

The Great Simplification

Nate Hagens (00:00:02):

You are listening to The Great Simplification. I'm Nate Hagens. On this show, we describe how energy, the economy, the environment and human behavior all fit together and what it might mean for our future. By sharing insights from global thinkers, we hope to inform and inspire more humans to play emergent roles in the coming Great Simplification.

(00:00:29):

I'd like to welcome Professor Steve Keen back to the podcast. Steve is author of *Debunking Economics* and *The New Economics: A Manifesto*. Steve is among many other things, a research fellow at the Institute for Strategy, Resilience and Security at University College in London. He is writing a new book, and today we discuss one of the chapters in his book, which is a economic sleuth story on the origins of energy blindness. We go back all the way to Adam Smith and look at a series of wrong turns in the road that classical and then neoclassical economists made on the treatment of land, energy, and things that are not capital and labor.

(00:01:23):

This is a difficult podcast. Steve is an economist, talks in a lot of economist language. I barely understood what he was saying, but I did understand the critical importance of his main message is that our main shaman of our culture today, those that we look to for answers and explanations of what's happening and what will happen in the future, are truly divorced from our biophysical and ecological reality in their formulas. So this ultimately is a really big deal. There's a chapter in Steve's upcoming book on that, but this is a one and a half hour treatment of energy blindness and its origins. Please welcome back to the show, Steve Keen.

(00:02:27):

Steve Keen, good to see you.

Professor Steve Keen (00:02:30):

Welcome. Good to be back again, mate. Good to talk.

Nate Hagens (00:02:32):

This is a monumental podcast for three reasons. One, it's my last podcast of 2023 recording. Two, it's my first podcast on prep for a colonoscopy, so hopefully we won't

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have to interrupt it too many times. And third, I think this is a, you have just finished a detective story about a concept that I often talk about: energy blindness. I know the result of why our culture, why our institutions are energy blind, but you have just written a book and a chapter on the energy production function, and you've gone back to the original papers from the classical/neoclassical economists and figured out why humanity has, over time, completely neglected the role of energy in our descriptions of wealth and productivity. So we could talk about climate change, you know a lot about that, we could talk about money, you know a lot about that, and we probably should. But today I want to just unpack your story of what you've been working on the last couple months with respect to energy blindness.

Professor Steve Keen (00:03:46):

Okay, let's roll. First question, hit me.

Nate Hagens (00:03:49):

All right, so take me to the beginning.

Professor Steve Keen (00:03:52):

Okay.

Nate Hagens (00:03:52):

We had classical economists back in the day, right?

Professor Steve Keen (00:03:56):

Yeah. And virtually every economist, if you ask them who's the father of economics are going to answer Adam Smith. And in a sense, I was inclined that way except that I've read previous economists to Smith as well, including the Physiocrats. And my attitude was that the Physiocrats were more advanced on important issues, both macroeconomics and the role of energy in production, than Smith was.

Nate Hagens (00:04:23):

Who were the Physiocrats?

Professor Steve Keen (00:04:25):

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They were a bunch of 17th, 18th Century French, mainly French, but also some Irish economists who worked in France, and this is before we actually had the term of economists in many ways. So they were people who were trying to analyze how the production system works and they're called Physiocrats because the leading personality, the leading intellect of the group was Francois Quesnay. And Quesnay was the physician to the King of France. And he was working at the time when we were having the very first autopsies to find out what was inside a body. Because for a long time in the West there were religious laws, rules against carving open a dead body. And then we started to do it, and Quesnay was involved in this. He found all these tubes running all over the body and had this vision of a system of circulation for the body.

(00:05:20):

And then when it came to looking at the economy, they had the same idea, there's a system of circulation. Goods go from one spot to another, money goes in the opposite direction. And there was this sense of saying, we can see the economy as a dynamic system in the same way we're now realizing the body is because all these tubes flow down and flow back up again. The arteries go through the body, they become veins, come back up again. There's circulation of blood, there's mixing of blood with oxygen, all these sorts of things where the vision. And in that sense, the basic paradigm they started from wasn't mechanics as neoclassical economists have ended up doing, it was biology. And that was a far more sensible starting place.

Nate Hagens (00:06:05):

And so instead of calling them bureaucrats, they were physicians that were advising the king, so they called them Physiocrats.

Professor Steve Keen (00:06:12):

Well, the most dominant personality was Quesnay, and there's two combinations. So he was a physician for the king, literally the king's physician. Now that did two things. He gave him enormous prominence. It also gave him plenty of spare time because he only got one person to occasionally have to do something medical with. So for the rest of the time he was working and the interest was in how the economy functions as a sort of monetary and physical goods version of the body's circulation system.

Nate Hagens (00:06:49):

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This was in the 18th Century in Europe?

Professor Steve Keen (00:06:52):

1700s, yeah. And they were trying as people like William Petty was trying to work out how the economy functioned in England at similar times, Smith afterwards, of course. But the curious thing about being based in France is that France at the time compared to Scotland, we're not comparing France to England, but France to Scotland because of Smith, France was still overwhelmingly agricultural. Okay, agriculture dominated production in France, you had some level of manufacturing. We had nothing like what was developing in Scotland at the time. Smith's book came out, I think the same year as the very first James Watt steam engine was sold. But of course we had the previous models before, which are much less efficient, were still steam engines. And you had steam power and water power and wind power being used in all the factories in Scotland. But from the point of view of the Physiocrats, they said, well, what they were looking at was rural France.

(00:08:02):

And what they saw was the farmer would plant one seed and a thousand seeds would come out of it. And so their orientation was that wealth comes from the land and it isn't the labor that goes into making something that gives it the value. They didn't even talk about that. Well, they did, but as a secondary factor. So they said the source of wealth is the land and the husbandman, as they called the farmer, is the one who exploits what they call the free gift of nature. And their perspective was first of all, to say that the land is the source of all value. That was the opening four or five words of Richard Cantillon's *An Essay On Economic Theory*, which was published in French 21 years before Smith wrote *The Wealth of Nations*. First of all, not only did Smith read French, he was in France taking a young nobleman around for education and met Quesnay. So he was quite aware of the literature in French before he wrote the *Wealth of Nations* and will never know whether Smith derived his ideas partially from the Physiocrats and interactions with them because he insisted that all his notes were burnt upon his death, so we don't have any long-term record of the influences on Smith. But this school of thought was very strong and had a definitive foundation for explaining where wealth came from. And it wasn't from labor, it was from land.

Nate Hagens (00:09:33):

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And then there were steam engines and we were off to the races and our stories changed, influenced by Adam Smith.

Professor Steve Keen (00:09:42):

Well, that's much right in the wrong direction, because what the Physiocrats also said was, of course with land, they said, well, the land receives the free gift of nature. And that had many potential meanings. But fundamentally, from our perspective, looking back, it was energy. Because the sun's energy lands on the soil, the plants absorb the energy, the plants grow, the husbandman's actual labor is far less important than the productivity of the soil and the exposure to natural elements, the climate, the sunshine coming in. And that was the source of wealth. And they said that the husbandman is the only source of wealth.

(00:10:22):

And if you look at the writings, people like Turgot and Cantillon and Quesnay had, and you look at it from the point of view that you and I have of the role of energy and production, they are fundamentally saying the free gift of energy is what enables us to produce anything. And what is often would be called the surplus by other schools of thought is the gap between the energy put in by the husbandman and the energy retrieved. And there's a wonderful sentence from Turgot where he says, "The husband receives the free gift of nature, which he did not pay for and which he sells." Okay, it's beautiful.

Nate Hagens (00:11:00):

That's a microcosm of our entire economic system today.

