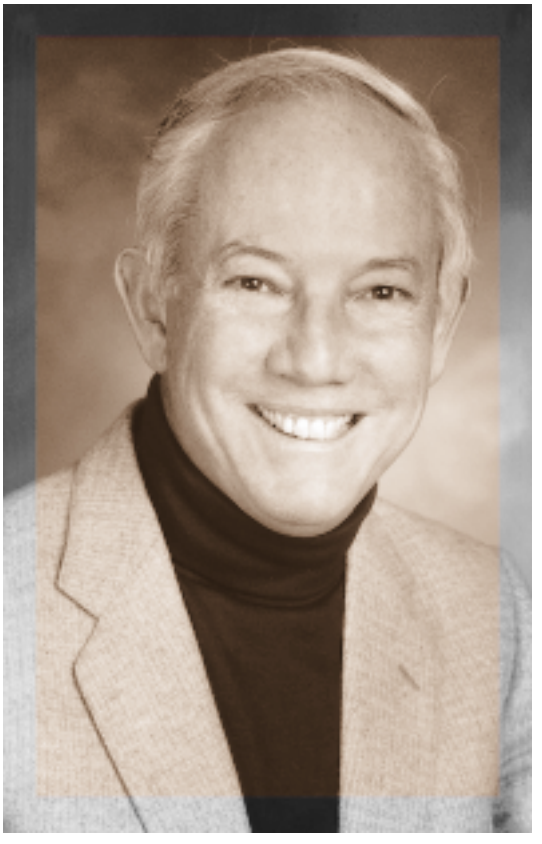
AN INTERVIEW WITH W. BRIAN ARTHUR



BY JOEL KURTZMAN

W. BRIAN ARTHUR, Citibank Professor at the Santa Fe Institute, a private think tank in New Mexico where he also serves as a board member, calls himself an "applied mathematician." He does so because he believes the tools of classical economics are no longer adequate to describe the world in which we find ourselves, where the main engine of value creation is not the production of goods, but the manipulation, transmittal and application of knowledge.

Among other things, economics in the age of knowledge, Professor Arthur asserts, is characterized by increasing returns, rather than diminishing returns, and by what he calls "network effects." He arrived at these conclusions after studying the rise of Silicon Valley, when he was the Morrison Professor of Economics and Population Studies at Stanford University, and by researching the history of technology. In addition, he has been a pioneer in applying insights from complexity theory to the world of economics. Professor Arthur's work not only explains a great deal about high technology, but it also sheds new light on strategy.

In the old world of diminishing returns, a mining company, for example, would find that each new ton of ore extracted from the ground cost slightly more than the previous ton. The reason that returns diminish lies in the fact that physical resources are finite. Remove a ton of ore and one less ton remains to be discovered. Early abundance leads to later scarcities. Prices rise as it becomes more difficult to find each remaining ton.

Information is different. It might cost Sun Microsystems $200 million to $300 million to develop Java, Professor Arthur argues, but once that software has been created, it costs next to nothing to reproduce it. In fact, it can be downloaded from the Internet, which means there are no distribution or production costs at all. As a consequence, once the initial invest-

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ment has been made, returns increase, rather than diminish, as each copy is sold.

But there is more to his argument. If, for example, Java, Unix, Windows 95 or some other software is early into the market and becomes widely adopted, then network effects come into play. This means that as more people use the software, the likelihood of others also using it increases. Individuals writing programs want to do so in a language that others can use.

Network effects govern other aspects of our lives as well. For example, since it is hard to learn a second language, people choose to learn the language that is the most widely spoken. This creates a bandwagon effect. The more people learning English, the greater the incentive for others to do the same.

Taken together, increasing returns and network effects mean that companies and technologies that gain a dominant position early on tend to increase their domination of the market. Over time, as their share grows, it becomes more and more difficult for others to dislodge them. These forces govern the markets for computer operating systems and Internet browsers.

Professor Arthur has been at the forefront of the debate about technology and markets. He has written and edited a number of books, most recently "Increasing Returns and Path Dependence in the Economy" (University of Michigan Press, 1994) and "The Economy as an Evolving Complex System II" (Addison-Wesley, 1997), as well as numerous articles about economics, technology and business.

