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## Pedagogical Exercise

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# Keplerian Economics: Wealth as Curvature

Part 2, by Jonathan Tennenbaum

*In Part I, “A ‘Keplerian’ Dialogue: What Do You Know About Economics?” (March 8, 2002 issue), Nerd brought with him three acquaintances to talk to Johannes about economics: Turbo, a stockbroker whom Nerd used to help with computer systems; Heavy Gripp, a former mining engineer, now unemployed, whom Nerd also used to do programming for; and Betty Gripp, Heavy’s wife, who, unknown to Heavy, had invested the family savings with Turbo, into “high-tech” stocks, and lost everything.*

**Heavy:** Johannes, I must say that argument with you the other day really got me thinking. At first it just seemed *crazy*, what you were claiming, that real productivity in the U.S. economy has fallen and the U.S. economy has been shrinking over the last 30 years! All the statistics say exactly the opposite! I always thought modern production technologies had become so incredibly efficient, that we really don’t need many people any more, to provide the goods we consume. So after we were finished, I went over to ask an old friend of mine, Mr. Widget, who used to work in manufacturing. Widget couldn’t believe your statements about a “precipitous collapse of U.S. productivity,” either. I tried to bring in the points you had made about geometry and technology, but I couldn’t quite get your argument together. Maybe you can explain it to Mr. Widget yourself.

**Widget:** Sir, my friend Heavy spoke very highly of your expertise in economics.

**Johannes:** What do they say? A one-eyed man is King, in the land of the blind.

### Cutting Production Costs Does Not Necessarily Generate ‘Profit’

**Widget:** I have quite a lot of experience in American industry, and I want to tell you that we have made enormous strides in cutting production costs, using state-of-the-art technology and modern organizational methods. That’s how we’ve been able to remain competitive on the world market. I suppose you have heard of “lean production”?

**Johannes:** Yes, indeed. It has been one of the main instruments for destroying what remained of U.S. industrial productivity during the 1990s.

**Widget:** You can’t be serious, sir!

**Johannes:** I am.

**Widget:** How can you say, that reducing production costs destroys productivity? Isn’t it exactly the other way around?

**Johannes:** Not necessarily.

**Widget:** Isn’t productivity the ratio of output to production costs? Either in terms of labor costs, in man-hours or wages, or taking into account other inputs to production—what they call “multifactor productivity”?

**Johannes:** No.

**Widget:** What do you mean, “No”? I got my definition from the textbooks!

**Johannes:** Think about it, Mr. Widget. If I take a skilled worker, and cut his salary by 30%, have I made that person more productive? Is he able to accomplish more? Does he have more skills, more knowledge, more experience and insight, by virtue of the fact that his labor has become cheaper?

**Widget:** Well, no.

**Johannes:** Then you better throw away those textbooks!

**Heavy:** You see, Widget, this guy’s on the ball.

**Widget:** However you want to qualify it or quantify it, our American industries and farms have done a fantastic job, during the 1980s and particularly the 1990s, in improving their performance in the face of stiff international competition. I am proud to say, that just before getting laid off, I was awarded a special citation for my contribution to “shareholder value.”

**Johannes:** Oh, my goodness!

**Widget:** Our management was far-sighted. They warned us in advance, that with globalization coming along, there were a lot of workers out there, in Asia and South America, who would be happy to do our jobs for 20¢ an hour or less. So if we wanted to keep our plant in operation, we were going to have to reduce our costs one hell of a lot.

**Johannes:** What did you do?

**Widget:** I got together with the other production managers and foremen, and we went over the whole production process. Streamline, streamline! No more fluff! We cut out all departments, all personnel, and all activities not immediately involved in getting out competitive products in the most cost-effective way. We slashed labor time, machining time, off time, and cut energy and materials consumption to an absolute minimum at each point, using computerized process control and total supply-chain management. The savings were enormous.

**Johannes:** Evidently. You ended up being eliminated, yourself!

**Widget:** I can’t bear any grudge. Our computer did it.

**Heavy:** Don’t believe that. There is a nerd behind every computer.

**Nerd:** I beg your pardon! Mr. Widget gave me the specifications for the program. Thanks to that, we’re all out on the street.

