, like humans. Three stages can be identified in evolution, corresponding to ever more efficient ways of dealing with the uncertainty problem.

First, simple biological structures react mechanically to external events. Their behavioral algorithms are preprogrammed in such a way as to permit them to collect the necessary material and energy inputs that prevent the internal entropy-increasing process from reaching the limits as which the structure disintegrates. If unforeseen (unprogrammed) events have an impact on the structure, it may disintegrate. In more complex biological structures, algorithms are genetically encoded, which allows programming of far more diversified but still fixed or innate reaction patterns. Genetically preprogrammed behavioral algorithms cannot adapt to unforeseen incoming information. However, in evolution, random mutations in genetic structures may result in better adapted species with increased survival chances. The word random is essential here: The behavior of the biological structure itself does not influence these mutations. The Lamarckian evolutionary model is not applicable at this stage of development.

In a second stage, the evolution toward cognitive capacity and the emergence of brains marks the gradual shift from purely Darwinian selection, with random mutations in preprogrammed genetic algorithms, to Lamarckian selection with adaptive programming through learning or information gathering processes that are not random but purposeful (Hodgson 1993): They lower information entropy. The development of cognition means that organisms acquire the capacity to create a second layer of behavioral algorithms on top of their genetic structure that can be learned and memorized and even repeatedly reprogrammed in the course of the organism's lifetime. This has considerably enhanced uncertainty reduction and flexibility of behavior in a more varied range of environments and circumstances. The effective internal complexity[6] (Gell-Mann 1995, p. 56) of IGUSs behavior has thus increased because it is able to identify and memorize more concise descriptions of regularities in its environment and react accordingly.

In a third stage, limited cognitive capacity can be used more efficiently within a group of agents through specialization and exchange of goods. This occurs when a division of labor emerges in a social setting. What are the evolutionary advantages of the division of labor and cognitive specialization? The short answer is that, given limited individual cognitive capacity, a group of specialized

[6] The internal effective complexity of a system is defined by Gell-Mann (1995, p. 56) as "the length of a concise description" of the regularities in the system's environment as identified by the system.

agents can accumulate more uncertainty-reducing behavioral algorithms – knowledge – than a group of identical (nonspecialized) agents. But this short answer is rather trivial. It merely says that the union of a number of differentiated knowledge sets contains more knowledge elements than the union of the same number of undifferentiated (or identical) knowledge sets. Showing how the actual mechanics of the division of labor work in reality is a more complicated matter that requires a longer answer.

To do this, a major disadvantage of specialization is first pointed out: Specialization increases risks for individuals within a population. They become dependent on a narrow set of knowledge, which may be advantageous in particular circumstances but disadvantageous in others, thereby endangering their survival. A corollary to this risk is increasing interdependence among individuals. Specialization or division of labor is apparently advantageous for the group but is not in the interest of the individual as it increases his or her risk exposure. To find an insurance system that protects individuals against the risks of specialization and fosters collaboration among specialized individuals to their mutual benefit, we must analyze the way in which individual knowledge can be put at the disposal of other individuals.

Limits to individual cognitive capacity make straightforward copying of specialist knowledge to interested individuals an uninteresting proposition: Copying the entire set does not generate any savings in scarce information-processing time. Potential recipients would have no (economic) interest in acquiring these copies. Hayek (1949) and Von Weiszacker (1991) pointed out that flows of knowledge in a society characterized by a division of labor are not meant to provide full information to all its members. In fact, individuals are not interested in full information but only in what they consider to be relevant information for their decision-making situations. Computer buyers, for instance, decide on hardware and software purchases on the basis of the relevant problem-solving algorithms that are embodied in these goods; they are not interested in the details of chips and hard disk manufacturing (unless they are computer freaks). Relevant information is a very elusive and subjective concept. Although manufacturing details may not be relevant to buyer A, they may be very relevant in the decisions of buyer B. When the machine breaks down, however, even buyer A may start wondering about certain manufacturing details. Clearly, the neoclassical hypothesis of perfect symmetric information on all relevant aspects of a market is not a workable concept anymore. Trading parties have different ideas on what they consider relevant aspects. Hayek (1949) summarizes this very well:

> "We make constant use of formulas, symbols, and rules whose meaning we do not understand and through the use of which we avail ourselves of the assistance of knowledge which individually we do not possess."

Here lies the clue to understanding the evolutionary advantages of specialization. Although we do not individually master all the details of all domains of knowledge accumulated by others, we are able to use these domains because they have been embodied in transferable carriers that, with a minimal input of knowledge and activities from our side, produce an output that is relevant to us. Take the example of clothing. Buyers usually do not bother about the textile production processes (i.e., that consumers don't in general worry about the process of production). They know how to put them on and keep them clean (user inputs). This way, clothing produces the relevant outputs, that is, protection against body health losses and social recognition.

