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TOWARDS A GENERALISED COASE THEOREM

A general theory of bounded rationality, rule-following behaviour and the emergence of social and institutional structures as a substitute for market transactions

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Abstract

This paper argues that the assumptions underlying the neo-classical economic paradigm of perfect competition are not realistic. In particular, assuming exogenously fixed production technology and consumer preferences, as well as the availability of perfectly symmetric information at zero cost contradicts the findings on the inherent bounded rationality of human behavioural decisions.

The paper builds on an information-theory approach. Bounded rationality is reflected in rule- or algorithm following behaviour. Establishing rules require an investment in information costs. Sticking to established rules entails economies of scale stemming from this investment. Behavioural rules can be stored in the human brain but can also be "farmed-out" into equipment goods and social structures. Farming-out reduces transaction cost (opportunity cost of information storage and processing). Increasing control and policing costs set limits on farming-out.

A Generalised version of the Coase Theorem is derived from this approach and it is shown that this provides a more realistic basis than the neo-classical paradigm to explain a wider range of individual (economic) choice behaviour. It allow allows to explain the emergence of rules, social structures and institutions as substitutes for negotiated market transactions and lays the basis for a theory of institutions.

Keywords: production theory, consumer behaviour, Coase Theorem, transaction costs, bounded rationality, institutional economics, evolutionary economics

1. Introduction

Present-day economics is characterised by a deep abyss between mainstream neo-classical economic theory and the practise of business management. Neo-classical theory is build on the perfect competition paradigm that leads to general equilibrium and the highest possible state of welfare. It is driven by two exogenous sets of fixed algorithms, consumer preferences and production technology. Equilibrium is reached when all pairs of marginal costs and benefit ratios are equalised. At that point entropy is maximised and economic activity - agents making choices - must necessarily cease because no agent can further improve his position. At best, economic activity keeps on going in 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.

I have already argued in a previous paper (Martens, 1995) that the neo-classical perfect competition paradigm is incomplete from a systems theory point of view. An entropy-maximising system is not self-sustainable. It needs an entropy-decreasing force - in this case a competition-reducing force - to keep it going. Behavioural innovation constitutes such a counterbalancing force. This can be generated by regular re-programming of the exogenous behavioural algorithms (consumption preferences and technology) with new ideas. Innovation fuels competition and keeps the economic system away from entropy death.

Re-programming of these exogenous algorithms[2] implies endogenisation of these algorithms into the economic system. This has been attempted since the mid-1980s by so-called endogenous growth theory (Romer, 1986, and Lucas, 1988). While these attempts initially remained within the confines of the neo-classical perfect competition paradigm, Romer (1990a, 1994) has shown that innovation-based endogenous growth theory basically conflicts with the neo-classical model because it violates the convexity requirement that is needed to reach equilibrium. Economic theory thus needs to switch to a new model, and indeed a new paradigm, taking into account both optimising behaviour in function of competitive forces and innovation in behavioural algorithms to escape from competition.

In this paper, I will first retrace Romer's argument on the conflict between neo-classical production theory and innovative producer behaviour and try to push this analysis somewhat further in the direction of an information or knowledge-based approach. Secondly, I will transplant the same arguments to consumer behaviour, a domain that has been neglected both by endogenous growth theory and the neo-Schumpeterian innovation school. Then I will present, in narrative format, the outlines of a new model that is more firmly rooted in present-day neuropsychological and information theories. It combines both neo-classical rational optimising behaviour and boundedly rational rule-following behaviour, both by consumers and producers. Finally, I will show how this approach results in a generalised version of the Coase Theorem. This may constitute the basis for a more comprehensive explanation of general socio-economic dynamics, including social structures and institutions. That is, more comprehensive than the neo-classical general equilibrium model.

2. Innovative producer behaviour

Since the early 1950s, mainstream economics' treatment of production is based almost entirely on the neo-classical Solow-model (Solow, 1956). The production process is a technological "black box" that transforms factor inputs (capital goods and labour) into outputs (production). The transformation ratios between factor inputs and outputs (factor productivity) are considered exogenous to the economic process. Empirical estimation of these transformation ratios, by Solow himself and others, showed, however, that its capacity to explain output growth was limited. An unexplained growth residual remained: the so-called Solow-residual. Clearly, there is productivity growth or technological progress inside the production black-box. But the neo-classical model is unable to explain this progress and considers it to be exogenous to the economic system.

