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Atoms, Bits and Wits: The Elements of Economics

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ABSTRACT

There are at least three elementary components of economics: atoms, bits and wits. This paper examines their role in economic analysis. The economics of atoms is quite familiar to economists, in the production of physical outputs – under rising and falling cost – treated as substitutes in consumption. The relation of value to scarcity among atoms shows in the water-diamond paradox, in which abundance undermines the worth of material goods.

The economics of bits is somewhat less well-understood, though in information network contexts the issues appear in network effects, where abundance actually augments the worth of intangible goods. Substitution is here replaced by complementarity in social relations: 'what goes around, comes around' in this setting, where competition defers to cooperation as an efficiency standard.

Economics becomes a socially embedded process in network contexts: the economics of atoms and bits appear in transportation networks akin to what distinguishes parallel from serial linkages: conflicts of interest (tradeoffs or negative feedbacks) are balanced with concerts of value (positive feedbacks or reciprocity) in our social relations and cultures, where both forms of interdependence are inextricably intertwined in a nondecomposable mix.

But learning also affects the organization of factor inputs into efficient productive outcomes: so do wits complete the picture of economic activity. Innovation, novel approaches, new sociocultural patterns and institutional forms – so therewith intelligence and diversity – enter the frame of economics as a 'force locomotif' of change in an evolving system of fully interactive forces, openly uncontained and indeterminate in their growth and development. The bounds of rationality open a theory of planning horizons as an ordinal entropic measure of organization expressed in wits.

Atoms, bits and wits are modeled to show why orthodox substitution only applies to atoms subject to decreasing returns; a general case for complementarity in economic relations emerges from both increasing returns and bits, where adding wits strengthens a case for cooperation as an efficient form of social organization. In the presence of complementarity, it is competition – not collusion – that stifles output, such as among intangible and social goods. The sociocultural and institutional implications of this synthesis are explored through diverse examples.

Atoms, Bits and Wits: The Elements of Economics

I. Introduction

This paper addresses three elementary components of economics: atoms, bits and wits. The realm of atoms and things or material goods has been much investigated throughout the last two centuries; the implications of substitution and decreasing returns – and even, to a lesser degree, of complementarity and increasing returns – are fairly well understood. The realm of bits and information or intangible goods is somewhat less well explored, though its contours are not unknown in the study of information networks. The realm of wits and knowledge or planning horizons has not been well developed, though it will link everything else into a unified frame. The whole scheme provides a vantage that warrants our attention; it opens some means for additional learning. The next three sections explore, in turn, these elementary concepts – atoms, bits and wits – and develop them into a general framework; then, after a few examples, the work concludes.

II. Atoms

Economics since Adam Smith has mostly focused on physical goods in their relation to output and welfare, under assumptions of substitution and decreasing returns. Some economists see the defining characteristic of economics as scarcity and tradeoffs, supposing a basic conflict of interest throughout economics. Social choices in this frame mean transformations of raw materials into one or another resource shaped to human needs, where the 'cost' of whatever we do resides in the 'value' of foregone options. Scarcity is all; each choice substitutes something for an outcome thereby lost, and the tradeoffs at some margin are seen as 'the best of all possible (Pareto) worlds.'

Starting with agriculture and the notion that the most arable land is to be planted first, after which more and more labor must be used 'at the margin' to grow a bushel of wheat, decreasing returns were then applied to manufacture as well. If any input is fixed or 'cranky,' as in all short run theory, unit costs eventually start to rise as output is increased. This was important to show why competition worked so well: as Hicks (1939, pp. 82-85; Reder 1982, pp. 17) said, decreasing returns were needed to prevent the total "wreckage" of economic theory augured by increasing returns.

So the case for competition was secured for a time. Marginal costs would rise with output, allowing competition to work, constrained by technical limits to firm size relative to some 'market' (defined as a population of close substitutes in consumers' eyes). In this setting, competition directs all economic resources into their highest valued uses through a price system managed through selfish aims shaped to the common weal by an 'invisible hand' of free choice. So would these conflicts of value resolve for the good of all.