Professor Steve Keen (00:11:03):

Exactly, exactly. In that sense, the Physiocrats had it right. The one mistake they made, and this is the thing where the whole thing fell over and Smith played a role on this, is that they could not see the same thing in manufacturing. So what they saw for manufacturing is that manufacturing receives the output of the agricultural sector and transforms it into some different form, but does not add value. Now, what we know, of course, is that manufacturing also receives the free gift of nature in the sense that we're exploiting fossil fuel energy, which has been there for millions of years, but it's basically stored solar power. And without that input in manufacturing, there'd be

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no production for manufacturing either. And at the same point, the manufacturing transformed the free gift of nature, which is raw energy into useful energy. So the sensible perspective would've been to go from the Physiocrats vision of the role of agriculture to then say, well, it's also in manufacturing.

(00:12:03):

And Smith could have done that because Smith could have thought, well, we don't have much farming in Scotland comparatively compared to France, but we do have manufacturing. And in manufacturing we're using the free gift of nature as well. We're putting coal into the early steam engines. We've got water power, which is another gift of nature, wind power to some extent. But predominantly it was steam power and charcoal power and coal. Coal is becoming very important, becoming dominant actually before Smith published the Wealth of Nations. So he could have said, well, that's also the free gift of nature. But he didn't, what he said instead was labor is the source of value.

(00:12:47):

What you have out of that is the switch from seeing the external, the existing universe being the source of us, transforming the inputs we form, find there into something useful for us, which is consistent with the laws of thermodynamics into labor being the source of wealth and division of labor being the source of growth of wealth. And this is all effectively inside the economy. There's no reference to outside the economy. So I see Smith, by simply changing one word, you have Richard Cantillon saying that land is the source of wealth to Smith saying labor is the source of wealth. And that completely pushed the economics off the rails.

Nate Hagens (00:13:33):

We can only speculate why that happened, but possibly because Scotland was further along on industrialization and all of a sudden we had this wealth and higher goods and services than a few decades earlier. And there was maybe a human exceptionalism dynamic, look at how clever we are and how industrious our citizens of Scotland are. We're creating these machines and we're creating this productivity. And so that statement, that shift from the focus of free gifts from nature to the husbandman, the farmer or the laborer, that was the origin of our current energy blindness, you're saying?

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Professor Steve Keen (00:14:18):

I think so, and I can't criticize Smith for this. I would say it's a great pity, but I can't criticize him because he had no idea of the consequences. He didn't know the laws of thermodynamics. You can't criticize him for breaching something which wasn't developed for a century after he actually spoke. But when you look at the, I'm not going to look at some of the-

Nate Hagens (00:14:36):

And even the word, even the word energy was invented after he wrote Wealth of Nations, I think.

Professor Steve Keen (00:14:42):

1809, I think. So the word itself was taken from Greek, but it was made up in the early 18th century by an English colonist-

Nate Hagens (00:14:53):

19th century.

Professor Steve Keen (00:14:54):

Early 19th century. It's easy to make that mistake.

Nate Hagens (00:14:57):

No, no, no. I always get that confused too. Sorry, I interrupted you. You were saying?

Professor Steve Keen (00:15:00):

It's quoted in 1802, so we can't blame them for not using post language, and we can't blame Smith for not knowing that there's a law of conservation of energy.

Nate Hagens (00:15:09):

The story continues though. It wasn't just Smith, the errors compounded. So what's next?

Professor Steve Keen (00:15:15):

Well, the next stage is once Smith said that labor is a source of all value, and division of labor is the increase in value and wealth, initially that was used by Smith and

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Ricardo to attack feudalism and argue in favor of capitalism. When you look at the role of the classical theory of economics played, it was to promote trade. It was to promote freedom of movement and freedom of enterprise against all the restrictions of the feudal system. So in that sense, it was pro-capitalist, and that was the way in which it was used by Smith and Ricardo. Nobody regarded Smith and Ricardo as calling for the oath of capitalism. But along comes Marx. Now, Marx, not only Marx, there were plenty of what they call Ricardian socialists before Marx turned up, who took the same idea that if labor is a source of value, why is the wage not equal to the entire product? Why does profit exist?

(00:16:12):

That was the twist that was then taken interpreting the classical argument that labor is the source of wealth. Say, well, if we're the source of wealth, why don't we get it? And you have to go back and think about the state of industry in the 18th and early 19th centuries. I'm going to fall over that 21st century thing, the 1900s all the damn time. But if you think about the state of Scotland at the time, if I have any analogy to what it was like, it was Calcutta in the 1950s. It was stench everywhere from pigs being disemboweled, chemicals pumping out, smoke out of the chimney stacks, et cetera, et cetera. And I've forgotten who coined the phrase of the dark satanic mills. But that was what Scotland looked like at the time. And you had people who used to work in an agricultural environment with quite a few rights that peasants had back in that time, who pushed through the enclosures movement, became landless laborers fundamentally.

(00:17:17):

Had to work in the industrial systems, then found themselves working 14 hour days, normally six days a week, thank God for the Sabbath. But six days a week, often sleeping inside the factories. It wasn't exactly going to be conducive to making you think what a great system capitalism is. The other hand, of course, the capitalists themselves were benefiting from all this and bleeding the industrialization and so on, and the technological change, they thought it was great. So what you had was for the working class and for the urban poor, Ricardian and Smithian economics became a ground for arguing for revolution and for fairer share of what's being produced. And that political shift was brought to a head by Marx starting in 1857. Well, he was prominent well before then, but 1857 with his work on what's called the Grundrisse and arguments for developing Marx's particular version of the classical theory.

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(00:18:20):

And Marx's was far more eloquent than saying capitalist exploit labor. He actually said, capitalists pay workers precisely what they deserve to be paid in the commodity production system. They get their means of subsistence. That's the cost of reproducing the worker. "It's a gain for the buyer of labor power, that there's a gap between labor and labor power, but by no means an injustice to the seller." That's a quote from Marx. But anyway, what you got was Marx being used as the means for saying, "Let's have a revolution." And now in that setting, the classical school from being regarded as positive by the capitalist class and the ruling class, effectively.

Nate Hagens (00:19:06):

The classical school being Adam Smith and the like?

Professor Steve Keen (00:19:09):

Adam Smith, Ricardo, and through to ultimately to Marx, but all the time there was a subgroup, which was called, had no particular name, but they were what I'd call proto-neoclassical economists. And the most prominent would be Augustin Cournot who gave us the mathematics, what's called Cournot oligopoly theory. And so comes from Augustin Cournot back in the 1820s, and Jean-Baptiste Say, who was a complete believer in a utility-maximizing view of human behavior and equally utility-maximizing view of capitalism as a system. And he was vehemently pro-capitalism, which I'm not criticizing here at the moment at all, but I'm saying he had a subjective theory of value, whereas the classical school was objective.

(00:19:57):

So Ricardo, for example, at one stage said, the price of co-products are set by the cost of production and not as has often been said by supply and demand. So Ricardo was anti supply and demand. Most people, including neoclassical economists don't realize that. But when Marx became the bastion of the classical school, this is in the 1860s and 1870s, at that stage, there was a very rapid turnover in economic teaching at the universities where the subjective theory of value became dominant. And passing on from Say and Cournot to Marshall and Jevons and Walras.

Nate Hagens (00:20:37):

Can you briefly state what subjective versus objective theory of value would be?