What follows are excerpts from a recent conversation with Professor Arthur that took place at the Santa Fe Institute.

S&B: *Brian, I'm very interested in your perspective regarding the confluence of economics and business. Business is usually out of the equation when people talk about economics — you've said that economists generally don't think about business. On the flip side, you don't think that the economy itself is taken seriously — or at least the view of it that we get from economists. That's a very provocative perspective, so I would like to begin there. Why isn't the economy taken seriously and how should we take it seriously?*

W. BRIAN ARTHUR: Dr. Jacob Bronowski, the scientist-philosopher, remarked two or three decades ago in one of his books that economics has never recovered from the fatal rationality that was imposed upon it in the 18th century.

Economics, which is really about 200 years old as a subject, developed a very persuasive logical framework. Earlier in this century, in the 30's, 40's and 50's, that framework was very heavily mathematized. It was such a success, it came to be called the neoclassical framework.

In fact, it was so well regarded that economists began to look only to the framework for answers. If the economy didn't quite comply, it was thought there was something slightly wrong with the economy, not with the framework. This overreliance on formalism happens in many disciplines. It happens in physics from time to time and it happens in linguistics. It is the logic that says if the world refuses to be shoehorned into some particular box, there's something wrong with the world, rather than the box.

Another way to put this is that economics became so sure of itself with its very logical neoclassical framework that economists began to believe they didn't have to look outside, except to verify the framework. So if you're looking at the economic history of slavery, which people did 20 years ago, most of the studies were verifying that slave owners were economically rational.

You could make a counter argument saying, "Well, economists are always looking at the actual economy. The Wall Street Journal's full of quotations from economists." But I'm talking about academic economists, not the chief economist for Morgan Stanley. I'm talking about economics as an academic discipline.

Secondly, economists would say, "Well, we have all of econometrics, we collect huge amounts of data," and so on. But actually that's kind of like collecting enormous amounts of data on I.Q. or school achievements and then saying you understand education and children's minds. Yes, you are measuring something and you are looking at something and economists do a great deal of work on poverty and issues of national policy that is quantitative.

But for my money, economists got away from really questioning at a deep level how the world works, how decisions actually got made. If something doesn't conform to neoclassical models, it is deemed to be "behavioral," meaning that it is ad hoc, that people are not somehow behaving themselves properly. It's like seeing real economic behavior as impurities in a physical system or chemical system that are messing things up.

S&B: *Are you saying that economics has been self-referential rather than examining the world that it's supposed to describe?*

W. BRIAN ARTHUR: Yes, in that economists are spending a great deal of time looking at what economists are spending time looking at. It goes around in a circle. The logical framework became very persuasive — by the 1970's and 80's, it became completely mathematized. Economists — the top layer, the theoreticians — tend to look very much at the framework. So it's becoming, in a sense, Talmudic and self-referential. This happens from time to time. In a couple of decades, we'll get away from it.

To be sure, there are some really excellent theorists who spend a great deal of time looking out into the world. Some economists are very aware of what's going on.

But there is another issue — a great deal of economics is done the way it is done for analytical convenience. It is not just that the framework has become, as I said, so persuasive that economists don't feel that they need to look outside anywhere near as much. It is also that the framework itself is 50 percent an approximation to reality and 50 percent analytical self-convenience.

Just to be very clear on my position, I'm not objecting to mathematics. I published several papers on mathematics. My objection is that I would like to see economics become more of a science, and more of a science means that it concerns itself more with reality. Economics is wonderfully deductive. The ability of economists to deduce — that is, to go through long logical deductive arguments in mathematics — is absolutely superb.

But we're facing a danger that economics is rigorous deduction based upon faulty assumptions. Science after science gets that way from time to time. When it does, we're in real trouble.

So if somebody comes along who is absolutely brilliant and mathematizes the field in the 1950's, adopting many assumptions on convenience, that locks in. The next generation isn't aware of the shortcuts that were made and takes these as gospel. I was looking at something this morning that catches the thought and is just delicious. It is from "Nature and the Greeks," by Erwin Schrödinger, the physicist: "The mistakes of the great, promulgated along with the discoveries of their genius, are apt to work havoc."