In the 1980s, two different gateways were explored to endogenise technological progress in the economic system. The first started from Nelson and Winter's (1982) micro-economic evolutionary approach to economic change that build the foundations for most of the present neo-

Schumpeterian entrepreneurial innovation models. The second gateway was situated at a more macro-economic level, where Romer (1986, 1987, 1990) 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 behaviour and focus on innovation as the driving force behind economic growth. Competitiveness is treated as an evolutionary problem: producers must adapt or perish. The market position of individual firms continuously changes because of innovations by competitors. A wide variety of evolutionary models has been build around this theme, starting with Nelson & Winter (1982). A good overview with recent examples is presented in the December 1994 issue of the "Journal of Evolutionary Economics", including Dosi (1994), Ulph & Owen (1994), Silverberg & Verspagen (1994), etc. Aghion and Howitt (1993) have developed a micro-macro model where economic growth, including business cycles, is driven by innovation and creative destruction.

The almost exclusive focus of all these models on the firm as the locus of innovation allows us to classify them 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 approach.

The general mechanism of these evolutionary models could be summarised as follows. The core of the models is constructed around investment in R&D that yields innovations, generated by a stochastic mechanism. These innovations are than linked to a standard production model. 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 can be coupled to time-patterns that simulate inertia in diffusion of innovation and spill-over to other producers, and thus the evolution over time of relative monopoly power in the market. Although the replication of ideas can normally be done at virtually zero marginal cost, in practise they are protected by legal patents, secrecy and time-consuming learning processes to acquire the ideas.

A key question is whether the standard neo-classical hypothesis of profit maximising behaviour by producers remains valid in these models. The strong version of profit maximisation, based on ex-ante rational expectations, can certainly not be maintained as innovations are randomly generated events and the co-evolving character of producers' competitiveness in a market excludes forecasts about competitors' behaviour. A weaker version, based on ex-post optimisation through competitive selection mechanisms is more acceptable. The impact of a weakened profit maximisation hypothesis has been discussed at length in the literature (for instance, Dietrich, 1994) and should not necessarily de-rail the coherence of the neo-classical train of thought.

However, innovation-based evolutionary models violate much more fundamental neo-classical principles. They introduce imperfect competition as the driving force for innovation. It strengthens a producer's monopoly power in the market and allows it to increase prices above prevailing market-prices for "standard" (non-innovative) products. General competitive equilibrium analysis does not hold anymore as innovative monopoly power allows producers to set prices above the marginal cost of production (which is anyway close to zero for ideas). Typically in neo-Schumpeterian innovation-driven models, prices are determined through mark-up procedures, completed by market share allocation mechanisms among producers, without taking into account changes in consumer demand (see next section).

Furthermore, ideas are non-rival goods. Contrary to ordinary goods, which are rival, ideas can be used by many users at the same time without loss of benefits or additional costs for any of them. It is important to underline here that this synchronic (same-time) non-rivalry of ideas pertains only to the idea itself, and not to its material carrier (paper, diskettes, video, any communication media). The material carrier may only produce diachronically (over-time) non-rival series of copies of the embodied idea. For example, the ideas embodied in the Windows operating system that runs my PC are used by millions of people all over the world at this very moment (synchronically). But my own registered Windows copy, that came on a floppy disk with a unique serial number, can only be used by one PC at the same time, although with a virtually endless series of repeats over time (diachronically).

Romer (1990) has demonstrated that non-rival goods result in production functions that have a degree of homogeneity higher than one. 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 since they become meaningless for the allocation of factor income. Some neo-Schumpeterian models try to solve this problem by splitting the economy in two sectors, one that produces non-rival innovation and a second that produces ordinary rival goods (with bought innovation inputs) which remains subject to the classical production functions (for example Aghion and Howitt, 1993). But this does not solve the problem of the first sector's incompatibility with neo-classical models.

Innovation-driven models thus violate at least three neo-classical principles: ex-ante rational profit maximising behaviour of producers, perfect competition on product markets (price exceeds marginal costs) and perfect competition in production factor markets (remuneration exceeds marginal productivity). The neo-Schumpeterians have never claimed to be or wanting to be consistent with the neo-classical 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 non-price strategies. Clearly, there is not much left of neo-classical producer theory.

A critique of the neo-Schumpeterian evolutionary supply-side models is that, despite these violations of neo-classical production behaviour hypothesis, their approach is still largely based on the same neo-classical production model with aggregate variables (profits, investments, prices and production). The only "innovation" which they introduce is to link production to a stochastic innovation generator, fuelled by investments. Production of material outputs (goods) remains a function of capital (investments) and labour. The production algorithm itself, the series of transformations in the "black box" that generate the output, is not explicit or explained. The process of embodiment of the innovative idea in the production process, the changes that it induces in the production algorithm, are not explained. Innovation is still measured indirectly by its results, changes in production costs and market prices, not by its intrinsic impact on the production process.