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Professor Steve Keen (00:20:42):

Yeah. The objective values theory says that the price of something is set by a cost of production. So they ultimately, the cost of production determines the price something sells for, whereas the subjective theory says it's a combination of the utility-maximizing desires of the buyer and the profit-maximizing desires of the seller. The two together set the price. And as Marshall ultimately says, "It is as ridiculous to ask whether supply and demand sets price as to ask which blade of a pair of scissors cuts the paper." So they saw both having to play a role, but they also came down to saying that it isn't just labor that is a source of value, capital as also a source of value. Now, when you read Marx properly, and I think there were three people who have done that, I'm one of them, Rosovsky is another, but most Marxists don't realize that Marx actually had an explanation for how capital can add value or be a source of surplus value in his terms. But I won't get into that here, but that's saying the Marxists don't read Marx properly. But anyway, the convention-

Nate Hagens (00:21:49):

But let me ask you a clarifying question, because where we're headed, we're going to talk a lot about labor and value. Labor is pretty clear. It's the husbandman, it's the worker. Now, how do you define capital back then? And is it the same today?

Professor Steve Keen (00:22:04):

That's the most difficult questions in economics.

Nate Hagens (00:22:08):

Okay.

Professor Steve Keen (00:22:08):

Capital is found in the machinery, capital is a word for machinery, which we also use almost identically as a word for money.

Nate Hagens (00:22:17):

Technology.

Professor Steve Keen (00:22:17):

Accumulated value of money.

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Nate Hagens (00:22:20):

Okay, money.

Professor Steve Keen (00:22:21):

But there is no simple mapping from the physical machines to the monetary value of machines. And we'll talk a bit about how an energy approach makes it easy to understand the role of machinery later in our conversation.

Nate Hagens (00:22:36):

So with the old equations, if you substitute the word machinery for capital, and then you say labor and machinery in these 19th Century formulas, that would be correct. That would be the same inferences.

Professor Steve Keen (00:22:50):

That makes sense, yeah. So Marx-

Nate Hagens (00:22:51):

Okay, keep going.

Professor Steve Keen (00:22:53):

The Marx side, the physical machine adds no value to production. And this both as a distortion of his own philosophy, which is, again, an issue for another day. But if you have the labor theory of value interpretation of Marx, a machine adds nothing. It simply contributes to the output, what it costs to make it in the first place. And there's a famous phrase in volume one of Capital, which says, "No matter how productive a machine is, if it costs 150 pounds to make or three weeks of labor, then it adds to the product 150 pounds or three weeks of labor." So it simply transfers its value, whereas the increase in value comes from labor. That was Marx's labor theory of value argument. Now that contributes to the whole political battle between workers and capitalists over who should get profit, should your capitalists deserve a profit, et cetera, et cetera? And that was where the classical school suddenly became on the nose for most capitalists. So the subjective arguments of Say and Cournot, and then ultimately Walras, Jevons, and Menger became much preferred. I really don't know the politics of the switch in the 1870s, but in 1850s and mid-1860s, the Classical school was still dominant at universities and dominant in public discourse. By the 1870s, it was the

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Neoclassical School, which was completely dominant and Classics were effectively marginalized, pardon the pun. So the marginal school takes over and the argument is both labor and capital contribute to production and contribute to output.

Nate Hagens (00:24:35):

So Marx actually directly or indirectly influenced the birth of what we refer to as Neoclassical takeover of economics.

Professor Steve Keen (00:24:46):

Yeah. Now, when that happened... Of course, the real thing I'm interested in is not Marx in particular, it's just his piece of particular... He's an actor in causing this, but he's not the main stage. What started was the Physiocrats had the proto version of energy as the source of value, and that's correct. We know from the point of theory of thermodynamics, we know that there is a set amount of energy in the universe and what humanity does in its manufacturing process is take significant concentrations of energy and use those to either convert energy into something more useful or to do mode of force with that energy and that is work and that is what enables us to produce goods and services. But we cannot create energy. We take energy in one form, we transfer it into another. We actually degrade it according to the second law of thermodynamics. So there's no surplus in that sense.

(00:25:45):

What there is, is a gap between the energy input needed to harness this free energy and the energy contained by that free source as well, the coal mine or et cetera, et cetera. And that is what we're taking advantage of, so we should have an energy theory of production. If we'd had the Physiocrats, we would've got there because once the physicists in that sense caught up with the economists and developed the laws of thermodynamics, the economists could have said, "Ah, that's what we've been talking about and we can simply integrate perfectly with that." Instead, we got the wars between labor and capital, workers and capitalists, over who's the source of value? That completely ignored the role of energy.

Nate Hagens (00:26:38):

So the Neoclassical economists starting in the 1870s continued to build on this separation from a biophysical Physiocrat explanation of our wealth and productivity,

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at the same time that coal started to expand, we had just found oil and we started the Industrial Revolution in earnest. Then what happened in the field of economics and the description of our productivity? Bring us gradually up to the present moment.

Professor Steve Keen (00:27:11):

Well, you had Quesnay having a theory of production, which was fundamentally a multiplier version of investment, being multiplied by transfer between different sectors and so on. The first mathematical models came out with both Marx and the Classical school and the Neoclassical school, but there was still no, as we're used to today, no models, no series of production, which is the mathematical equations saying, "Here are your inputs, there's your GDP as output."

Nate Hagens (00:27:45):

So until that point it was just stories and rhetoric?

Professor Steve Keen (00:27:50):

Yeah.

Nate Hagens (00:27:50):

And all of a sudden then at the late 19th century, we started to put math to it and equations?

Professor Steve Keen (00:27:56):

Yeah, Marshall and Walras and Jevons being the main three that did that, Marshall adding into the 1920s. But the first attempt to have an actual what's called aggregate production function. So trying to relate the aggregate level of output to the aggregate level of inputs at the level of a macroeconomy. The first attempt to do that in the Neoclassical School was called the Cobb-Douglas production function.

(00:28:22):

In both Marshall's work and in Jevons' work, you can find this idea of inputs having marginal productivity. So you put a certain amount of labor in and you get a certain level of output. You add more labor, you get not as much increase in output as the previous level, but still some positive returns. So this idea of marginal productivity of labor and marginal productivity of machinery, which turned up in the Neoclassical

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theory. I think in 1898 or early in the 1890s, J.B. Clark developed the marginal productivity theory of income distribution, which said that workers receive the marginal product and capitalists received their marginal products. So that concept became built into Neoclassical theory. So the wage is supposed to reflect the contribution to output of the last worker hired, and the rate of profit is supposed to reflect the contribution to output of the last meat machine turned on.

Nate Hagens (00:29:26):

But how did they know what percentage of the value of the product that was created was from the worker and from the machine?

Professor Steve Keen (00:29:37):

Well, they didn't actually know in that sense, and they're wrong with the answers they gave. But the basic concept with the marginal productivity theory of income distribution was that the marginal products would be based upon the share of income going to different what economists call factors of production. So if labor gets 75% of GDP, and that was roughly the term that applied in the 1920s, and capitalists get 25%, then the marginal product of cert labor is .75, and the marginal product of capital is .25. So that was the general expectation, but nobody put a mathematical number on it until Cobb and Douglas, one being a mathematician, the other being an economist, Douglas being the economist-

Nate Hagens (00:30:23):

And this was 1920s, 1930s?

Professor Steve Keen (00:30:23):

1928, I think it was.

Nate Hagens (00:30:23):

Cobb and Douglas?

Professor Steve Keen (00:30:23):

Yeah.

Nate Hagens (00:30:24):

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Okay.