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That's absolutely true. Somebody comes along and does beautiful work, but the assumptions aren't quite right. Then that beautiful work becomes the gospel. There are arguments over the deduction but few are looking at the assumptions.

What is the problem? It has to do with what the philosopher William Barrett called the illusion of technique. It has to do with a form of modernism called logical positivism that developed early in the century. The idea is that you can take one subject after another — philosophy, logic, linguistics, mathematics, physics, economics — and reduce them to a set of axioms and then deduce the rest of the science. In other words, build up the rest of the structure from a logical foundation.

It's a wonderful idea but William Barrett found that it's totally cockeyed. It never works. It hasn't worked in any field, including physics. Part of the movement in thinking in the 20th century is what I would call a loss of innocence or, if you prefer, a loss of certainty. We have had to understand that the world, no matter how we try to cage it, slips out between the bars. The world is complex and it can't be caged in any set of simple axioms.

S&B: *If economics is self-referential, if it is spending too much time looking at its own framework and too little time looking at the world, where is the place to start to change it? Here is an undercapitalized discipline, from the standpoint of science, that has profound implications across all of society, from the way we regulate to the way we compete. What do we do now?*

W. BRIAN ARTHUR: I think that the economy is changing, and in ways that call for a different approach in economics. We're going from a mass pro-

duction, commodity manufacturing, bulk manufacturing economy to something that is information based, digital, high tech. Let's call it a technically based economy.

Every 50 or 100 years, the economy goes through a shift like this, involving deep structural changes. What is salient in the economy, what really matters, changes. So you go from cottage industries to simple manufacturing in the late 1700's, the Industrial Revolution, steam-powered manufacturing. Then international trade becomes important around the 1820's, and in the mid-1800's the economy splits into those who have capital and those who are supplying the labor. At the turn of the century, mass production comes to the fore.

As each of these means of production changes, the economy changes its character and the basic rules of operation appear to change as well. Of course, nothing changes about human nature, nothing really changes about some of the real basics of the economy. People still choose, more or less, what is the best course of action for themselves. If this were a physical system, you might say there's been a phase change — a regime change.

For example, aerodynamics below the sound barrier calls for different wing designs and different assumptions than beyond the sound barrier. No rules of physics are violated, but if you apply the below-the-sound-barrier rules to the beyond-the-sound-barrier regime, then you're going to get yourself in trouble.

So the basic assumptions we need to work with change. Let me describe them briefly, and with them some of the deep changes going on in the economy.

As we're shifting more and more into high technology — into I.T., into almost-costless communications, into close-to-costless computation — we're shifting into an economy based more and more on that technology. What's interesting about that shift is that for two or three different reasons, high-tech markets operate under increasing, rather than diminishing, returns. That's something I've been arguing since the early 80's. At the time, it was considered very odd and weird. It's like saying that there could be reverse gravity. Now, that's totally accepted in academia.

Let me give you some definitions. In the market of diminishing returns, the more you get ahead, by increasing your market share or your market, the sooner you run into difficulties, with increased costs or lower profits. Let's say I am shipping plywood out of Canada, and I get bigger and bigger and my market increases. Sooner or later, if I've started to ship to California, my transportation costs are sky high. So you get many small lumber companies shipping locally.

The hallmark of diminishing returns is that there are many firms and they tend to share markets. As one company gets very large, it runs into more and more difficulties. So you get bound to an equilibrium and a high degree of stability in markets and nothing much happens. In these markets, you don't hear that Bill Gates has just bought a steel company and that company is about to take over all of the steel in the United States. You simply don't hear that. Or that somebody's started a small lumber company and in five years there is an I.P.O. and that person is now worth half a billion dollars. This is not like Netscape.

In high tech, though, there are two or three characteristics that overturn diminishing returns and give you increasing returns, meaning the more you get ahead, the more advantage you have toward getting further ahead. You can call it positive feedback. No one uses the phrase nowadays of increasing returns to scale — this is not a scale phenomenon. Increasing returns simply means that whoever gets advantage, gets further advantage. Whoever loses advantage — think of Apple Computer — will lose further advantage. Encyclopedia Britannica, T.W.A. 10 years ago, I.B.M. You start to lose advantage, you get in a worse position. You gain advantage, you get in a better position.