But there were some flaws in the argument. First, the 'natural monopolies' of vast transportation networks such as canals or railroads suggested decreasing returns were not universal, leading to questions about their regulation and the optimal price. The whole discussion became one of 'market failure' due to increasing returns and externalities, special cases in which the virtues of competition did not apply. In any 'second-best' domain, none of the social policy implications of optimal competition necessarily held: free entry, open markets, individual choices, invisible hands, all would have to be tailored to each specific case. Substitution and decreasing returns were required for competition to work consistently as our route to general social well being. Absent these central conditions, we may not be so well served by rivalry as economists think. Competition – though optimal in the presence of its defining conditions: substitution and upturning cost; independent agents (no externalities); free and complete information; perfect capital markets; etc. – cannot be relied upon to work outside these severe restrictions.

Worse, such provisions show why economists' case for competitive frames should be overthrown. Realistic economic concerns suggest that none of these suppositions are reliable in application, while any one of them – violated – define a 'second-best' circumstance so obviating the rest. There is no handy escape from the brittleness of the competitive frame (Stiglitz 1985, p. 21). Our preoccupation with substitution and decreasing returns, static equilibrium models, short run theories and other restrictive assumptions sideswipe any understanding of how real

economies work, given that they are ruled by increasing returns, externalities and – too frequently – limited information.

The rise of game theory in economics stands as a testament to increasing returns and interdependence. The whole thrust of argument in this setting calls for cooperation, telling its stories in a context where rivalry and selfishness subvert social needs. But this style of framing illustrates better than it explains; we need a closer review of increasing returns to analyze social effects. After all, increasing returns was the impetus for the 1930s debates. Clapham (1922) opened the argument; then Pigou (1927, 1928) rejected decreasing returns in cost and supply. The Hicksian Getaway in 1939 (Jennings 2009b) revived decreasing returns – solely by assertion – defining a rigid doctrine of denial exemplified by the Chicago School in its graduate training (Reder 1982, pp. 17-19). Economics has yet to emerge from its Age of Denial into more realistic constructions. Game theory is simply illustrative of the helpless state of our models in the face of increasing returns; economics itself is trapped within this Prisoner's Dilemma.

Kaldor (1972, 1975) offered a useful insight to increasing returns, saying they meant economic complementarity, based on Allyn Young's (1928) work without referring to Pigou. Kaldor endorsed a 'positive feedback' concept tied to what Myrdal (1978) had called 'cumulative causation'; no equilibrium models suffice to analyze systems of ongoing movement of fully interdependent phenomena. The logic calls for a dynamic complex systems approach to understanding, couched in a novel language unfamiliar to economists steeped in neoclassical lore.

The issue of increasing returns – subject to rigid denial in neoclassical circles (Waldrop 1992, p. 18) – sits like an 800 pound gorilla in a delicate china shop, where any mention thereof may initiate a rampage. Simon (1976, pp. 140-41) deemed this situation "the permanent and ineradicable scandal of economic theory." So in the world of atoms, economics has some uncomfortable lessons to learn and teach on increasing returns and complementarity issues; indeed, the whole scenario reeks of fascinating questions that transgress standard theories and point to unexplored domains. Not only are increasing returns – at least in the view of many economists – spread throughout the economy; if they imply universal complementarity in economic relations, something else ought to give in terms of how economics is done. Neoclassical theories simply are incompatible with these assumptions, as shown in the realm of bits.

III. Bits

The economics of bits – of information and intangibles – will not open to standard theories of substitution and scarcity. As students of this realm explain (Lamberton 2001, Matthew 2001, Elsner 2004), due to increasing returns and complementarity (information, given away, is kept by its donor), theories of economic abundance replace scarcity here, implying collaboration – not competition – is our route to efficiency. If so, why orthodox scarcity models still hold sway is open to question; an economics of falling cost and positive feedbacks should be examined as an alternative framework. Scarcity does not apply to an economy of intangible goods.