Professor Steve Keen (00:30:26):

So they had painstakingly assembled a set of index numbers. Again, this is why it's important to know your history because as well as knowing how things happen, you also know the context in which they happen. And today we're used to getting GDP figures off the Bureau of Economic Analysis every three months. Then we get a breakdown of the contributions from different sectors and there's huge tables and statisticians. Groups of statisticians involved in making this all look consistent. Back then, there were no numbers. There was one person maintaining an index series for GDP, but there were no numbers on the amount of labor and no numbers on the amount of machinery. So Douglas made up, fairly carefully, but put together a number of different series that he could find to produce an index of labor, an index of capital, and had this index of the output of machinery, not the entire GDP, that was pre-existing at the time, and put together the annual data between 1899 and 1922, and then fitted that data, the mathematician Cobb doing the work there.

(00:31:43):

Again, of course, this is on paper. We probably had manual calculators back then. I imagine they would've been extremely expensive. They would've existed, maybe it was done by hand, but the calculations were much, much more painstaking than we're used to today by pumping numbers into a computer program and almost instantly getting the result. So just 23 numbers, all index numbers, all starting at 100 in 1899, and then going through to different values in 1922. When they did a regression against that, they used what's called a homogenous of degree one production function. What that means is that you had output being some constant, and it was a constant, not a variable, a constant multiplied by capital raised to one power times labor raised to one minus that power. So the question was what is the term? I'll call it alpha here, because they use K and one minus K and that's getting too confusing.

(00:32:47):

Most economists use alpha for the share of machinery in GDP or share of capitalists in GDP. Back at the time, roughly speaking, the share of capitalist and GDP was 25%. So the value for alpha is 0.25, and therefore the value for one minus alpha is 0.75. The reason it's a homogenous of degree one, if you multiply all labor in all capital, you double it, you get twice as much output because the exponents sum to one. So that's

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the term they found, and lo and behold, the regression came back with values of 0.76 and 0.24 and they said, "Hey, this is so close to what we expected."

Nate Hagens (00:33:26):

That's pretty close to 0.75 and 0.25.

Professor Steve Keen (00:33:29):

Yeah, so they got a number which, and in fact I've redone it recently just using a modern program of course, and I get exactly 0.25. So you get a very strong apparent confirmation of their data. They gave this the correlation coefficient, the R squared is the square of that of course. The R squared for doing it now is 0.94. Now the correlation coefficient is 0.97. Their response was, "Oh, it looks fabulously high correlation coefficient and it fits exactly what we expected for Neoclassical Theory." Now they got a lot of pushback initially, but that was a major reason for why it became so popular because the results looked very strong and they supported Neoclassical Theory.

Nate Hagens (00:34:15):

But the entire formula was based on a data set from 1899 to 1922?

Professor Steve Keen (00:34:22):

Yep. What Cobb and Douglas did, they showed the numbers, the regression for reversing GDP against the index for capital and the index for labor. But they said that their changed data also gave the same correlation coefficient of 0.97. What they used was not what we'd use today, which is the annual change in the indices. We take the log and the log difference, or they'd look at percentage rate of change and say, "What's the percentage rate of change?" That when you do it, this is where I started finding a bit of, there's a hole in the bucket dear Eliza, dear Eliza, the correlation coefficient that they claimed was 0.97 for exactly the same value of alpha. So you got a higher... You're confirming you didn't just get the high correlation with GDP and out labor and capital, which are all growing. So the fact that they're all rising at the one time will give you a higher correlation. They said same correlation coefficient, same value for alpha. When I do it over the alpha of -0.15.

Nate Hagens (00:35:43):

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Why is that?

Professor Steve Keen (00:35:44):

Because they didn't use the annual, the percentage change they used the three-year moving average. I don't know. I wouldn't be able to find the original notes, but it wasn't the same result that they got for the data, which was all rising at one time. Any statistician will tell you that if you have data which is all rising, you're going to get a high correlation coefficient just because they're all growing, not because they're related to each other. So we should be looking for the differences and try to get something where the trend should be around zero. Even that doesn't apply to the first differences here. But in other words, they didn't get the results that people accepted that they did, and the confidence people had in the results wasn't justified.

Nate Hagens (00:36:31):

But people were confident.

Professor Steve Keen (00:36:33):

Oh, yeah.

Nate Hagens (00:36:33):

In the 1930s and 1940s, this was considered a valid and profound explanation of the inputs and outputs of an economic system describing our wealth and productivity.

Professor Steve Keen (00:36:46):

Yeah. Now, we had all sorts of other approaches to how you model production in the meantime. There was a long time, and this actually still applied when I was doing my PhD back in the 1980s or 1990s, that Neoclassical economists were doing what they call computable general equilibrium models. These models had an input-output table as part of their production system. Now there's all sorts of issues for them, which again, that's tangential to what we're talking about. But at the same time, you had the rise of what they called themselves the New Classical economists, and these were Neoclassical economists who wanted to revive the idea of the market economy being perfectly flexible, get rid of this nasty Keynesian stuff. They started using much more commonly the Cobb-Douglas production function because they replaced an input output model for the production today with the idea of production over time and they

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went back to a single commodity idea. This is the aggregate production function. Of course they use the Cobb-Douglas production function.

(00:37:51):

Now we had 30 or 40 years of that, and typical Neoclassicals, they don't know their own history, they've forgotten they ever used anything different to that. All of them use a Cobb-Douglas production function. They've all done what Solow brought in the 1950s, and that's bringing in what they call technological change as part of the system. So they have output as a product of state of technology, which they use the capital letter A for, multiplied by labor to one minus alpha times capital to alpha. That's where I think everything went wrong. Not that it was already going wrong with Cobb and Douglass, but this is where you got--

Nate Hagens (00:38:31):

It was already going wrong with Adam Smith.

Professor Steve Keen (00:38:33):

Yeah, it's error after error. Economics is...I can define economics as compound error.

Nate Hagens (00:38:43):

All right, we're going to eventually translate all this because I'm mostly tracking with... You're an economist and you're a friend and you care about the system of humans and our planet, but you're also, here, you're functioning as a historian, which is a totally separate skill that you have. I've talked to you offline on what you've all been working on and it's quite the detective story. So keep going and bring us up to the present. So what did Solow do?

Professor Steve Keen (00:39:14):

Well, you started with Cobb and Douglas having their function was a constant multiplied by L to the one minus alpha times K to the alpha as the production function. Now then one of the criticisms that was made of Cobb and Douglas by other Neoclassicals, is where's technological change here? So they said, "Well, we can bring technological change in." This is in 1956, '57. "We can bring it in and the way we have to do it, there's a cost." I'll actually read them here, "The new wrinkle I want to describe is an elementary way of segregating variations in output per head due to technical

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change from those due to changes in the availability of capital per head. Naturally, every additional bit of information has its price. In this case, the price consists of one new required time series, which is the share of labor in total income and one year assumption."

(00:40:10):

Here we go, "That factors are paid their marginal products." Other words, rather than being a mathematical derivation by Cobb and Douglas, that alpha is 0.25 and one minus alpha is 0.75. Let's just assume that they're... What the current values of the share of labor and capital and output are. Alpha is 0.3, which means capitalists get 30% of output and labor gets 0.7. So we just assume that and then we fit the data to the... We have a data series for labor, a data series for capital, a data series for GDP. We don't have technology. So the gap between the result we get for GDP and the sum of labor and capital is what they call the growth of technological change. That ended up being 0.85. So 85% of the variation in output was explained not by the proportions of labor and capital to each other, but by this technological component. That became known as a Solow residual.

Nate Hagens (00:41:14):

So hold on a second. So from 1928 onwards, they had 75% was described by labor and 25% by capital of our productivity. Productivity is basically could be said our wealth change year over year. Then 30 years later they change it and said that 85% is unexplained, but it's by some change in technology?