Evidently the benefits of the division of labor can be realized only if the products of each agent's specialized knowledge can be traded. Because they permit communication of truncated or relevant parts only of knowledge sets, trading systems provide agents in a group with effective access to a far larger stock of potential problem-solving and uncertainty-reducing knowledge than they could ever hope to accumulate on their own. Societies that allow specialization and trading systems to emerge thus have an evolutionary advantage over those that do not. They widen an individual citizen's access to problem-solving and uncertainty-reducing knowledge.

Economic systems are more efficient survival machines than biological or genetic reproduction mechanisms. Although genetic reproduction involves copying an individual's entire set of algorithms into every new generation, communication and trading systems require only the reproduction of a small subset of a "parent's" behavioral algorithms into a material carrier that transfers this to any other recipient. This is far more "economical" than genetic reproduction of entire bodies.

5 The emergence of transaction costs

The division of labor is thus a more efficient way of using limited information processing or cognitive capacities. At the same time, however, the emergence of the division of labor, and trade that goes along with it, creates new types of opportunity costs called transaction costs.

Coase (1937, 1960) was the first to introduce this concept in economics. His definition (1960) points to the existence of imperfect information:

> "In order to carry out a market transaction it is necessary to discover who it is that one wishes to deal with, to inform people that one wishes to deal and on what terms, to conduct negotiations leading up to a bargain, to draw up the contract, to undertake the inspection needed to make sure that the terms of the contract are being observed, and so on."

In this view, transaction costs represent resource losses that are due to lack of information and to uncertainty. They are induced by cognitive differentiation or specialization between individuals. As such, transaction costs are a subset of information costs. The latter refer to the opportunity cost of any type of information; the former refer only to the information input required for achieving a transaction between two individuals with different knowledge sets. Whereas information costs are costs incurred to reduce general uncertainty, transaction costs are incurred to reduce uncertainties concerning interindividual transactions.

This definition excludes costs that are due to geographical differentiation, such as transport costs, which are sometimes used a substitutes for transaction costs (Yang and Borland 1991). It firmly roots the transaction costs concept in a world of imperfect information in which no individual has perfect information on the good or service he or she wishes to acquire, and no two individuals have identical knowledge sets. Cognitive differentiation is both the source of comparative advantage, and thus of exchange, and of transaction costs.

Transaction costs are inherent in an economy with a division of labor and specialization. This can easily be understood in light of the preceding description of the requirements of information exchange between individuals. Because exchange of complete knowledge packages would not be efficient, truncated packages are exchanged, embodied in goods. However, these truncated packages have to be understandable to the receiver, who needs to share a minimum amount of common knowledge with the producer so as to be able to use the good. According to Polanyi (1958), making truncated messages understandable is achieved through codification and the presence of tacit knowledge among interacting agents.

Transaction costs may run up so high that they prevent a transaction from taking place. When uncertainty prevails and the cost of acquiring all the necessary information to make the outcome of a transaction more predictable exceeds the potential value of a transaction, then it will not take place. In general, transaction costs prevent agents from reducing uncertainty in their environment and in their dealings with other agents. They have to be overcome in order to satisfy an agent's implicit behavioral motive of uncertainty reduction, subject to the agent's information capacity constraint. How this can be done is the subject of Section 6.

6 Toward a generalized Coase theorem

The transaction cost debate was initiated by Coase (1937, 1960) and revived by Williamson and the New Institutional School in the 1980s (Williamson 1995). Coase (1937) opened the debate from a supply-side angle: Why do firms exist? Why can't individual producers trade parts of production processes among each other to arrive at the same final product? Alternatively, why can't all firms be absorbed into one huge company? Coase's answer was that firms are a means to circumvent transaction costs inherent in market-based exchanges: the cost of acquiring information on supply and demand, the cost of negotiating a separate deal for each transaction, the cost of uncertainty. Firms are more cost effective than a network of individual producers working through open-market transactions because they work on the basis of contracts that fix quantities, qualities, and prices, rather than passing every time through an open-market transaction. Fixed and repeatable contractual arrangements save transaction costs. On the other hand, all firms cannot be amalgamated into a single company because the amount of information required for supervising the whole company would be overwhelming (and very costly). It could not possibly be processed by a single agent and would thus require decentralized decision making anyway, thereby eroding the benefits of integration.

Coase saw the firm as a set of contracts between individual producers who economize on transaction costs by bypassing the market. Coase shows that, contrary to the neoclassical view that competitive markets represent the highest degree of efficiency in an economy, it is indeed possible to outwit the allocative function of the market, precisely because of the presence of imperfect information. The neoclassical economic universe appears to be just a special and unrealistic case of the Coasian Universe, with transaction (and information) costs set to zero.