Why? For three reasons. The first is cost advantage. High-tech products — things like Microsoft Windows 95 — are complicated to design and require huge amounts in upfront R&D costs. With Windows 95, that came to $250 million for the first disk. But the second disk costs just a few cents. So does the third. The more you produce in the lifetime of that product, the lower your per unit cost. In other words, the more cost advantage you have, the larger your market gets.

Secondly, there are what economists call network effects. That means the bigger a network gets, the more I'm likely to need to join that network. For example, as more people use Java, the downloading language for the Internet, the more likely it is I would have to have

Java in my computer to download off the Net. As fewer people use its competitor, ActiveX, it is less and less likely that I would have to have ActiveX.

Thirdly, there are what I call groove-in effects tied to customers and consumers. Basically, this means that the more I use a product, the more I'm familiar with that product, the more convenient it gets for me. I use Microsoft Word. There might be a better program out there, but I know all the tricks with Word that I mastered over several years and I am very reluctant to give that up to start over with another product.

So these characteristics produce increasing returns. The more Java is out in the market, the more prevalent Java gets in the market, the more advantage it gets.

But these characteristics also make markets very unstable. If two or more products or companies are competing, if one gets sufficiently ahead, it gets more and more advantage. Under certain circumstances, that can often be enough to sort of tilt the market and lock it in. So it locks into whatever gets ahead. Whatever gets ahead may have got ahead by good fortune, by clever strategizing, by small events, by sudden changes in government regulations, by who got sick one day and didn't show up at the office.

You know, there are legends about this in high tech. Consider Gary Kildall. He ran a company writing operating systems in Albuquerque in 1980. I.B.M. came to see him — it was looking for an operating system for its new PC. The legend is that Kildall went flying that morning and missed the meeting. That's not true. What's correct is that he was a few minutes late and I.B.M. didn't like the terms of the contract.

Meanwhile, Bill Gates's mom was serving on the Red Cross board with some people from I.B.M., and she says, "My son Bill could help you there." So three weeks later, they put the same tender out to Gates, who was a small-businessman at the time. Gates said, "I can do that." Thus was born DOS, instead of Kildall's system, CP/M.

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Those are a series of small events. With different small events, we would be oohing and aahing over Kildall. Gates wound up with $40 billion, Kildall wound up with nothing and he was embittered. He died in a brawl in a bikers' bar in Monterey in 1994.

S&B: *So serendipity plays a role. It's not a strictly rational world in which people are making decisions based on what's best. Rather, the dynamics of the environment are key, which means that for a certain product at the right time, and with enough good breaks, advantages accrue.*

W. BRIAN ARTHUR: Absolutely. It's like presidential primaries. If someone starts to get ahead in New Hampshire or Iowa and gets a bandwagon rolling, then that candidate attracts further support that produces more television time and more money and starts to shut out the others. There are increasing returns in politics. You have to ask yourself, does that mean the best person normally wins? Well, look at Washington.

S&B: *You can say the best person didn't necessarily win. I have read what you've written about Beta versus VHS, and how the better product did not win in that contest for the video market. But while the winner may not have been the best, at least it was a good alternative, wasn't it? Or are you saying that the markets are now skewed to make the wrong choices?*

W. BRIAN ARTHUR: I want to be clear about this because I have been accused lately, by the Libertarian right, of saying that markets don't work. I have never said that — I am a great admirer of markets.

What I am saying is that under increasing returns, and under very specific mathematical conditions, markets become unstable. One product, one company, can take a great deal of the market, 70, 80, 90 percent. Think of America Online, think of Microsoft's dominance in computer operating systems, think of Intuit's Quicken, think of Java. And think of Boeing — it doesn't

necessarily have to be in the computer industry.

You get these dominances. In high tech, you see companies getting very wealthy, cash rich, buying other companies, merging, and so on. You don't see this in steel and lumber and cement and dog chow and corn flakes. There may be large branded companies, but you don't see anything quite like high tech.

So what am I saying here? I am saying that small events early on can get magnified by the force of increasing returns, as they might in presidential primaries. Under certain conditions, that can lock in the market to dominance of one product.