Professor Steve Keen (00:41:46):

Yeah.

Nate Hagens (00:41:47):

How does technology in Solow's definition versus your definition, how does technology differ from capital?

Professor Steve Keen (00:41:55):

Well, this is the problem. Technology in my opinion, is embodied in capital in that sense. When we have technological change, what we get is new machines that have a higher capacity to process energy and produce more complex goods than the previous

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ones had. So Cobb and Douglas were in that stance right not to differentiate out technology and capital. But by Solow ringing in this idea of a residual, first of all, he assumed that the exponents for labor and capital were given by income distribution data. By that stage it was 30% going to capital rather than 25%.

Nate Hagens (00:42:32):

So he did do data from the 1920s to the 1950s and the 0.25, 0.75 shifted to 0.3 and 0.7.

Professor Steve Keen (00:42:41):

That's what he found when if you look in his paper, he does include the national distribution of income and it's pretty much 30%/70% capitalists and workers.

Nate Hagens (00:42:50):

But he looked at the numbers and said, "Wait a minute, there's something not right here." And when you find a residual of something, a residual effect, sometimes it's 5% or 10%. But in his case it was 85%.

Professor Steve Keen (00:43:04):

85%.

Nate Hagens (00:43:06):

The vast majority of the productivity could not be described by capital and labor.

Professor Steve Keen (00:43:11):

Well actually 87.5% in his initial paper. And that's okay in one sense you can say, "Well, most of our improvement isn't a case of adding more labor or more capital or getting the ratio between labor and capital correct. It's technological change." But fundamentally that was because technological change turns up in the machines and the labor component when we're talking about unskilled workers, you basically have people working on a process line. I've actually done that at some stage in my youth, but you just get told, "Now press this button, pull this lever, put that thingamajig on that whatchamacallit, and that's your role."

(00:43:53):

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So where the technological change actually turns up is in the machine itself. So if you go back before I worked as a manual hand inside a factory, at one stage you would've used rivets to weld aluminum together, and now you're using spot welding machines. So the technology is actually embodied in the machinery. This is where the confusion of machines with money becomes a reason why your mind gets clouded if you don't distinguish the two. But the terms we use capital for machinery and capital for money and capitalist for the social class does confuse matters. What I'm talking about is progressive confusion.

Nate Hagens (00:44:36):

Yeah, I'm a little confused myself now, but I know you're telling a really important story, which you outlined to me on the phone, on our call earlier this week. So keep going. By the way, from Marx onward, Marx and Cobb and Douglas and Solow in the 1950s, they're all using terms like land and capital and technology and the word energy is found nowhere in these papers.

Professor Steve Keen (00:45:07):

Correct. The only one who really does, for example, Marshall talks about energy. He uses the word 79 times in his Principles of Economics every last time talking about the innovative spirit of humans, not energy as you and I mean it.

Nate Hagens (00:45:22):

Energy is our... Yeah, not fossil energy, but the human spirit.

Professor Steve Keen (00:45:27):

Yeah, human spirit. So he actually talked about energy as various raw materials, which of course contain energy, coal, and oil as inputs. But when it came to talking about energy itself, there was no awareness of the theories of thermodynamics or the role of energy as a production force. Whereas in Marx, Marx was actually reading the early thermodynamic workers and going to lectures in London and so on. So there's more awareness of the role of energy in Marx than there is in the Neoclassicals. But what's happened is energy's dropped completely out of the picture at this stage. So first of all, Cobb and Douglas give you a theory of production, which fits the marginal productivity theory of income distribution. They give you coefficients, which are what Neoclassicals expect them to do, but they're derived from the data. Then along comes

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Solow and said, "Let's assume those coefficients are correct. So the marginal product of labor is 0.7, and it is equal to their contribution or their share of GDP. Then let's work out the residual and oh, I got 87.5, but that's okay. We're talking about technological change."

(00:46:37):

But it was an unnecessary fudge. It then shielded Neoclassical economists from looking at the data again to see whether the share of workers in GDP is equivalent to the contribution that labor makes to output and capital makes to output. That's where it goes all awry. Because when you take a look at the data that Solow was looking at and data subsequent to that, and you do a regression based on the change in GDP or the change in labor and change in capital, rather than getting a coefficient for capital of 0.3, which is close to the income distribution, you get a coefficient for capital of 0.85, and that suddenly means, hang on a sec, we've got a contradiction between an empirically derived term for the contribution of capital to output and the theory of income distribution. The return to capital is actually much higher. So the exponent for capital is much higher than capital share in GDP. And suddenly we would've seen this if Solow hadn't jumped in with the idea of separating our technological change from capital itself.

Nate Hagens (00:47:55):

Oh. So that was a red herring that took us down a different flawed pathway on understanding the production function.

Professor Steve Keen (00:48:05):

Yeah. And leaving-

Nate Hagens (00:48:06):

So, what happened after... Go ahead.

Professor Steve Keen (00:48:08):

We're leaving energy out all the way through. So, what we have is in the Neoclassical camp, the idea that the payment of labor and capital reflects their marginal product becomes just ingrained in the mindset of Neoclassicals. And they stick with the coefficients that Solow first worked down in 1957, and more than half a century-

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Nate Hagens (00:48:31):

Still today?

Professor Steve Keen (00:48:33):

Still today. They haven't changed them. So if you look in almost any neoclassical paper, it will assume the exponent for capital is 0.3, and the exponent for labor is 0.7.

Nate Hagens (00:48:44):

Using data that Solow used from 1928 to 1950s?

Professor Steve Keen (00:48:49):

Yeah. If anybody's smart, they might go and take a look at income distribution and find that capital now gets 40%, and labor gets 60%. So they change to the 0.4 and 0.6, but they simply assume they can use the income distribution data, to choose what the exponents are in the production function.

Nate Hagens (00:49:04):

When you're getting a PhD in economics today, or when you were in school, was it a requirement to read these fundamental papers of Marshall-

Professor Steve Keen (00:49:15):

Oh, no.

Nate Hagens (00:49:15):

And Cobb-Douglas and Marx and... No?

Professor Steve Keen (00:49:18):

No. This is one of the reasons why neoclassical economics has gone so totally off the rails. They don't even know their own history. So, when I went through, you had to sit through master's courses on advanced micro and advanced macro and so on. They were part of... There's now what's called an America ABD, All But Dissertation.

(00:49:39):

And the American system has enormous coursework load, and I'm not sure, I thankfully that didn't go through the American system, but I think something like two-thirds of

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your time is spent doing courses rather than writing a thesis. And you don't go back...the oldest paper you might read is one where the Lucas critique was developed in the 1970s. So, they just don't know their own history.

Nate Hagens (00:50:05):

What's the Lucas critique?

Professor Steve Keen (00:50:08):

That's another rabbit hole. But arguing that macro should be based on micro, that's the fundamental idea behind the Lucas critique.

Nate Hagens (00:50:17):

Okay. So, from Adam Smith to Marx to Marshall to Cobb and Douglas to Solow, we've had a progression away from the physiocrats of something physical. Back in France it was land, and the free energy from the earth. And then we had a bonanza fossil carbon added to our economic system. What happened next? Solow all the way to the present day, or was there another wrong turn?

Professor Steve Keen (00:50:50):

Solow all the way to the present day in terms of the production function that neoclassicals use. And then of course, energy is we've got to bring our people back to energy all the time. Because the thing is what happened to energy, we know energy's absolutely critical for production, but it's left out of those theories. And you then had a group of non-Orthodox economists, Bobby is being the main one, a physicist who became fascinated with economics, and then realized economics didn't include the role of energy, and thought, "We've got to bring energy into production," working with Kummel and quite a range of other non-orthodox economists-

Nate Hagens (00:51:26):

I know both Bob and Reiner-

Professor Steve Keen (00:51:28):

So, did I.