Grossman and Hart (1986) show that transaction costs can never be reduced to zero. That would amount to fixing all possibilities in contractual rules and leave no space for unforeseen events. But even the most elaborate contract is necessarily incomplete as rules have been identified in a boundedly rational environment. Because of this inherent uncertainty, transaction costs are always positive. In his 1960 article on "the problem of social cost," Coase demonstrated how positive transaction costs can impinge on property rights and prevent a solution of the problem of externalities. Because property rights are necessarily incompletely defined, events can occur that require further negotiations on property rights issues. The cost of dealing with all parties concerned, however, may run up so high that it is not worth seeking a settlement of the issue. This led Coase to the conclusion that externalities can always be settled or internalized again through interindividual bargaining, subject to a transaction cost. Stigler (1966) later on coined the label Coase theorem for Coase's 1960 analysis and summarized it as follows: In an efficient economy, the difference between private and social costs can never exceed the level of transaction costs.

Dixit and Olson (1997), in line with a long series of arguments concerning the nonexcludable nature of public goods started by Samuelson (1954), argue that the Coase theorem is not applicable to public goods and therefore is not a theorem in the sense of a statement of general validity. Public goods are, by definition, nonexcludable and their benefits are entirely dispersed through externalities. No amount of bargaining and investment in transaction costs will ever be able to internalize these externalities. Free riding on public goods is rational from an individual point of view and can be contained only through government intervention that overrules individual rationality.

The argument of Dixit and Olson (1997) is correct when considered in the context of a single transaction. However, Ullman-Margalit (1977), Axelrod (1984), and Skaperdas (1991, 1992) demonstrate how free riding and externalities can be contained in a game-theoretic setting of the Prisoner's Dilemma type. Repeated games lead to the emergence of norms of behavior that rein in free riding and settle into a long-run stable strategy with an equitable distribution of costs and benefits, at least with respect to the initial resource distribution. The norms or rules of behavior constitute a decision on the appropriation of costs and benefits, without free riding. Credible commitment devices, such as tit-for-tat strategies in repeated Prisoner Dilemma games, ensure that free riding does not occur. Ultimately, the emergence of norms serves as a transaction-cost-reducing and uncertainty-reducing device. Uncertainty about the mind-set of the other players results in initial very high transaction costs that prevent players in the game from moving to a better situation for all of them: If one takes the initiative to move, the others may free ride on the benefits he or she generates and make him or her even worse off. Gradually awareness of this situation grows and players communicate, directly or indirectly, and build up mutual confidence that allows them to move jointly to a better situation. Uncertainty reduction, or transactions costs, is at the root of a solution to Prisoner's Dilemma games, in both a theoretical setting and in social reality.

If we take the norms and rules of behavior that emerge out of Prisoner's Dilemma-type situations as the sources of decision making on public goods, then the Coase theorem is indeed a theorem of general validity whose applicability extends to public goods and even to situations in which no ex ante defined and enforceable property rights exist.

More in general, the 1960 Coase theorem can be combined with Coase's 1937 article on the role of transaction costs in the emergence of firms and generalized into a theorem on the role of norms, rules of behavior, and public laws, etc., as uncertainty-reducing devices in society. They give rise to islands of reduced transaction costs, groups of agents who adhere to a specific set of rules of behavior, thereby enhancing the prospects for more efficient transactions and stimulating economic growth.

7 Conclusions

It has been demonstrated that the neoclassical paradigm of perfect competition, based on perfect information and exogenously fixed consumer preferences and production technology, is an unsuitable starting point from which to introduce innovation into economic models. Attempts to do so by so-called endogenous growth theory and by the neo-Schumpeterian School have ended up in models that are basically inconsistent with the neoclassical paradigm. The introduction of innovation into consumer behavior and the endogenization of consumer preferences has been largely neglected in the literature, except for Lancaster's contribution.

Another route has been presented toward endogenization of innovation by the introduction of the concept of IGUSs, derived from evolutionary science and information theories. IGUSs are uncertainty-reducing – and therefore survival-probability-enhancing – devices that come in two kinds, preprogrammed and reprogrammable. The latter are classified as cognitive carriers because they have the ability to learn and store learned behavioral algorithms in memory. It has also been shown that the introduction of specialization and the division of labor represents a further step toward uncertainty reduction, as it makes more efficient use of limited cognitive capacities. However, it also creates new risks, uncertainties, and transaction costs, as the mind-sets of interacting agents differentiate. Transaction costs and uncertainties can be reduced through normative behavior, the introduction of laws, and institutions.

Coase introduced both the concept of transaction costs and the so-called Coase theorem in the literature. Here it is shown how the two can be combined in a single, more general theorem that explains the emergence of rule-based behavior and institutions, both private (companies, clubs, households) and public (government), as an attempt to overcome transaction costs and uncertainty. This generalized Coase theorem is nothing but a continuation of the evolutionary search for more adaptive and flexible complex survival systems.

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