Am I saying it's never the best product? No. I'm saying sometimes things go wrong and we lock into a clunker, like DOS, which computer people tell me was unimpressive. It locked in for 10 years even though there was a superior alternative on the market, the Macintosh operating system. It locked in because if everybody down the hall had DOS, I had to have DOS. It was safe to buy I.B.M. because everybody was buying I.B.M.

S&B: *How does instability relate to lock-ins? How does a lock-in get unlocked and removed?*

W. BRIAN ARTHUR: There tends to be an instability when a market is just starting out, say Java versus ActiveX. It's often difficult to say how things are going to go. But as one side gets farther ahead, gets more advantage and locks in the market, there is a period of stability. Then nothing much happens until the next wave of technology rolls over into something different. So these lock-ins are not forever. Lotus 1-2-3 locks in spreadsheets for a while. Digital locks in mini-computers for 10 years. But then Digital is bypassed with workstations and PC's. That's certainly one reason I'm not too concerned about lock-ins.

You can also always give a story about why a lock-in was inevitable, whether it was VHS, the Qwerty typewriter keyboard or DOS. You can do a story that Kildall would never have gotten that contract because his personality was wrong, and that Bill Gates had to get the contract because he was a nice guy and very techy. You can always shine some light on any product and show that under certain criteria it was best and hard not to lock in. But this is not reality.

S&B: *So where do you and the Libertarians part company?*

W. BRIAN ARTHUR: The Libertarians are upset because I'm saying that the invisible hand is not perfect. Indeed, the invisible hand is a little bit arthritic. It's pretty good, but it's slightly less than perfect. I think we need to grow up and recognize this.

Markets work pretty well. Would I want government intervention? That's a complicated story. The answer is that I'm a believer in free markets, but I think we need to be less naïve. We need to accept that markets give us pretty good solutions, but occasionally they will lock in something inferior.

You can always argue that under certain circumstances, the Qwerty typewriter keyboard is better than any alternative suggestion. For me this not important. For me the big story is not whether something is slightly superior or inferior. The big story is that these markets are unstable and tend to temporarily get dominated.

S&B: *How should companies respond?*

W. BRIAN ARTHUR: If you are in a technically based industry, then it's not sufficient to think in terms of lowering your cost, improving your quality, keeping products moving out the door. That's the traditional challenge for what I call the bulk manufacturing economy. But in high tech, that's no longer sufficient. If these markets are unstable, they can lock in to something and become dominated.

In that case, business strategy has to go far beyond the usual adages about costs down, quality up, core competency. High tech adds a new layer of complication. You have to allow that you are playing games where the winner can walk off with a great deal of the market and the losers are left with practically nothing, even if their products are technically brilliant, and the cost is right. So basically the strategies are very much the strategies you would apply in presidential primaries. You want to build up market share, you want to build up user base. If you do, you can lock in that market.

To market Java, Sun Microsystems essentially gave it away for free. That built up a huge amount of user base. Sun also formed a consortium to put up $100 million for software developed to write applications in Java. So this creates an unstoppable bandwagon.

But if you go into the market and think that you have a wonderful prod-

uct and it's sufficient just to make sure it's technically brilliant and priced right, you're going to get blindsided or creamed by somebody else's bandwagon. In high tech, you have to realize that you must build up a user base and go from there.

Consider America Online, which was up against Prodigy and Compuserve. Prodigy was the first to mass market, I believe. America Online, however, just gave the browser away. After that, it was unstoppable. Was it the best on-line service? I don't know. But I will say this — AOL just bought Compuserve, it is the dominant player now. It doesn't have all the market, but it may have 80 percent. That's sufficient to get monopoly profits.

S&B: *We started off talking about getting a more realistic picture of what is going on in the economy. So where are we?*

W. BRIAN ARTHUR: The answer is that to be realistic, we could start by recognizing that we're moving more and more into a technically based economy. If we are looking at technology, then we have to realize that increasing returns are legion in these markets, and not just an exception. That leads to a very different way of thinking, about instability, timing, bandwagons.

Let me put in an addendum. I am in favor of largely free markets here. If somebody gets a monopoly on silver or pork bellies or God knows what, that's a definite threat to the consumer. If somebody monopolized the railroad 100 years ago, that needed to be dealt with.