Nate Hagens (00:51:28):

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And you.

Professor Steve Keen (00:51:30):

So poor old Bob parting, what about three, four weeks ago?

Nate Hagens (00:51:33):

I know, I know. I saw that.

Professor Steve Keen (00:51:36):

Maybe two months ago now. I'm glad I got to see him. Would've been only two months before he died in Holland at a conference that we caught up. So working with Bob, I thought, "We've got to bring energy and there simply has to be a way of bringing energy into production." And what Kummel and Bob were doing was at some point they went from using total numbers to index numbers in what they call the LINEX production function. This was an attempt to bring energy in, but through the legs of the Cobb-Douglas production function.

(00:52:06):

So at some point they had the idea of index number values for output, labor, energy and capital being part of the way they derived the LINEX function. And my discomfort was that fundamentally what they were doing, and this is what neoclassical themselves have also done, is add energy in as an additional factor of production.

(00:52:28):

So you see, the way you produce output is you combine labor and capital and energy. Now, there's two problems with that. One is, that if you combine labor independently, and machinery independently, and energy production independently, you don't have output, you've got an explosion. Energy has to be an input to labor and capital. And so what it finally occurred to me literally while being in Bob Ayes' flat in France, which was full of statues, that walking through it one day on a trip from the bathroom, the little thought popped in my brain, "Labor without energy is a corpse. Capital without energy is a sculpture." And bang, "That's it." And I sat down at a table.

Nate Hagens (00:53:08):

That's it.

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Professor Steve Keen (00:53:11):

Five minutes typing in a program called Mathcad, as it happens, and feed that into the Cobb-Douglas production function. So the basic idea was that energy is not an independent factor. It's a factor you have to input to labor in one form, and input into machinery in a different form, otherwise they can't produce anything.

Nate Hagens (00:53:31):

Said differently, the laborers need food and housing and shelter and such, and the machines, capital, need to be turned on and powered by electricity or heat or movement-

Professor Steve Keen (00:53:45):

Exactly. Exactly.

Nate Hagens (00:53:45):

... which absolutely requires energy. Without energy the machines are worthless.

Professor Steve Keen (00:53:49):

Yeah. Now what then happened out of that was, the Cobb-Douglas production function. If I fed energy as an import to labor, the basic point was that the number of workers you've got, times how much energy they consume, multiplied by how much of that energy is used in production. Now if we go back to the days of the Roman slaves, most of the energy they consumed went into production, fed a pittance, worked to the bone, and therefore, given 200 watts equivalent of energy input, they could put out 100 watts output. And so their factor is 50%.

(00:54:29):

But if you fast-forward to today, you and I are surrounded by energy. We're consuming tens of thousands of watts of energy in our houses with our devices, the heating, hot water, et cetera, et cetera. But only a tiny amount of our energy actually now goes into production. And fundamentally the amount of physical work we can do, runs out at about a hundred watts and I'm terrible on the terms by the way, being an economist who haven't been properly trained on the terms of energy and watts and joules and so on. So, I'll make all sorts of mistakes there.

(00:54:58):

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But the basic point is, the energy input of a worker to production is in terms of actual measures of energy, is no greater than was 2000 years ago, because we haven't evolved in any sense, to be able to consume more energy and output more energy. On the other hand, machinery has had an incredible increase in the energy input that a machine can take.

(00:55:21):

My favorite instance, I like what Musk is doing with SpaceX. So I'm a bit of a space junkie. And a friend of mine was being abusive about this last rocket blowing up and I worked out what was the energy equivalent of the energy inside that rocket. It was one third of a Hiroshima bomb. Now, for that to actually not lead to an explosion that devastated Boca Chica, but led to a rocket taking off and reaching a hundred kilometers above the surface in a few minutes, that is the amount of energy that the ultimate machine of our day can consume.

(00:55:59):

If you go back to James Watt's steam engine, it was about 30 tons of coal a day. Now, that's a damn site less than one third of a Hiroshima bomb. So, most of what we've seen is a growth in our wealth, and our growth in the consumption levels we have has come from that increase in energy. And now we're cooking with gas in that sense, because we're finally we're acknowledging the role of energy in production, but that's not what neoclassical is doing, of course.

Nate Hagens (00:56:28):

So, this was a story of false turns at intersections all the way. And now, what would a neoclassical economist listening to this last forty-five minutes, say to you in rebuttal, or defense, or contradiction, or alarm?

Professor Steve Keen (00:56:54):

I'm going to have a bit of fun here. Rudi, if you're listening, Rudi Bachmann, solved me the case of saying what a neoclassical economist would say, by actually saying what he said in a paper, because now I'm going to come down to how have economists on the very few occasions they've tried to include energy in a Cobb-Douglas production function, what they've done, and what they therefore deduced about the role of energy and production.

(00:57:16):

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And Rudi thinks, I haven't got a sense of humor, but I laugh at him all the time, so I want to share why I do that. So, Bachmann and Co, about three or four authors, wrote a paper for a German language working paper with an English translation on the issue of, "What's going to happen to output in the GDP of Germany if we're cut off from Russian energy during the Ukraine war?" The argument they made was that was done by saying, "We're going to include energy in the Cobb-Douglas production function." Now what they did, and this is where the mistakes compound upon mistakes, is they took the standard coefficients of 0.7 and 0.3, and then said, "Let's allocate 0.04 of capital's coefficient to energy." So you've still got the same homogenous production-

Nate Hagens (00:58:07):

Because energy is 4% of-

Professor Steve Keen (00:58:08):

4% of GDP. Therefore, the coefficient is 0.04, and this is where you get the total. This is where the twist comes in. Because the coefficient is 0.04, the mathematics of the Cobb-Douglas production function then tells you that the contribution of energy to change in output is also 0.04.

Nate Hagens (00:58:30):

But all of the labor, and all of the machinery is fully dependent on the energy.

Professor Steve Keen (00:58:35):

Far more important. Now here we got to get some quotes out of Rudi here. So they compared their work to what's called the Leontief production function, which we haven't even mentioned yet, but I'll bring that in now. And Wassily Leontief, is one of the few winners of the Nobel Prize that I absolutely applaud. He was a Russian mathematician/economist, and he gave us input-output analysis and a whole range of other positive contributions.

(00:59:04):

But when looking at the ratio level of capital and level of output in most economies, however the numbers were developed, what he realized was the ratio of capital to output was roughly constant. Different between different countries, very different between developing and developed countries, but generally speaking, the ratio,

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whichever your way, was roughly constant. And he then said you could use that as an aggregate production function. So rather than saying, "The aggregate level of output is labor to one power times capital one minus that power," you said, "Output is capital divided by capital output ratio." And it was just an empirical regularity. And the post-Keynesian school, which I'm part of, basically said, "That'll be our production function."

(00:59:49):

So rather than the complicated neoclassical with exponents and marginal products, et cetera, et cetera, we just say, "Output is K divided by V ," and V normally in terms of the conventional figure, people normally used about three for the value of V . So output each year is one-third the value of capital that same year. And then we get ridiculed for that, and because they say, "Well, you don't enable the possibility of substitution between labor and capital as input, so you must be less sophisticated than we are with the production function that can enable for substitution of labor for capital."