3. The origins of economies of scale in production

Romer's (1990) explanation that the non-rival nature of ideas causes economies of scale in production is intuitively understandable but it does not explain the fundamental origins of economies of scale in production processes.

Ideas are expressed in information algorithms. Algorithms are rules that separate order from chaos (Gell-Mann, 1995). The information contained in an algorithms reduces entropy, it creates differentiation between previously undifferentiated elements. Information can not be stored or transmitted without an energy/matter vehicle. It has to be stored in a material form, whether in our brains, on a computer disk or on paper. Every "created" object - objects worked on by men - are, by definition, moulded according to a specific algorithm, an idea. To work on something is to shape it, to differentiate it from a less-ordered environment from which it is extracted. In a purely thermodynamic sense, to work means to lower entropy in a sub-system by extracting energy from the outside world, to imprint a lower-entropy informational algorithm on a sub-set of a higher-entropy system. Putting that imprint takes energy, work (Georgescu-Roegen).

The essence of production is the transmission of algorithms, the application of rules that increase order. Recent developments in the economic theory of production (Scazierri, 1993) look at production as a process, a sequential/parallel chaining of rules for action, algorithmic transformations. Innovation could then be defined as a change in the chaining of algorithmic transformations or a change in a particular algorithm itself. Such changes are brought about through learning processes (that embody new algorithms in labour or in management) and the production of new equipment goods (that embody the algorithm of an innovative idea). Different algorithms produce different outputs altogether, not just improvements in the quality of an existing product.

In the pre-industrial and industrial stages of economic development, moulding of matter according to certain simple algorithms was the predominant production activity in the economic process. As long as the algorithmic "blueprint" remained resident in the human brain only, there were few economies of scale in such production processes. Each human work cycle resulted in only one copy of the algorithm. The cost of each replication of the algorithm (labour input) was more or less constant. Matter and energy based activities are subject to the laws of thermodynamics: total energy in a closed system remains constant and decays (lower entropy or availability) through work.

With the development of tools and machines (equipment or capital goods), economies of scale set in. The essence of capital goods is that a piece of equipment embodies an algorithm, generated in the brain of the designer. This single copy of the designer's algorithm can be imprinted endlessly (many copies) on other pieces of matter. One work cycle - the embodiment of the algorithm in the equipment - generates a (potentially) endless series of copies of the algorithm. The capital good acts as an intermediary storage "memory" for the algorithm, which can be copied endlessly without changing or eroding or destroying its content. In practise, the number of copies is limited only by material wear and tear of the equipment good (physical depreciation). With every copy, a tiny bit of matter is also displaced and the capital good physically decays. Equipment or capital goods generate economies of scale because a single investment in design of an algorithm generates many copies at zero marginal design cost. There is no need to re-design the algorithm for each copy. The cost of running the equipment is, of course, positive.

Thus, the distinction between capital goods and recurrent inputs in a production process is entirely defined by the transmission mechanism of their algorithmic information content. A capital good transfers only the content of its embodied algorithm (possibly with a marginal amount of matter) to the output; a recurrent input transfers both the full amount of matter that carries the algorithm as well as the embodied algorithm itself into the output. In other words, the distinction between rivalry and non-rivalry depends on the extend to which the material algorithmic carrier is incorporated in the output. A production process can than be described as a series of transformations, some of which involve the incorporation of matter into an output product (rival stages of production) and others which involve only algorithmic incorporations (non-rival stages of production).

Non-rival transmission of algorithms is a fundamental source of economies of scale in production processes. A production process that involves only algorithmic transfers enjoys virtually endless economies of scale, limited only by the wear and tear of the hardware. For instance, copying public domain software into the Internet (the transfer of the physical carrier for the software algorithm, electricity, is a marginal cost compared to the value of the software).

4. Innovative consumer behaviour

Both endogenous growth theory and the neo-Schumpeterian approach to endogenisation of innovation and technical change have neglected the consumer side of the innovation story. They introduce changes in the exogenous set of technology parameters but leave exogenous consumer preferences untouched.