This is the realm of bits. Complementarity is the rule; economic connections in this setting are really 'both vs. neither' rather than 'either/or'. In this scenario, human needs are positively correlated; this is the nature of complementarity and increasing returns. The interaction of value with scarcity is inverted here, as shown by comparing the 'water-diamond paradox' (scarcity yields high value) with 'network effects' (where scarcity undermines worth). This inversion implies an upheaval in how we do economics.

An information network is an example of how an economy works. A transportation network captures some of the basic concepts; here we find two forms of interdependence – substitution and complementarity (under increasing returns) – that cannot be decomposed. Instead of beer and wine depicted as substitute drinks in a 'beverage industry,' we must acknowledge pretzels and cheese. A transportation network combines end-to-end and parallel lines, but their economic identity alters with routes and direction of travel, so is specific to purpose and place. One agent's end-to-end ties are another's alternate tracks: their relations are inextricably joined.

This implies an indeterminate balance of substitution and complementarity in networks, so here economists cannot define an 'industry' as 'substitutes,' so package the answer into the question. Instead, we are left with a concatenation of economic interdependencies – beer, pretzels, cheese, wine, playing cards, movies and bowling

alleys – so we must deal with the relative weight of substitution and complementarity in addressing which form of organization is efficient, competition or cooperation. If each situation is different, the answer may not be generalizable. Once we move beyond the industry concept, there are no easy answers about institutional form.

But the matter requires solution, as we get only one set of rules at a time, at least in any specific context. To leave the issue of institutional choice swinging free in the air is intellectually unsatisfactory and economically inexcusable; the problem cannot be dodged. The realization that substitution arises from our use of 'industries' says any means of aggregation not tucking the answer into the question – as with the balance of substitution and complementarity offered above – frames some meaningful lessons.

If competition fosters substitutes and discourages complements, while cooperation does the opposite, there is an argument here. If Kaldor (1975, p. 348) is right that increasing returns make complementarity "far more important" than substitution in an economy, competition is stifling output and welfare in these settings. Such is already known in our theories of public (complementary) goods and of positive feedback (externalities); it is also revealed in the 'Richardson Problem' (Earl 1983, p. 29; Richardson 1959, pp. 233-34) of firms' inter-dependence and their relative impact on output. The balance of substitution and complementarity in network contexts applies throughout economics, shorn of its substitution assumptions as an exclusive form of relation. But information networks stretch beyond transportation, in that their dominant – if not only – interdependence is complementary.

This is because information is not lost when given away. Indeed, the exchange itself frames new information neither possessed, so it is productive as well as a transfer of value enhanced for all parties. 'What goes around, comes around' here. Like love or smiles on the street, these gifts increase the welfare of all; your gain is tied to my own. The optimal price of 'bits' is zero; welfare rises and falls in concert. There is no separation; no individual tally of value makes sense (Nelson 1981, pp. 1053-55). The economics suggest that cooperation is what we need, that competition – in its separation – decreases output to all. The realm of bits seems solely of complementarity and increasing returns, so their avoidance in neoclassical theory is costly if the effect is to recommend competition as optimal in network contexts. If falling costs are the rule and not the exception – as seems the case for intangibles – substitution, displaced by complementarity, yields strong arguments in favor of cooperation as the means to efficient production.

This is the realm of bits, and even of atoms if Pigou, Young and Kaldor are right about increasing returns as a general condition. Decreasing returns apply in the short run due to cranky inputs. For long run atoms and all bits, substitution does not apply and neither do neoclassical arguments favoring competition. Indeed, if bits are complementary, orthodox scarcity models steer us wrongly as a guide to choice. Our analyses should be open to both substitution and complementarity and their elementary difference. As Georgescu-Roegen (1970, p. 9) declared, "the elementary is the hotbed of the errors that count most."