(01:00:26):

So Rudi then dived in this and took a look and compared the Cobb-Douglas production function to the Leontief, using a form which is called Constant Elasticity of Substitution, but I won't go into that. Basically, in regard to Cobb-Douglas is at one extreme of that, and the Leontief at the other. And they said that if you have the standard Cobb-Douglas production function, then it tells you you have a 10% fall in energy inputs, you'll have a 0.4% fall in GDP.

Nate Hagens (01:01:00):

So we lose 10% of our energy, and GDP goes down by 0.4%.

Professor Steve Keen (01:01:05):

Yeah. Yeah. Now-

Nate Hagens (01:01:08):

Well that's ridiculous.

Professor Steve Keen (01:01:09):

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I know. Okay, you and I both know that's ridiculous, but he didn't know that because they don't look at the data. So, what they then said was that, and this is the quote from Rudi's paper. The heading is, "Extreme scenarios with low elasticity of substitution, and why Leontief production at the macro level is nonsensical." So they had the blue dashed line, and the figure shows that output falls one for one with energy supply in the Leontief case, the marginal product of energy jumps to one over alpha, which is the exponent they used for it. So, $1/0.04$, while the marginal products of the other factors falls to zero. And then here's an assumption: "If factor prices equal marginal products, this then implies the price of energy jumps to one over alpha, and prices of others fall to zero. This also implies expenditure and energy jumps to 100%, blah, blah, blah. We consider these predictions to be economically nonsensical."

(01:02:05):

They are, but not because the Leontief case is wrong. The Leontief actually fits the data. It's because the assumption that wages equal marginal product of labor is wrong. So, it's an empirical contradiction of the neoclassical theory of production. And the basic argument is that they think that production is quite insensitive to energy. That's also a quote from the paper. So because they explained it at 0.04, that means that it's 10% change in energy causes 0.4% change in output. So labor is far more significant, and capital second, and energy a far distant third. When you look in the data, energy is 100% of the answer.

Nate Hagens (01:02:53):

Explain that. What is the truth, based on all your work with Bob Ayres, and Reiner, Kummel and others? What is the actual equation of labor and capital, and whatever other variables?

Professor Steve Keen (01:03:07):

The basic truth is that the output is fundamentally energy transformed into a useful form. If you take a look at the rate of growth of energy, in the rate of change of energy, and the rate of change of GDP at the global level, you find a correlation coefficient for them, I was looking for this now, of 0.7 roughly, and the relationship between change in GDP and change in energy is change in GDP is 0.97 times change in energy. So, in other words, fundamentally what GDP is, is energy transformed into useful work.

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Nate Hagens (01:03:47):

And so the core flawed assumption, which has built upon some basic flawed assumptions, and changed over centuries, is that we can describe our... It's almost like there's been a supernova the last two centuries of energy use, and wealth and productivity, and people are just trying to scramble in real time putting math equations on that, and increasingly divorced from the truth, because the supernova keeps growing. And so, the energy blindness is that adding more energy, particularly energy dense fossil energy to the whole thing every year, that itself, that little addition of more energy, is a big explainer of our productivity.

Professor Steve Keen (01:04:45):

It's the fundamental explainer, and therefore what we've really done over time is developed machines which can handle more and more energy, more and more precisely. That's where our wealth has come from. And economists have been blind to that by having this, first of all, introduction by Adam Smith to throw out the physiocrats and say, "Labor's the source of value." And then you have the neoclassical saying, "It's labor and capital." Then you had Cobb and Douglas saying, "It's 0.7 and 0.3," which means that the contribution of labor to change in output is 70%, and the contribution of capital is 30%.

(01:05:21):

That then gets locked in by Solow, to turning their empirical non-discovery into an assumption, and then putting it all in technological change which becomes disembodied from capital itself, but also hides them from the fact that the relationship doesn't hold up on the data anymore anyway.

(01:05:38):

And now, when they come bring energy, they just tack it on as a third factor and give it a coefficient based on the percentage of energy in GDP, which is trivially low, and therefore say energy has almost no role in production, which is complete bollocks.

Nate Hagens (01:05:53):

And part of the reason is, that the energy input into our machines, and into our economy, is only the cost of energy that it is to extract, plus a little profit for the oil company or whatever. It's not the value that it provides, which is four, five years of my physical labor, and all that-

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Professor Steve Keen (01:06:17):

In each barrel of oil. Yeah.

Nate Hagens (01:06:21):

Seriously, this is Nobel Prize sort of observation, I think, because it's so decoupled from what people say at high positions of authority in our world. Again, I'll ask you would just a standard economist, not Rudi, someone you know, but just anyone listening to this who has a Ph.D. in economics, or maybe someone who's in grad school getting a master's or a PhD in economics, listening to this program, is their initial reaction going to be one of critical rejection, "Steve doesn't know what he's talking about?"

Professor Steve Keen (01:07:03):

Oh, yeah.

Nate Hagens (01:07:04):

Or, is it like... Yeah?

Professor Steve Keen (01:07:06):

Absolutely. I mean-

Nate Hagens (01:07:07):

Because it affects their identity, or because they know otherwise in their research?

Professor Steve Keen (01:07:12):

It affects their identity. A younger one might actually go, "Oh, hang on, that's surprising." You'll get a few who might react that way and change, but the old ones are locked in their ways.

Nate Hagens (01:07:21):

Okay, so speak to the young ones right now.

Professor Steve Keen (01:07:24):

Okay.

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Nate Hagens (01:07:24):

If they're curious about this, and something doesn't sit right with what they've been told, and what they've just heard, what would you recommend that they do to get clarity on the truth?

Professor Steve Keen (01:07:38):

The main thing is to realize that economics can't be derived from the laws of thermodynamics, but it can't be inconsistent with them either. And what you are being taught, with your production functions and so on, is leaving out the role of energy in an absolutely critical way.

(01:07:52):

Now, if you go and want to do it empirically, you go and take a look at what is the relationship between energy and production, drive it empirically, and you'll find that it's somewhere in GDP, is 0.7 to 8.9597 as I've got in that particular Excel regression of the value of change in GDP. So the fundamental insight from a thermodynamical point of view within economics is that the first approximation, GDP is energy turned into useful work. And then that means that the whole argument you were taught in neoclassical economics that, "The wage reflects the marginal of product of labor," is completely wrong.

(01:08:35):

The wage and the return to capital for that matter, have nothing to do with their contribution to production. What labor and capital do, is harness energy successfully in factories, to produce output. And that will normally be done with machines. The machines have very fixed ratios of per workers, per machine, and energy throughput per machine. So fundamentally, you get a fixed ratio. And that sense, the Leontief as an empirical observation, we now have an explanation for. That explanation is that the Leontief production function is actually, "Output is equal to machinery, multiplied by the efficiency with which machines turn energy into useful work."

Nate Hagens (01:09:20):

Neoclassical economists, back when I was in school, are among the smartest people in my class. And smart people can be fooled, but they're not dumb. So really, it still today boggles my mind how neoclassical economists can totally neglect energy, given anyone with three minutes on the internet, can find that a barrel of oil has 5.7 million

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BTUs in it, which is a lot of energy, relative to the 0.6 kilowatt hours that I do per day. So do they really think this?

Professor Steve Keen (01:09:59):

They really do. And the trouble is, this is where your mind gets set by your training. So, if you get trained on the idea that production is a combination of technology, labor, and capital, and energy doesn't even turn up there, you don't even think about energy, and you can be completely energy blind in the sense that I lead that book with, that humans know as much about energy as fish do about water. They simply take it for granted.