However, if someone monopolizes the market for personal finance software, are you going to go after that company and dismantle it? I would contend no. Because these temporary monopolies are a prize for innovation. They're the incentive for innovation. If you took that incentive away — by requiring, say, that for every lock-in you have in high tech, somebody else has to be cut in on the deal for 50 percent or there have to be at least three players — then you will see less innovation.

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People innovate and innovate and innovate in high tech. They are readying these products, they're getting them going, with the knowledge that if they lock in the market, they're going to get very rich and if they don't, they're going to lose everything. So they are making large bets.

That makes high tech a very different culture. It becomes mission-oriented. It's always looking for the next big thing. It makes it more like a casino.

Another metaphor I use is that it is like a land rush of the 1880's. Companies are all behind a starting line and whoever takes that market first, gets it. I don't think we should worry about that, because that's the prize. It's not so much for risk taking as for innovation.

But there's a big however. If you have won six land rushes in a row, that shouldn't mean that you can parlay your winnings into a four-wheel-drive instead of a horse. It also shouldn't mean that you're allowed to hobble the other horses in the dark.

So I'm in favor of free markets, but I'm in favor of fairness, too.

S&B: *Does this mean that high tech should be regulated more? Or that it should be treated differently?*

W. BRIAN ARTHUR: To the degree that markets are winner takes most, and very many of them are, then the concern in high tech is not so much prices as it is innovation. Prices keep falling in this area. The main concern is to make sure that innovation stays alive. Does innovation ever die? You bet it does. We're still using fax machines that were wonders in the 60's but with quality still from the 60's.

So the big thing is to keep innovation going. But you can stifle innovation if you start to worry that someone locks in workstations for five years. Let them lock it in. Why not? They deserve it.

So how does all this relate to the conversation at the start? One of the realities is that as we're moving into a more high-tech economy, the economy works under increasing rather than diminishing returns a significant proportion of the time. If you start to

deny that, you're going to blow it in terms of government regulation or in terms of management strategy.

But there are two other things to note. The first is that when you start to think about these unstable markets, what you're actually dealing with is process. That is, you're not dealing with equilibrium. Your main concern is what happens. Again, think of presidential primaries. The interesting thing is not who wins; the interesting thing is watching these teeter-tottering dynamics at the very start produce a bandwagon. Once there is a bandwagon, it becomes uninteresting, at least from an analytical point of view.

So this shift to a high-tech economy throws a lot of the spotlight onto dynamics. In that case, economics has to start worrying about how markets form, how instability works and so on. These are certainly new concerns. Now, you could say that economics has always dealt with dynamics. To some degree it has, but not in any essential way. So high tech forces you into positive feedbacks. Positive feedbacks force you into looking at dynamics.

The second thing I want to draw attention to is what I call the cognitive side of the economy. Meaning that in standard economics, we assume that every agent in the economy faces "Problems" to which there are "Solutions." These problems are conveniently formulated mathematically and the solutions are "rational" — if you have a problem, you logically solve it.

That fits quite well in the bulk commodity manufacturing economy. You can assume that there are big "Problems" scheduling your fleet of oil tankers or balancing your production line. Over many years, by dint of much thinking or operations research or just experience, managers get it right. Or reasonably right. And that's fine.

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But, again, in this technically based part of the economy, that's no longer the case. Let me go back to the casino metaphor. The problem is that if you sit down at a table and there's a new game opening up, let's say digital banking, and you want to play, you might have to ante up $2 billion just to get your company in position before the game starts. You don't know who the players are, you don't know what the rules are going to be, because they will be settled as the game starts. It's not that you're sitting down to play poker and everybody understands the rules.

Instead, you're sitting down to play a game and the rules are going to be dictated in part by the technology, by the relevant government regulations and by how people proceed as they go. You don't know what technologies are going to be developed. You don't know what the government regulations are going to be. You don't know who's going to ante up what. Still, you have to decide whether to play or not to play. So this is not amenable to game theory or to any logical analysis. In fact, these issues are ill defined.