Neo-classical general equilibrium models assume that consumer preferences are exogenous and fixed. A strong statement in defence of this assumption has been made by Becker and Stigler (1976), although Becker (1991) seems to have somewhat softened his views. Pollak (1976, 1977, 1978) has weakened the neo-classical stance and allowed for various sources of endogenous influences on consumer preferences: own past preferences, preferences of other consumers and prices. He underlines that endogenously determined consumer preferences rarely result in personal utility maximisation. Since Pollak's seminal work on this issue, an endless series of variations on the theme reduced consumer sovereignty have been developed. Birchandani et.al. (1992) introduce a theory of fads, fashion and customs on the basis of "information cascades", that bears close resemblance to Arthur's (1989) lock-in mechanism. Ditmar (1994) has eroded consumer sovereignty to the bone. Her socio-economic investigations led to the conclusion that consumer behaviour is largely dependent on norms and values within peer groups. A substantial body of psycho-economic literature has developed around the theme of "socialisation" of consumers from early childhood onwards. See, for instance, Lea (1990). In short, the perfectly sovereign neo-classical consumer, who maximises utility solely in function of his own ex-ante exogenous preferences, does not exist anymore in present day economic theory. If he would still exist, then the vast amounts spend on marketing campaigns would not make sense.

However, economic theory has still not taken the last step in the endogenisation of consumer sovereignty, that is the emergence of preferences for new goods *ex nihilo*. How can a consumer know (ex-ante) how much preference he will attach to all possible new and improved goods that will be available in the future? Obviously, he can not. Preferences can only be revealed after the producer has put his innovative good on the market. Ulph and Owen (1994) have tried to find a way around this by augmenting consumer preference by the amount of quality improvement as reflected in the price increase. But this technique does not solve the question how consumers can (ex-ante) determine the augmentation of their preference for an improved good without knowing the nature of the improvements. Furthermore, it does not allow for the introduction of new goods; only improvements to existing goods can occur.

Preferences for new goods must necessarily emerge endogenously and ex-nihilo. That ruins the neo-classical consumption model but stands much closer to our perception of reality. But just like the technological black-box in neo-classical production theory, so does the transformation of acquired consumer goods into consumer satisfaction remain a black-box mechanism in neo-classical consumption models.

Birchandani et.al. (1992) come much closer to ex-nihilo emerging preferences with their information cascade models. This brings us closer to an information- or algorithm-based approach to the consumption process. Consumption could be described as a match-making process between learned algorithms or representations in the consumer's mind and the algorithms or representations embodied in consumer goods. A consumer will buy a good when the embodied algorithmic representation corresponds to the representation ("preference") in his mind. Consumer satisfaction occurs when the embodied representation is copied to (matched with) the representation. Non-durable consumer goods can only be consumed once: both the embodied algorithmic representation and the material carrier are "destroyed" in the consumption process. This category contains goods that are physically (matter/energy) taken in by the human body. Example: food, heating. All other consumer goods become durable in the sense that the embodied algorithm can be consumed endlessly as long as wear&tear of the material carrier allows it. Only the embodied algorithm is copied to the consumer, and can be copied repeatedly[3].

Representations in the consumer's mind are established (learned) through communication (social interaction, information gathering). Producers produce goods and services that correspond to these representations or they may try to modify the representations in the consumer's mind through marketing campaigns.

For example, clothing. The structure of the tissue (mechanical and chemical algorithm) slows down heat dissipation or absorption by the body which improves physical survival chances. In that sense, and from a purely utilitarian point of view, old fashioned clothing will do as well as modern clothing. However, people generally prefer fashionable clothing. Fashion means that the embodied design (algorithmic representation) has been modified to take into account preferences for certain colours and styles that have been established through social communication processes, not on the basis of individual consumer sovereignty. They constitute the preferences in the consumer's mind on what one should wear this season.

"Utility" or "preference" become tautological concepts in this view. Useful is what is perceived as useful in a given individual and social information context. Consequently, utility is fully determined within the system and utility maximisation cannot be the driving force behind consumer behaviour anymore. Utility functions lose their status of objective functions, which they had acquired in the neo-classical economic model.

Describing the consumption process as transfers of algorithmic representations also allows us to widen the neo-classic consumption concept and to include "consumption of representations", apart from consumption of goods and services. For instance, we can "consume" behaviour, attitudes, ideas and information emitted by other persons. We can enjoy their emission of representations, dislike them or simply don't care. This widening of the consumption concept has two substantial implications for the neo-classical consumption model.