## Nonlinear Curvature

**Johannes:** Gentlemen, don't waste time blaming each other. The problem lies in the idiocy of the whole way of thinking that has been running our economy in recent decades. After all, wouldn't you say, that the approach of "cost-effectiveness" and "lean production," is rather like choosing a straight-line pathway as the shortest distance between two points?

**Widget:** A pretty fair comparison.

**Johannes:** And this is the most effective?

**Widget:** Why not?

**Johannes:** But what if such a "straight-line" approach to optimizing production, in the way you have described, automatically eliminates exactly that feature of economic activity, from which productivity, growth, and even the survival of society depend? If so, then you shouldn't be surprised to find, as Heavy here has, that the profits of major industrial corporations suddenly evaporate, one after the other. Because there was no real net growth in the U.S. economy, from which profits might be derived.

**Widget:** How could that be?

**Johannes:** Because actual productivity—in the sense of a net creation of wealth in an economy—lies in the nonlinear *curvature* of the economic process. Following a linear optimum "cost-effective" pathway means reducing productivity to zero, and actually below zero!

**Widget:** Wait a minute! You are talking completely over my head. Take it again, step by step. First, what do you mean by the *curvature* of the economic process?

**Johannes:** It's nothing very exotic. Let me give you an example. You may have heard about a curve, called a brachistochrone, which was investigated by Johannes Bernoulli and other physicists 300 years ago.

**Widget:** Never heard of it.

**Johannes:** Among all possible curves joining any two given points lying in a vertical plane, there is unique one, for which a small ball, rolling down along that pathway from the higher to the lower of the two points, arrives at the lower one in the *least time*. That pathway Bernoulli called the brachistochrone. It's a kind of inversion of the catenary. See, I have a demonstration model right here.

**Widget:** Uh huh . . .

**Johannes:** You notice the curvature of the brachistochrone, don't you? It is not a straight line, nor does it contain any straight-line segments.

**Widget:** Obviously not.

**Johannes:** Now observe, how a second ball, made to roll on the straight-line path connected to the same two points, arrives *later*, than the ball following the curved, brachistochrone pathway. See?

**Widget:** Amazing! I wouldn't have expected the first one to arrive first, because the curved path is considerably longer.

**Johannes:** Exactly. And you note, if you follow the brachistochrone path, that its direction and curvature are con-



stantly *changing*, as you go along. It must, in fact, if the ball is to arrive at the bottom in the least time.

**Widget:** Obviously has to do with the force of gravity.

**Johannes:** But rather than talking about gravity, why not say this: The existence of the brachistochrone reflects a universal character of action or change in the universe, which violates what most of us would call "common sense." Namely, that the apparently simplest, most elementary, most self-evident pathway—the straight line—turns out *not* to be the quickest and most efficient one. All processes in nature follow pathways of everywhere-changing curvature. This had already been explored by Fermat, in his work on the refraction of light, and before him by Kepler and Nicolaus of Cusa.

**Widget:** But what does that have to do with industrial productivity?

**Johannes:** The essential notions of economy, such as "wealth," "growth," "productivity," and so forth, are all *non-linear magnitudes*. They are not susceptible to linear sorts of measure and cannot be expressed by simple arithmetic numbers. They are all associated with the *curvature* of the Riemannian-Keplerian trajectory or "orbit" defined by a society's cultural-economic development.

**Widget:** Why do you make it so complicated? Don't tell me you have to know Kepler and Riemann to understand what "wealth" means.

**Johannes:** Oh yes you do! If the disaster all around us is not enough to convince you, then I'll prove it to you another way, by showing you the kinds of *monstrous* paradoxes that are created, by any attempt to avoid the issue I just raised. But be prepared for an extended discussion.

**Widget:** The more the better. Heavy and Nerd here will help me, if I get into trouble.

## The Source of Wealth

**Johannes:** All right. Mr. Widget, I suppose you believe industry actually does *produce wealth*, don't you?

**Widget:** Naturally.

**Johannes:** And you mean by that *net wealth*, over and above the wealth consumed in the production itself? In other words, if you take the gross output of your factory or plant, and subtract off the wealth that had to be *input* into the production process, in the form of labor, energy, materials, machinery, and so forth, then you would get a positive result, right?