Let me switch to another metaphor. You are in the prow of a ship with Bill Gates, Scott McNealy and others. The ship is moving through a fog, the fog of technology. You can see outlines of a city not far away. That's how this game is shaping up. The outline is not very good through the fog. But it's not just trying to make sense of what you see. What you see keeps changing, with the sense that other people are making of it.

That means that formally all of this is ill defined. You're trying to give sense to a Rorschach ink blot that keeps changing with the sense that other people are giving to it.

S&B: *What is driving these new markets? In the past, in the commodity era, it was shelter, food and other basic human needs. Has that changed?*

W. BRIAN ARTHUR: No. The driver of the markets is the possibility of getting banking from my desk, the possibility of downloading movies at night into my television, the possibility of being in a chat room on the Net. These are still basic human needs that are intermediated by technology. It's still the same old story, a fight for love and glory. It's just that now technology provides for some of these human needs. I can talk with my kids by

cellular phone if I leave the house. So the drivers of the new economy are the same human needs as before.

S&B: *Yet management strategy must change?*

W. BRIAN ARTHUR: Yes. Because it's not just that things are uncertain in this game, but that there is simply no correct answer. So the challenge to management in this game is not so much to optimize or get things right or to lay their bets just right. Instead, the challenge is to make better sense out of the situation than the next guy.

You and I schedule rival fleets of oil tankers. You can get it right, I can get it right. If I can get it more right than you, I can make more profit than you. No problem. That's old standards.

But suppose you and I are rival factions and we're going into Bosnia. Who's going to do well there? The people who do well are the ones who go in with a deeper sense of understanding. There's no getting it right. The challenge is a cognitive one.

It is the same challenge when it comes to strategy in high tech. We're all staring at the same game, trying to figure it out. But it's not like poker or roulette, where there's an official correct strategy. The game's ill defined. The people who do well, and here I would mention Bill Gates, are the people with better vision and cognition, who can sort of understand how things will shape up. But again, there's no correct answer.

It won't serve you well, when markets shift, to confront problems with a simple cognition and say, "Oh, yeah, this is just like when I had to optimize production," and start speeding up the assembly line, laying off workers and getting costs down. That does not help. You might have to do that, but what helps is seeing how these markets are shaping up. So the real players in these markets, the people who are very good, are those who come in and can see that suddenly the game has changed.

To repeat, then, the strategic challenge here is a cognitive one. This in turn means that if economics wants to understand the new economy, it not only has to understand increasing returns and the dynamics of instability. It also has to look at cognition itself, something we have never done before in economics.

S&B: *Look at cognition from what perspective?*

W. BRIAN ARTHUR: Every perspective. Economics has always taken a shortcut and said, assume there is a problem and assume that we can arrive at a solution. Now I would say, assume there's a situation, how do players cognitively deal with it? In other words, what frameworks do they wheel up to understand the situation, like a Bosnia? Do they wheel up an inferior framework and say this is just like Palestine in the 1940's, this is just like whatever? We tend to shoehorn situations into a previous cognitive framework and we do that prematurely, and when we do we nearly always lose.

There's a saying in Northern Ireland, where I'm from, that if you're not confused, you don't know anything. This is true. Confusion means having no cognitive framework, and that is better than having a wrong cognitive framework, which is what happens if you prematurely close in on an understanding. There's no correct understanding, but there are very bad ones.

So the challenge in Bosnia is making sense. It's spending a lot of time figuring out what on earth is going on. The challenge is not optimizing U.N. troop placements. That has to come after you make sense.

The challenge is similar when it comes to strategy and management in technology. My friend John Seely Brown at Xerox PARC put it this way: "In the old economy, the challenge for management is to make product. Now the challenge for management is to make sense."

To take the challenge back to economics, we're being forced into a different world. There will be plenty of commodity production that works the same as it has always worked. But as high tech takes over — through the Net, cheap computing, low-cost telecommunications and highly complicated products like missiles, biotech and custom-made pharmaceuticals — the economy will be driven more and more by increasing rather than diminishing returns. It has become a place where we have to look more to the dynamics than the statics, at how things teeter and shift. We also have to look at games that are not well defined and how human beings make sense of them.

If you keep looking through the prism of diminishing returns, equilibrium markets and rational problem-solution economics, you won't be able to understand this new economy at all. SB

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