First, it introduces consumption of "pure" information. Consumers are willing to pay entrance fees to be in the presence of persons they like or to hear ideas and see scenes which they approve of. They don't pay for the material carrier of the information or representation (book, audio disc, theatre) but for the representation itself. In the neo-classical model, "pure" information (representations) is assumed to be freely available and symmetrical, that is identical for all economic agents. In the algorithmic approach, information usually comes at a cost and is, in any case, not symmetrical because supply of and demand for a particular information or representation is not homogenous among economic agents.

Second, it allows for the introduction of "negative consumption", consumption of things which we do not like but still care for. We may incur substantial opportunity costs to stay far away from people and situations we dislike. We may spend money on buying an opposition party newspaper just to read how ridiculous their ideas are. We spend time protesting in the streets against nuclear bombs or human rights violations by governments in distant countries where we will never set foot. Neo-classic consumption models have difficulties coping with such consumer behaviour. The introduction of algorithmic representations as the basis for consumer behaviour facilitates the analysis. Consumer preferences then come in three kinds: those you like, those you hate and those you ignore; only the latter has no impact on your allocation of opportunity costs. The neo-classical consumption model can only cope with the first kind.

Intermezzo

In the preceding sections, we have tried to shed some light on two black-boxes in the neo-classical model, namely production and consumption processes. We have shown how the underlying transformation mechanisms (inputs into outputs, goods into consumer satisfaction), that are implicit in the neo-classical model, can be made explicit by adopting an algorithmic approach. Production and consumption can be described as algorithmic (rules, representations) transfer activities. This approach, however, casts serious doubts over the neo-classic assumption of exogenously fixed production technology and consumer preferences. Algorithm-based behaviour is, almost by definition, learned behaviour, established through communication processes that are endogenous in the human interaction model. We are now confronted with the problem that endogenisation of production and consumption parameters renders the economic model steerless: where do we start, where do we go to?

Economics is fundamentally the science of human choice: what is the best choice given the circumstances? The word "best" implicitly assumes that there is something to be optimised: profits, income, human satisfaction, etc. Optimisation requires a driving force, a motive for choice and action. Endogenisation consumption parameters takes away the motive for consumer behaviour. What motivates consumption behaviour and consumer choice when consumer satisfaction derived from bought goods constantly changes and - worse - depends on the choice itself. Like in every detective story, we need a motive for behaviour. The search for a new motive - beyond consumer preference - is the subject of the next section. We leave economics for a while, and start roaming around in information and evolution theories, biology and psychology.

5. Survival probability maximisation under bounded rationality

The starting point in the neo-classical world view is that economic agents are, at any moment, rational optimisers. They have, at any moment and at zero opportunity cost, perfect information on their economic environment that permits them to maximise a utility/profits objective function subject to exogenously given preferences/technology. Ever since the work of H. Simon on bounded rationality, we know that this is an unrealistic assumption in most circumstances. Rational choice assumes the continuous re-calculation of pleasures and pains. Such behaviour implies enormous information gathering and processing costs as well as transaction costs to continually change arrangements. Given the limited computing capacity of the human brain, continuous and comprehensive optimisation is impossible. At best, intermittent and partial optimisation can be achieved, based on a limited set of information. Even if the brain's computing capacity was not limited, the fundamentally unknowable universe would only allow for partial comprehension and thus bounded rationality.

It is precisely in response to imperfect information or bounded rationality that complex adaptive systems have developed. Gell-Mann (1995) calls them Information Gathering and Utilising Systems (IGUS). IGUS sift through the limited amount of available information to identify regularities (algorithms) in an uncertain universe. Regularities separate randomness and uncertainty from order (synchronic) and predictability (diachronic order). The algorithms identified by IGUS allow to - partially - reduce the unpredictability of the world. Algorithm identification is called "learning". The learned algorithm is stored in memory and can be used repeatedly. Although algorithms are only an imperfect approximation of reality, being able to identify and memorise them enhances the survival probability of IGUS. Rather than simply awaiting the course of external events and hoping that none of these will be harmful or even lethal, IGUS can try to foresee the course of events and devise strategies to reduce harm and increase benefits. Langlois and Csontos (1993) have shown how this two-track approach (rule-following combined with intermittent re-optimisation) can converge to a single behavioural track. This is what biological, including human, behaviour is about: maximise perceived survival probability in a world of uncertainty. You can not be sure to find food anytime anywhere, so you devise (learn) behavioural algorithms that permit you to increase chances of finding food.

Survival probability maximisation should not necessarily be interpreted strictly in the live-or-death sense but should be considered in a context of mostly marginal behavioural adaptations that smoothen the path of life and steer it so as to maintain or improve perceived survival probabilities. Like in Darwinian evolution, survival maximisation does not have to be an explicit behavioural objective. But it is always implicitly there: IGUS that do not improve their survival probability, improve their death probability - by definition.