In the realm of atoms, substitution derives from short run theories of arable land of varying quality; if all inputs rise together over a longer run period, then any increase in scale loosens an organizational limit to specialization that ought to reduce unit costs. For these and many other reasons, substitution and rising cost only apply in short run theory; for all long run output of physical goods, increasing returns should obtain along with complementarity. If all intangibles also reflect increasing returns and complementarity, then the only acceptable application for substitution assumptions is in short run atoms, so maybe competition is not advancing but rather retarding growth and welfare in all longer run cases (Jennings 2009a). To add wits to the argument opens additional lessons.

IV. Wits

So what is the most significant difference of short from long run theory? One way of framing that difference is with the planning horizon as an ordinal index showing our rational bounds in any decision. The time horizon in choice is akin to the move horizon in chess; the better one knows what others will do in response to one's own actions, the further out may anticipations stretch in their range of view. The planning horizon in a decision differs from the time horizon mainly in terms of emphasis; the time horizon extends through a better grasp of causal relations in all dimensions of choice, seen as a normative process of multidimensional causal projection

by an agent. The range of foresight captured in a decision – at the moment of choice – suffuses all our related designs and their resulting effects. Surprises set the horizonal limit to where reality opens in a direction not anticipated at the time of action. The actual (*ex post*) planning horizon is based on *accurate* expectation, though we have no certain knowledge. So how do planning horizons subsume our relations of atoms and bits?

First, the proper unit of measure for understanding and knowledge – as suggested by Boulding (1966, pp. 22-23) – is the 'wit,' akin to the 'bit' of information. The planning horizon needs to be seen as an *ordinal* index of 'wits,' so we do not talk of 'how many' but of 'horizon effects' as shifts – inward or outward – in our ranges of foresight. Thus our planning horizons respond to internal and external changes, such as new understanding, confidence, effort, attention and hope on the inside, and greater stability or uncertainty in our decision environments, the moods and expectations of friends along with their horizon effects, as sundry outside determinants. The impact of longer and broader horizons shall differ from more myopic concerns in numerous ways subsumable into economic constructions.

So 'horizon effects' shall matter. For individual pricing decisions, longer horizons mean lower costs, markups and prices, *ceteris paribus*, so higher growth in sales relative to any shorter horizon. Further, private horizon effects spread outward to infect others, shifting social horizons in the same way. Horizon effects are thus contagious in their interpersonal impact (called 'interhorizonal complementarity'). If so, an important implication emerges from this story.

It was argued above that 'industry' groups swayed our understanding in favor of substitution, where – at best – among atoms we actually see a balance of both forms of interdependence in every economic context. For all bits and wits, we find a purer case of complementarity and increasing returns; substitutional elements may be present, but they are overwhelmed and dominated by complementarity in the general case. So once we assume a 'balance' of substitution and complementarity and so cannot determine what the proper institutional choice should be, how do we proceed? What might we do to resolve this puzzle?

This is where we use our wits to ask the horizonal question: how do 'horizon effects' shift the balance of interdependencies? If private horizon effects stimulate similar social effects – due to interhorizonal complementarity – and given horizons' impact on pricing, then the answer is wholly general: social relations shift due to horizon effects in the following way. Longer horizons enhance complementarity and reduce substitution, changing the balance of interdependence away from conflicts to concerts of interest in economic and social relations. Shorter horizons do the reverse, shifting the balance in favor of substitution as complementarities shrink. The nature of interdependence is not 'given,' as in neoclassical theory; instead, the balance of substitution and complementarity is horizonal. What are the reasons for this?