**Widget:** Of course. Otherwise I would be operating at a loss.

**Johannes:** And if you left any of those costs out, when accounting for the net wealth-creation of your enterprise, then someone might rightly say you were *stealing*, in effect, the margin of wealth represented by those omitted costs?

**Widget:** Of course. But why are you asking this?

**Johannes:** You know, perhaps, that there are people who claim that man actually produces nothing, but only steals or expropriates wealth from nature, in the form of natural resources and the like. And they have a "proof." Would you like to hear it?

**Widget:** If we must. As a former mining engineer, Heavy knows a lot about natural resources.

**Johannes:** Here's the argument. First those people point out, that without the food growth from Mother Earth, and without the coal, iron ore, and so forth, which we procure from her bosom, we would have no economy and no economic wealth. Right?

**Heavy:** Yeah, but we add *value* to the raw materials and so forth, by our labor, don't we? I mean, the coal would be useless, unless we dug it up out of the ground.

**Johannes:** They would answer: A *thief* must work, too, to get hold of what he steals. Sometimes very hard.

**Widget:** A preposterous comparison!

**Johannes:** But I am not finished with their argument. For us to mine the coal, and other mineral resources, those materials had already to exist in the Earth, right? Just as the soil and water man uses in agriculture, and so forth?

**Heavy:** Yes.

**Johannes:** The coal mining company did not *create* the coal, but only mined it. Your company did not have to *pay* Mother Nature, or God, for having created the coal, did it? Nor did anyone pay the Earth back for other minerals or for the use of its fertile soils, water, and so forth.

**Heavy:** True.

**Johannes:** So, if we were to make a complete balance-sheet of the creation of wealth in an economy, including *all* inputs to the production process, we would have to include the coal in the ground, that was an input to the coal mining, and the other minerals, the soil that the farmer works on,

the water and so forth, wouldn't we? That's a lot of wealth, isn't it?

**Heavy:** So it would seem.

**Johannes:** But does the mining company include that input of wealth in its books, and in its calculation of costs and profits? Or does it not rather treat the original coal itself as *free of charge*, and count only the expense to extract it?

**Heavy:** Well, usually the mine company had to buy or rent the land, or otherwise pay for the mining rights. And that payment would be on the books.

**Johannes:** But whoever receives that payment, they certainly did not create the coal deposit either?

**Heavy:** No.

**Johannes:** Nor any of the persons and companies, who at various times might have claimed, owned, bought, or sold the land or the mining rights. None of them, down to the first man who set foot on the original site of the mine, had anything to do with the creation of the coal—an accomplishment which, by the way, took nature millions of years.

**Heavy:** Of course.

**Johannes:** So, in our hypothetical balance-sheet for the creation of wealth in the economy, counting everything together, the original coal deposit was never paid for, although it is being used up. Are we not thus justified to say that the entire economy, which consumes the coal, the electricity and steel made from that coal, and consumes oil and gas and other minerals extracted from the Earth, is living off stolen goods? Wealth expropriated from Nature?

**Widget:** I object to the term, "stolen." Nature is not a person. Nature doesn't *own* anything, and God does not demand repayment for having created natural resources! The coal and other minerals are just *there*.

**Johannes:** So it would appear. But we are gradually *using them up*, aren't we? The coal we are presently extracting, the oil and many other minerals, exist only in relatively *finite* quantities, at least in terms of the reserves that can be economically exploited under present conditions.

**Widget:** Admittedly.

**Johannes:** And so, the people I am referring to, compare an economy to an automobile which runs on fuel in a gas tank. In an economy the "fuel" is natural resources.

**Widget:** I suppose one could say that.

**Johannes:** But tell me this. Does an automobile engine *create* energy?

**Widget:** Of course not.

**Johannes:** How do you know?

**Widget:** Everyone knows that: the Law of Conservation of Energy. The automobile motor just transforms the chemical energy, contained in the fuel, into heat, and part of that heat into motion of the car. Actually, today's auto engines convert much less than half the energy of combustion, into mechanical energy. The rest is heat loss.