The qualification "perceived" is essential. A person does what he thinks is best for him. Because of inherent uncertainty, IGUS have no means of knowing which behavioural rule will indeed maximise absolute survival probability. A change towards more "optimal" behaviour and higher "perceived" survival probability is relative only to the present challenges and offers no guarantee to cope with future challenges (Hodgson, 1993). Consequently, IGUS can only maximise perceived survival probability.

6. Layering and farming-out of algorithms

Order-creating IGUS exist at various levels of complexity, from simple biological structures to complex entities with cognitive capacities, like humans, to complex societies of humans. Simple biological structures react mechanically to external events. The mechanisms are designed in such a way as to collect the necessary material and energy inputs that prevent the internal entropy-increasing process from reaching the limits where the structure disintegrates. Algorithms are pre-programmed and reactions to events are fixed. If unforeseen (un-programmed) event impact on the structure, it disintegrates. In more complex biological structures, algorithms are genetically encoded, which allows programming of far more diversified but still fixed or innate reaction patterns. Reaction patterns can not adapt to unforeseen incoming information. However, in Darwinian evolution models, randomly generated genetic mutations may result in better adapted species with increased survival chances. The word "random" is essential here: the behaviour of the biological structure itself does not influence these mutations. The Lamarckian evolutionary model is not applicable.

The evolution towards cognitive capacity and the emergence of brains in evolution marks the gradual shift from purely Darwinian selection (pre-programmed genetic) to Lamarckian selection (adaptive programming or learned behaviour) (Hodgson, 1993). Biological organisms have acquired the capacity to create a second layer of behavioural algorithms that can be learned and memorised and even repeatedly re-programmed in the course of the organism's lifetime. This has considerably enhanced flexibility in behaviour and increased survival probability in a more varied range of environments and circumstances. The effective internal complexity[4] (Gell-Mann, 1995, p.56) of IGUS behaviour has thus increased because they are able to identify and memorise more concise descriptions of regularities in their environment, and react accordingly.

Recent developments in neuro-psychology clearly demonstrate the validity of "double-layered" algorithmic behaviour. Damasio (1994) has reversed Descartes' mind-body dualism into a unified approach, whereby the brain is build on, but also dependent on, a bodily substrate. The innate mechanisms of the old brain cortex are largely genetically pre-programmed and include pleasure-pain (emotional) algorithms that ensure survival-oriented behaviour of the body. Development of the neo-cortex has enabled learning and memorisation of algorithms that allow us to interpret representations (symbols, images) of the outside world. Damasio shows, however, that purely rational (learned algorithms) behaviour is not possible without the interference of early cortex emotional algorithms. Behavioural decisions are often incomputable on the basis of learned algorithms because they do not give complete information and emotional mechanisms intervene to cut endless reasoning short. Pre-programmed emotional algorithms reduce brain computing time and thus economise on brain use, making room for more decisions to be taken in a shorter time span. Damasio defines "normal" behaviour as mostly rule-following, steered by emotional algorithms, and sometimes rationally optimising to adapt new learned algorithms.

Wilson (1975) had already formulated a similar hypothesis on hierarchies of genetic and learned algorithms. He maintains that social behaviour is fundamentally subordinate to a limited set of biologically programmed behavioural rules that orchestrate behavioural responses so as to ensure survival and reproduction. Both Damasio and Wilson arrive at the conclusion that human behaviour is based on "double-layered" programming: genetically pre-programmed emotional algorithms and learned adaptive behavioural algorithms. It is both Darwinian and Lamarckian and the most efficient approach to survival given the limited information gathering and computing capacity of the human brain.

Beyond building successive more complex and adaptive internal layers of algorithms, a third stage in the evolutionary process of IGUS can be identified, which could be described as "farming-out" of algorithms. The limits to IGUS's internal information processing and storage capacity result in a need to economise on that internal capacity and search for external processing and storage possibilities.

We have already identified one type of "farming-out" in sections 2 and 3, that is the development of tools, equipment. As explained in section 3, tools, instruments and machines embody fixed knowledge algorithms, designed by the IGUS's cognitive capacity, but stored externally in a material object.