First, think of the difference between rising and falling costs, where – in the realm of atoms – upturning costs occur with 'cranky' inputs only in the short term. The time horizon – as one dimension of the planning horizon *in toto* – is also an index of 'run length'; if so, then longer horizons shift the slope of the unit cost curve downward, such that decreasing returns slowly yield to falling unit costs or increasing returns. That is a reason that longer horizons shift the balance of interdependence in favor of complementarity.

Another reason for this relation between horizons and interdependence is that longer horizons mean lower prices, greater efficiency and more rapid growth (though 'growth' need not involve atoms), so any horizonal lengthening increases the size of the aggregate pie, yielding more for all. This, almost by definition, expands the role of complementarity in the form of a concert of interest, therefore reducing conflicts of interest in economic connections. So would horizon effects shift the nature of social relations.

A third justification of this shift to complementarity associated with longer horizons (which can seen as an ordinal index of personal growth and maturity) is seen in Abraham Maslow's (1954, 1968) notion of hierarchical needs. Social and economic development – according to Maslow's view – entails an evolution away from material needs – once satisfied – toward intangible interests. Such a move from atoms to bits suggests a rise in complementarity at the expense of substitution, at least if our institutional setting allows this shift to occur. And that is the nub of the problem.

If our social institutions fail to evolve accordingly in favor of cooperation and away from competition, then this process of growth is stifled due to the dual impact of a decline in complementary outputs (which

competition stifles) and the shortening of horizons due to higher-order need deprivation (Argyris 1960). Competition – as social system – assumes substitution in our relations. In the presence of complementarity, competition must fail. Among complements, rivalry undercuts output just like collusion with substitutes. In complementary realms, social welfare recommends cooperation as our route to improvement. A social system based on competition undermines complements; substitution does not apply where cooperation is sought. This is true even in the absence of horizon effects, which only exacerbate the problem.

When notions stray from applications – so reducing the 'fit' of theory to fact – our planning horizons shorten relative to more realistic conceptions. Such offers an answer to Friedman's (1953) support of unrealistic constructions: without a theory of planning horizons, we cannot see the horizon effects spawned by competition. Competition is failing us, not only due to complementarity, but also with a myopic culture resulting from its horizon effects.

It would be hard to overstate the importance of this massive failure or its source in neoclassical theory and assumptions. The Hicksian Getaway and The Hirshleifer Rescue of decreasing returns (Jennings 2009b) stands as a monumental error regrettable in the extreme. There is no case for decreasing returns save for short run theories of cost; the whole claim is based on assertion devoid of foundations in logic or fact. The reality is an economics of increasing returns not only in all long run atoms but also for all bits and wits. The fact that an Age of Denial has stifled our research into increasing returns and its significant implications stands as a mark that has "prove[d] misleading to a whole generation of searchers" (Samuelson 1963, pp. 235-36). Such is a good example of what Arrow (1974, pp. 28-29) referred to as one of "the greatest tragedies of history" – re: The Hicksian Getaway and The Hirshleifer Rescue (which might be what Arrow meant, though he did not say so explicitly) – about "this sense of commitment to a past purpose which reinforces the original agreement precisely at a time when experience has shown that it must be reversed." The tragedy here is immense. Some of the enduring effects of decreasing returns in its support for models of competition in economics should be addressed at this point.

V. Examples

There are many examples of failures stemming from competition, if one understands its effect on horizons. Some mentioned below are the media, education, politics and – perhaps most tragically – ecological loss. Each suggests some of the costs of the Age of Denial in economics initiated by The Hicksian Getaway and then improperly reinforced by The Hirshleifer Rescue. Once economists see the problem, maybe it can be changed or reversed. But the time for reform grows short.

The Media. Even a cursory overview of communications media in the United States and elsewhere reveals a 'dumbing down' of potential content to satisfy public demand. This is an outcome of fierce rivalry in a complementary setting of information exchange; the associated horizon effects are very hard to deny. Interhorizonal complementarity implies that any short horizons in one's decision environment truncate also one's own; there is no escape from media's impact on social horizons. One might argue that the media only give what the public wants, that learning and knowledge are not desired as much as mere entertainment. The question is why, if this is so. The answer resides in another realm of mass socialization, namely in our educational system.