**Johannes:** I see you can regurgitate your college thermodynamics. But don't you see the terrible implication?

**Widget:** No.

**Johannes:** Couldn't you say, with exactly the same justification, that an economy does not create wealth, but only transforms some of the natural wealth, contained in the raw materials, into some other form, while wasting the rest? But the total wealth remains constant?

**Widget:** That's somehow absurd.

**Johannes:** But the conclusion is exactly as good as the so-called "Law of Conservation of Energy." You wouldn't dare challenge that, would you?

**Widget:** Well . . .

**Johannes:** So maybe the environmentalists are right after all, when they point out, that the so-called "creation of wealth" by society is occurring on the basis of a gradual, irreversible, and uncompensated depletion of the mineral and other wealth of nature. Or have we left something out of account? Speak up, Mr. Widget!

**Widget:** Frankly I don't know what to say. It just seems to me the whole train of argumentation is something wrong . . .

**Heavy:** Me too, but damned if I can find a way out.

**Johannes:** Perhaps it will help if I pose the problem another way. We said the amounts of coal and other resources are essentially finite, right? The coal that we extract and burn up, is irreversibly consumed. That coal is not going to grow back inside the ground; or if it somehow did, then certainly not anywhere fast enough to keep up with our consumption. And the same for many other ores and minerals which our economy consumes on a large scale. Is that so, Heavy?

**Heavy:** Correct.

**Johannes:** So to the extent we use those large quantities of resources today, there will be *less* left over for our children and grandchildren?

**Heavy:** That follows.

**Johannes:** So what should we do? Should we stop using natural resources? In that case our society would collapse, and our grandchildren wouldn't even be born!

**Heavy:** There is a whole lot of coal down there. We are not about to run out. In fact, the more we look, and the deeper we dig, the more we find.

## Improved Technology

**Johannes:** Nevertheless, isn't the physical effort and investment required to extract coal, steadily *growing*, as we gradually deplete the best and most profitable deposits and have to go over to lower-quality ones?

**Heavy:** Of course. That is a well-known "law" of the mining industry.

**Johannes:** So, speaking generally, long before such mineral resources are completely exhausted—which is indeed a very long way off, in most cases, as you say—the world economy faces a constantly growing expenditure, in physical terms, to secure the raw materials it needs?

**Heavy:** Definitely.

**Johannes:** In that sense, instead of asserting that the economy is living "at the expense of nature"—which might rightly seem a bit superstitious, since nature is neither a person nor God—we ought rather to say, that today's economy is living at the expense of tomorrow's. And that our generation is living at the expense of future generations.

**Heavy:** I suppose that's right.

**Johannes:** But is there any way we might *compensate* the coming generations, and even tomorrow's economy, for the margin of added trouble and expenditure, in the procurement of raw materials and other resources, which our present consumption would otherwise cause?

**Widget:** Beg forgiveness? . . . Try to consume as little as possible?

**Heavy:** No, no! I have it! At the same time as we exploit the existing resources, we should develop *improved technologies* for the extraction and processing of those materials.

**Johannes:** Aha!

**Heavy:** That way, we can constantly reduce the relative cost of supplying them to the economy, despite the gradually declining quality of the deposits. In fact, that is the whole history of the mining industry. From ancient Greek times, during the Renaissance, to the time of Leibniz and the Freiberg Academy, and into the 19th and 20th Centuries, mining was always a focal point of technological development. So it happened, despite industrialization and the so-called explosion of the world population, which increased the consumption of energy and most raw materials by orders of magnitude, there is no sign of scarcity in the supply of those resources. In 1972 the Club of Rome published its *Limits to Growth* report, claiming that the supply of 11 vital minerals could be exhausted before the end of the 20th Century, including oil and natural gas, copper, gold, lead, mercury, silver, tin, and zinc. The study was translated into 29 languages and sold 9 million copies. Many fools believed it. But today, after 30 years of intense consumption, the proven reserves of these minerals are *larger* than they were when the Club of Rome made its prediction! That is to a large extent due to the advances in techniques of prospecting, extracting, and processing raw materials. Technological development has expanded the available resource base of the world economy considerably *faster* than resources have been used.