Another type of "farming-out" behavioural algorithms is the emergence of social (group) behavioural rules. Skaperdas (1991, 1992, 1995) has shown how behavioural convergence and equilibrium positions can emerge from economic interaction between individuals without common behavioural rules. Exchange between individuals can be voluntary (a transaction) or involuntary (theft, fight). Under certain conditions (similar perceptions of risk, not too different fighting technology) it is better to negotiate a voluntary exchange (certainty) than to force an involuntary exchange (uncertain fight). Perceived survival probability is normally maximised by switching to voluntary transactions, unless one of the parties has significantly lower risk perceptions and/or vastly superior fighting technology. Certain situations, such as prisoner's dilemma, may offer an incentive for co-operation (Axelrod, 1986) while others may not.

Strictly speaking, this is not necessarily a form of "farming-out" because there is not always an external entity that takes responsibility for storage and implementation of "group" algorithms. Such entity exists only when an institutional set-up is created for that purpose (a club, a government, a board of directors, etc.). In fact, we need more analytical material to describe what is happening here. That is the subject of the remainder of this paper.

7. Algorithmic behaviour and transaction costs

We have identified the perpetrator of economic behaviour - the human IGUS - and his motive - perceived survival probability maximisation in an uncertain world. The motive led him to build ever more complex and adaptive layers of algorithms, in defence against the inherent uncertainty of a partially comprehensible universe. He even started to "farm out" algorithms because the limits on his brain capacity create positive opportunity costs for information. Processing one package of information prevents him from processing another package: he has to make a choice.

Positive information costs give rise to an asymmetrical or non-homogenous distribution of information among economic agents. We go through different learning processes and acquire different sets of algorithmic knowledge, either by choice or because of purely environmental factors. Learning processes start at birth and gradually lock the human carrier into specific behavioural algorithms (language, social rules, perceptions of the environment, skills). Individuals grow up in different environments, have different experiences and learn different rules of behaviour. Consequently, information asymmetries are bound to occur: some agents dispose of algorithms that others don't have. On the information supply side, information monopolies lead to information pricing at higher than the marginal cost of production - that is, above zero since information is a non-rival good. On the information demand side, because of limited brain capacity, information and algorithm acquisition (learning) has opportunity costs: agents have to make a selection of what they want to learn themselves and what they prefer to leave to others (farming-out), in function of perceived opportunity costs.

The emergence of information asymmetries and positive information costs as a result of bounded human rationality has several consequences.

First of all, it gives the final *coup de grâce* to the neo-classical economic universe. The unrealistic assumptions on exogenously fixed consumer preferences and production technology were already demolished in the preceding pages. The last key assumption, perfectly symmetric information distribution at zero cost, is crushed under the weight of bounded rationality.

Secondly, and more importantly, it is economical for human IGUS to stick to already learned algorithms as long as possible. A switch to new behavioural algorithms entails information costs and possibly costs for the acquisition of the material carriers of the new behavioural algorithms. Alternatively, we can say that there are economies of scale from sticking to the same behavioural algorithms as long as possible. Discussing the costs and benefits related to algorithms brings us to the debate on transaction costs - a key concept in a boundedly rational economic environment.

The transaction cost debate was initiated by Coase (1937) and revived by Williamson and the New Institutional School in the 1980s (see, for instance, Williamson, 1993 for an overview). Coase opened the debate from a supply-side angle: Why do firms exist[5]? Why can't individual producers trade parts of production processes among each other to arrive at the final product? Alternatively, why can't all firms be absorbed into one huge company? His answer was that firms are a means to circumvent the inherent transaction costs of 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. Firms circumvent the market because they work on the basis of contracts that fix quantities, qualities and prices, rather than passing every time through an open market transactions. These contractual arrangements save transaction costs. On the other hand, all firms can not be amalgamated into a single company because the amount of information required to supervise the whole company would be overwhelming (and very costly). It could not possibly be processed by a single IGUS and would thus require decentralised decision-making anyway, thus eroding the presumed benefits of integration.

Coase saw the firm as a set of contracts between individual producers who economise on transaction costs by by-passing the market. In his view, it is indeed possible to out-wit the market. The New Institutional School that emerged in the 1980s is founded on the view that firms are a "nexus of contracts". For an overview, see Williamson and Winter (1993). As Demsetz (1993) and Dietrich (1994) point out, transaction cost minimisation is a necessary but not a sufficient condition for the emergence of firms. Total firm cost is minimised, and profit maximised, if and only if the sum of production and transaction costs is minimised. Dietrich (1994) maintains that the firm is not just a "nexus of contracts" but also a "production-distribution" unit. However, since we defined production as the application of a series of algorithms, by machines and men, we can safely abandon that distinction. Contracts describe agreed behavioural algorithms.