The Educational System. Making competition the guiding principle of design in education means that everyone tries to outdo each other to be noticed. In schooling, kids are rivals, pushing for recognition against each other, even if this entails sabotaging others to help oneself. More typically, the effects show in an avoidance of error, which transforms into a fear of learning as mistakes are part of that process. At higher levels – in academics – any alternative view or other approach that differs from one's own is strongly opposed or resisted, to be argued against, dismissed, derided and duly attacked on all fronts. Such is seen as a 'scientific' conjecture and refutation process (Popper 1959, 278-79; 1963), though Polanyi (1958, pp. 78-79) endorsed a different view. With departures seen as a threat and not as a chance to learn new ways, growth in knowledge is stifled. In economics, such is the reason for rigid doctrines opposed to change, when educational settings should

be open to learning and novel ideas. The tragic conundrum manifests in a socialization process that enforces strict conformity at the expense of diversity and truncates social planning horizons, spawning a myopic culture.

Politics. Any examination of our political processes shows a rampant dysfunctionality yielding a low level of discourse stunning in the extreme, making cooperation or rational action nearly impossible. This is a realm in which we enact the rules for society, yet the system is so corrupted by competitive forces that the process seldom brings sensible outcomes. With the politics so uncertainly indecisive – given our voting behavior – ramifications also include disastrous short horizons due to the spread of social horizon effects. Such behavior rises from our rivalrous system of elections, superficial media coverage and the disengagement of voters. The inability of our regulations to keep pace with corporate drivers of the economy yields deep perturbations in our planet's life-sustaining capacity.

Ecological Consequences. The political failure to come to grips with the sundry ecological crises spreading across the earth due to uncontrolled 'free market' depredations by large-scale corporate interests seems a dangerous trend. The oceans have been stripped of fish, the forests and jungles shorn of their wood, the very life-forms on which we rely are under threat and duress, while the political process seems so ineffective in protecting the earth's resources, it is hard to deny – although many do – that we are in dire peril. With longer horizons we'd deal with these matters, but egoistic concerns, selfish interests and an overwhelming fear of facing reality yields a rigid denial instead. This is truly a Prisoner's Dilemma in need of cooperation to meet the inherent complementarities of ecological systems. Indeed, the fragmentation due to competition is undermining any organic environment due to its need for full integration: each part interacts with the rest and cannot tolerate disintegration. The parsing of wildlands into island habitats threatens animal life, especially at the top of the food chain: larger predators suffer the most as their ranges shrink away. Yet this sort of fragmentation is the essence of competition; it shows in all of these illustrations. And all human-caused ecological losses are horizonal, almost by definition: the myopic culture reinforced by any competitive frame in its effect on human growth and development threatens all we hold dear.

VI. Conclusion

The elementary economic realms of atoms, bits and wits show why increasing returns and complementarity are a general and not a special characteristic of social relations. Substitution only applies to short-run production of physical goods; for all long-run output of atoms and all bits and wits, substitution does not apply and, therefore, neither does competition as a means to social improvement. Indeed, the general point was made that competition is spawning a myopic culture as well as stifling output, if the most basic characteristic of economic interdependence is complementarity, not substitution. The scarcity models standing on substitution need to be augmented or replaced by analyses of abundance in network contexts. Systems showing complexity and dynamic (chaotic) causality ought to become more relevant to an economics of complementarity and cumulative variation. No equilibrium models survive this shift to an ecological view of evolving complexity. Instead the economics of atoms, bits and wits show why a horizonal view will lead to a case for cooperative values as a way to address or resolve various social ills, such as seen in our media, education, politics and ecology. A proper understanding of complementarity and horizon effects shall lead to a new economics of cooperation and organizational learning as a means to reform.

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