**Johannes:** Excellent!

**Heavy:** If we can *continue* that process of technological development from one generation to the next, always keeping a step ahead of the marginal depletion of resources, then tomorrow's world will not suffer from today's consumption! In fact, using the higher-level technology, they will be even better situated to supply their needs than we are today, even though large amounts of resources might have been consumed in the meantime. So, nobody could claim we were living at their expense. On the contrary, they will live better than we, because we gave them more powerful ways to deal with the universe.

**Johannes:** Heavy, I think you have caught a very, very interesting critter by the tail. Let's not let go of it.

**Heavy:** What critter? Where?

**Johannes:** I mean an idea. Remember, last time I pointed out, that not every sort of *apparent* technological advance—as seen on the level of a particular mine, factory, or even a whole sector of an economy—really represents an increase in the overall ability of a society to sustain itself in the long term. That ability depends not only on mining and processing of raw materials, or any other particular activity, but on the mode of development of the economy as a whole, as the instrument of man's relationship to nature. Don't you agree?

**Heavy:** Yes.

**Johannes:** For example, isn't it true, that as the quality and concentration of mineral deposits decreases, and they become more difficult to mine, the mining process requires the application of more and more *power*?

**Heavy:** Absolutely. For example, coal mining today is already quite energy-intensive, and will become more so in the future.

**Johannes:** So if we continue to produce energy by burning coal, we will eventually come to the point, that the mining of one ton of coal will require more energy, than we get from burning that same ton of coal!

**Heavy:** Come to think of it, you are right.

**Johannes:** And long before that, the economic efficiency of the whole, archaic fossil fuel-centered energy and transport system of the United States—and the pathological land-use structure associated with it—will have dropped far below zero. We are actually at that point already. The attempt to prolong the existence of such a monstrously wasteful system, even on the basis of what appear to be useful technological advances, actually drives the economy deeper and deeper into the mud. What do we do?

## A Nuclear-Based Economy

**Heavy:** Well, first of all, I guess we'll have to go for a nuclear power-based economy, as you said last time. The fission of uranium is more than 50,000 times more energy-dense than chemical combustion of coal and other fossil fuels. That means, in particular, that the ratio of power produced per ton of uranium fuel, to power consumed in the mining, transport, and processing of that fuel, is orders of magnitude larger than for fossil fuels. With nuclear fusion, which is already within reach, even better. Going to that kind of higher energy-density, would revolutionize the resource base and real efficiency of our economy. This time not simply building some power plants, as we were doing in the 1960s and 1970s, but rebuilding the whole energy system from top to bottom.

**Widget:** I am all for it. I used to work in nuclear industry,



back in the old days.

**Johannes:** But the first realization of nuclear power during the last century, required the mastery of *new physical principles*, beyond those that were known in the period when the large-scale use of coal and other fossil fuels began. Correct?

**Widget:** Quite true.

**Johannes:** And for this reason, even the very first practical applications of nuclear energy, in the military and then the civilian domains, required the education and training of entire armies of scientists, engineers, and skilled technicians; the creation of new branches and capabilities in the metallurgical, chemical, electrical, machining, and other industries; a vast development of radiobiology and medicine, and so forth—all potentials which will have to be revived and rebuilt, because much of that capability no longer exists, on the scale we need, in the United States today. But during the 1940s, 1950s, and 1960s, nuclear energy was one of the spearheads for a rapid process of technological development, whose effects reached into every branch of economic activity—before the whole process was aborted, in the late 1960s and 1970s.

**Widget:** Absolutely. I was part of that.

**Johannes:** Were you? Well then you ought remember what real productivity is, as opposed to the insanity you were advertising to me a little while ago. Just imagine, that the principles of “cost-benefit analysis” and “lean production” had governed economic practice in the United States, at the moment when the principle of nuclear fission was discovered. Who would have made the enormous investments in science and education, that had to be made, long before a cent of profit could be made on nuclear energy? What industry would have maintained the teams of engineers, that prepared, sometimes many years in advance, to retool for the production of new types of equipment, that had never existed before? Nobody, certainly! Everyone would have said, as you did a little while ago: “All this is not immediately involved in getting out competitive products in the most cost-effective way.” There

would have been no nuclear energy, and no residual capabilities to build upon now, when we really need them.