In a way, Coase has discovered a new source of costs that was unknown to neo-classical economics. He has added transaction costs to production costs. 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. The Coasian layer on top of the neo-classical cost landscape can be very thin but never be fully erased.

But its importance goes much further than just another cost layer. The introduction of transactions costs in the economic universe has wiped out perfect information and, most importantly, dethroned the market as the ultimate efficient allocator: contractual arrangements can be more efficient that open-market transactions. The neo-classical economic universe appears to be just a special case of the Coasian Universe, with transaction (and thus information) costs set to zero.

8. A Generalised Coase Theorem

The original firm-related Coase Theorem can easily be generalised to include all types of groupings of individual economic agents, not only producers, and all types of economies of scale stemming from rule-following behaviour.

Generating behavioural algorithms requires an investment in information acquisition, processing and storage (transaction costs). The more often the algorithm is used, the lower the amortisation costs of the initial investment in information. (Transaction) cost are minimised when the algorithm is applied to as many decision-making occasions as possible. This conclusion applies to all behavioural algorithms, independent of their carrier and means of storage (in the human brain, in a capital good, in a contractual arrangement between individuals, in social institutions).

The case of rules embodied in capital goods has already been discussed in section 3 above. The longer a producer sticks to existing equipment goods and a consumer to acquired durables, the higher the value of economies of scale accumulated over time. Durable goods can endlessly replicate the embodied algorithm at no additional cost, subject to physical wear and tear only. Switching to new durables involves transaction (search and learning costs) and acquisition costs.

The extension to all types of groupings of economic agents is also easy to understand. In line with North's (1994) definition of an institution, a social grouping (a social structure, an institution) can be defined as any group of individuals that adhere to an agreed set of rules. Thus households, clans and tribes, nations, companies, sports-clubs, etc. can be called groupings or institutions. In this extension of the Coase Theorem, groupings or social structures are advantageous because they reduce transaction costs among members of the group. Social structures are a way to "circumvent the market": rather than going through lengthy discussions and open-market negotiations (with an uncertain outcome) every time we meet somebody, we better stick to an agreed set of behavioural rules.

Take language, for instance, which is a set of commonly agreed rules for the use and interpretation of vocal and written symbols, for the purpose of communication within a group of persons. Other social groups have different sets of rules for the same purpose of communication. Acquiring (learning) this agreed set of rules takes time and effort and thus transaction costs. For an individual, born in a community, transaction cost minimisation implies that it costs less (in terms of opportunity cost of time) to stick to the prevailing language and thus stay within that community. However, a company aiming at profit maximisation may decide on exports to other communities, using a different language. In that case, it may be worth the effort for the company manager to learn the other language so as to be able to communicate with the other community and sell his products there.

If we would pursue this economies-of-scale approach to information costs to its limits, we would end up with a single firm organising all production processes - which is tantamount to a centralised plan economy - , a single country inhabited by people speaking a single language and adhering to the same set of social conventions, behavioural rules and consumption patterns. Imagine the enormous savings in transactions costs from translations, international institutions, legal cases between companies, inter cultural conflicts, etc.! Clearly, that is not the real world. Fortunately or unfortunately, there are factors that limit integrationist trends due to economies of scale and maintain diversity in behavioural patterns.

A social grouping is stable and sustainable if and only if none of the members can increase his or her perceived survival probability by switching to another set of rules. If more attractive alternative arrangements exist in other groupings, strong defection motives will occur and possibly lead to disintegration. There are various reasons for defection, all related to the motive of maximising perceived survival probability which drives individuals to minimise personal costs (or socialise personal costs) and maximise personal benefits (or privatise social benefits). In a social interaction environment, this can be achieved by driving a wedge between private and public costs and benefits.

Permeable and/or incompletely defined rules-sets facilitate the emergence and widening of the wedge and trigger free-rider behaviour. Individuals can get away with slightly or totally disobeying the rule without incurring individual costs that exceed their individual benefits. Rules are often approximative only and provide only a rough separation between order and disorder. They need interpretation and adaptation to specific situations. A sub-set of society may be designated or designate itself to manage the rules: the bureaucrats, the managers, the priests. When the transaction costs related to policing the rules-set exceed savings in transactions costs from adhering to the rules, than the rules cease to be useful to the group and it disintegrates.

It can be concluded that a Generalised Coase Theorem (a) not only provides a more realistic basis than the neo-classical paradigm to explain a wider range of individual (economic) choice behaviour but (b) also explains the emergence of rules, social structures and institutions as substitutes for negotiated market transactions. It lays the basis for a theory of institutions.

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