## Nothing But Slavery Comes From The Free Market

**Widget:** I get your point. But nuclear energy came out of a war-time project, not the “free market.”

**Johannes:** Nothing but slavery comes from the “free market”! Quite apart from narrow military considerations, it was still generally understood, into the 1960s, that maintaining high *rates* of technological progress, requires a very special structure of investment, education, and employment of the labor force, completely different from what you would get if you sought to optimize existing modes of production for lowest possible cost. Also, a completely different cultural attitude and quality of emotion. The two are absolutely incompatible species of “orbits” or trajectories of a society’s development.

**Nerd:** Like the difference between least distance and least time, in physics!

**Johannes:** Exactly. And so, to wrap up what we were discussing before, you will agree, that nuclear energy in its presently known forms will also have to be superseded, for similar reasons as we discussed for coal.

**Heavy:** For sure.

**Johannes:** This also means discovering new physical principles, again and again, in the future.

**Heavy:** Certainly.

**Johannes:** And our educational system, our labor force and its mode of employment, our industries, our infrastructure, and so forth, will have to be organized and developed in such a way, that we can rapidly transform such new discoveries into new species of technologies, produce and assimilate those technologies on a large scale, and thereby increase the per-capita power of mankind to sustain its development into the future.

**Heavy:** Just so.

**Johannes:** But that process of technological development would have to keep on going, *without end*, wouldn’t it? If it ever stopped, then the entire accumulated burden of previous consumption of resources, in the form of depleted reserves, would finally fall on the society unable or unwilling to continue developing on the trajectory of technological progress. Besides that, with the cessation of scientific and technological progress, the intellectual powers of the labor force and population would rapidly decay; the society would become more stupid and irrational, and might very well destroy itself, long before a lack of material resources became a visible problem.

**Heavy:** That’s right. But if society maintains at least a certain minimum, “baseline” rate of technological advance, then there will be no penalty connected with the apparent depletion of resources, and no bills to be paid to either God or nature, except the necessity to maintain technological progress itself.

## The ‘Orbit’ of Development

**Johannes:** So, relative to your hypothetical “baseline” pathway of development of an economy, a society having a *lower* rate of technological progress would, in effect, be exhausting its own basis for existence. For such a society we could truly say, that it loots nature and lives at the expense of its future generations. There is no net creation of wealth and no basis of real profit. Sooner or later such a society would surely collapse.

**Heavy:** It clearly would have to.

**Johannes:** Whereas a society realizing a *higher* rate of technological progress, would actually be creating net wealth?

**Heavy:** It would.

**Johannes:** Then, the measure of economic “wealth,” and the answer to the question, whether a given economy is growing or collapsing, lies in the relationship of entire trajectories or “orbits” of development, and not simply in the momentary states of the economy—no matter how much statistical data are supplied.

**Heavy:** Obviously.

**Johannes:** Since real wealth depends on an “endless” perpetuation of scientific and technological progress, and a certain rate of discovery and integration of new physical principles into human practice, it corresponds to a special sort of self-sustaining *change*, does it not?

**Heavy:** Indeed.

**Johannes:** Each such discovery, moreover, is a creative act of a single human mind, that breaks out of the “flat,” linear world of existing formal knowledge, to generate a new principle of human action on the universe. And the transmission of that discovery to successively larger circles of individuals, and its gradual assimilation into the economy, generates dense waves of secondary “breaking-points” or “changes of direction” in the overall geometry of human activity. Do we not require, for this, a generalized notion of *curvature*, of the sort studied by Riemann, and which corresponds to Kepler’s understanding of the way an orbit determines the motion of a planet?

**Heavy:** That makes perfect sense, although I will have to work these ideas through a lot more, before I really master them.

**Johannes:** Do that. It is well worth the effort. But Mr. Widget here seems a bit overwhelmed.

**Widget:** More thinking than I have done in a very long time.

**Johannes:** Exactly. So you see, my friends, why imposing linear concepts of number and measure on economic processes, in the form of “cost-benefit” and similar criteria of management and decision-making, collapses the rate of technological progress, properly defined, and dooms a society to inevitable destruction. Bearing in mind, that exactly this sort of shift occurred in the United States 30 years ago, we had better correct the orbit soon. Elementary, wouldn’t you say?