(01:10:22):

And then you see this when neoclassicals actually come to pose themselves the question of, "What is the role of energy in production?" So this is again, this is from the paper by Bachmann and Co. about the impact of the loss of Russian energy on German output. And they to take the Cobb-Douglas production function and differentiate it with respect to the inputs, and then we can say what's going to happen to GDP from a change in energy, and here's a quote from the paper. "Therefore, for example, a drop in energy supply of minus 10%, reduces production by 0.4%, which shows that production is quite insensitive to energy as expected." This is expected from-

Nate Hagens (01:11:06):

Production is quite insensitive to-

Professor Steve Keen (01:11:06):

Quite insensitive to energy-

Nate Hagens (01:11:06):

...energy.

Professor Steve Keen (01:11:09):

... as expected by neoclassical economists,

Nate Hagens (01:11:14):

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Right, it's a tautology of sorts. A tautology.

Professor Steve Keen (01:11:18):

They think that energy has a trivial role because it has no role in their production function. But when you revise-

Nate Hagens (01:11:24):

Why aren't there people calling them on this?

Professor Steve Keen (01:11:30):

Well, I am.

Nate Hagens (01:11:30):

The prime minister, or a senator, or a CEO-

Professor Steve Keen (01:11:36):

They all do-

Nate Hagens (01:11:36):

... saying-

Professor Steve Keen (01:11:36):

... one unit of economics. They all get the idea of labor and capital producing output and the production function if they go that detailed in first year. But fundamentally, they get taught the whole idea that we get paid our factor products. And that actually ideologically is very reinforcing for a CEO, because it says, "My enormous weight per salary, is because of my huge contribution to production." So it ends up having an ideological role, and that blinds them to the physical reality that you simply don't have that impact on production. If you come down to the nuts and bolts of it, it's energy which is producing the output and you are getting a share of it, an overblown share given your system and the power structure of capitalism.

Nate Hagens (01:12:22):

So if we truly defined energy correctly in the production function, that giant gift from nature might not all be funneled to the top the way it is now.

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Professor Steve Keen (01:12:35):

And that, of course, leads to one of the reasons why people continue being energy blind because it enables them to be blind to their outsized share of the wealth of the civilization that goes their way.

Nate Hagens (01:12:50):

And also continues to indicate why we're blind to the waste component as well. Because if you include that, that reduces... Yeah.

Professor Steve Keen (01:13:02):

Yeah. The other side of the production function is waste. And when I do the Leontief function, which makes sense. So with the logical reinterpretation of the empirical regularity of Leontief, that output is capital divided by capital output ratio, becoming output is capital times the efficiency with which machines turn energy into useful work. That coefficient is going to be less than 0.5, substantially less than 0.5. So it means most of what we produce is waste energy. They can quantify it and say, "If the efficiency with which machines turn energy used for work is about roughly 0.2 or 0.25, then 0.8 to 0.75 of energy input produces waste." And that's what we dump into the environment. And that, of course, feeds back and damages our capacity to produce output. If we had that insight 50 or 60 years ago, we would never have got to the conundrum we are in now of relying so much upon fossil fuel energy for our production today.

Nate Hagens (01:14:07):

Okay. I'm going to ask you an easier question, but it might be a harder question for you specifically, Steve. What would you tell to a graduate student learning about the world in another discipline like philosophy or French or chemistry or biology who will never take a class in economics? To those people, why is it important that energy underpins the production function and that our economists, and therefore, our politicians and such have been misled about the core driver of our wealth the last century plus?

Professor Steve Keen (01:14:54):

Fundamentally, human civilization only exists because we exploit energy. If we didn't have energy in the form of the coal and oil deposits we found, we would still be sitting

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around fireplaces starting fires with flints. We might have a moderately sophisticated culture to the stage that you got with your animal power and slave power under Romans and the medieval period and serfs and so on. But there wouldn't be the philosophy, there wouldn't be the art, there wouldn't be the computers that we take for granted today. So if we don't understand the role of energy, we don't understand where our civilization came from.

Nate Hagens (01:15:34):

How does your view and that of Bob Ayres and Reiner Kummel and other what we might call biophysical economists, or in your case, Post-Keynesian economists, how does your current understanding of energy and the production function differ from the biophysical economists that started to gain traction in the 1970s, Howard Odom and Georgescu-Roegen and Charlie Hall and such? Is it nuance? Is it different? Okay.

Professor Steve Keen (01:16:10):

No, it's just basically finding a better way to put it together. I mean, for example, Bob of course was in the house when I made that discovery. I was staying in his flat. It took me 10 minutes or less to work out the mathematics. It's ridiculously simple. But he then just said, "That solves it. That brings in the role of energy." Because neither he nor Kummel had ever thought making energy an input into the labor and capital. They had energy as a third factor. And once you just say, "It's got to be an input," it all falls together.

Nate Hagens (01:16:44):

I totally agree with that, but here's what I don't understand. If we don't have energy, all technologies are sculptures. I added to your statement and said, "Cities are museums," but we do have energy and we're probably going to have less energy in the future. But how we use that energy, how we combine that energy with materials and human imagination and creativity, that does add something to just the raw value of the energy.

Professor Steve Keen (01:17:19):

Absolutely. Yeah.

Nate Hagens (01:17:19):

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So it's the combination of machines, raw materials like copper and silicon and-

Professor Steve Keen (01:17:29):

Phosphorus.

Nate Hagens (01:17:31):

... neodymium and phosphorus and the fire, some electrons or flame, either kinetic or potential energy. And that comes up with a product that humans value. So how do you distinguish the contribution of actually the flame or the electrons versus the machine and the new invention?

Professor Steve Keen (01:17:58):

I'm actually going to go right back to 1774 and give you an explanation for that. And I quote this in my new book because I think Turgot wrote one of the most brilliant paragraphs in the history of economics. And I just wish this had been where economics came from rather than 1776, two years later with Adam Smith. So pardon me, reading out a substantial segment and looking above the camera to do it.

(01:18:19):

And because the mistakes I was saying this being with agriculture as any production system including manufacturing, obviously. "The husbandman is the only person whose labor produces something over and above the wages of labor. He is therefore the sole source of all wealth. The land pays him directly the price of his labor independently of any other man or agreement. Nature does not bargain with him to oblige him to content himself with what is absolutely necessary, what she grants as proportional, neither to his wants nor to contractual valuation to the price of his days of labor."

(01:18:51):

This is one of the punchlines. "It is the physical result of the fertility of the soil and of the wisdom far more than of the laboriousness of the means with which he is employed to render it fertile."

(01:19:03):

So that's the role of humans involving concepts, changing how we bring out the energy. "As soon as the labor of the husbandman produces more than his wants, he can with this superfluity that nature records him as a pure gift over and above the

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wages of his toil, there's energy return and energy invested by the labors of the other members of society. This latter in selling to him gain only their livelihood, but the husbandman gathers beyond his subsistence a wealth which is independent and disposable, which he has not bought and which he sells."

(01:19:36):

Now all the ideas we're talking about are tied up in that one paragraph.

Nate Hagens (01:19:41):

Earlier, you said you had a quote that you start with a seed and you plant it and nature gives you back 1,000 seeds. But what if the husbandman was really clever and found out a way to plant a seed and get back 2,000 seeds? The gift would still be from nature, but it was doubled because of his creativity and intelligence.

Professor Steve Keen (01:20:05):

That's the line in the middle, "It is a physical result of the fertility of the soil and of the wisdom far more so than their laboriousness." So in the terms of wisdom, what he's saying is we devise new ways of doing different things, and that wisdom is far more important than the effort we put in physically to do it. Again, our ideas play an essential role and we wouldn't be able to exploit this free energy without our minds that can devise new ways of harnessing the energy far more rapidly and far more effectively. The wisdom is definitely in there and the wisdom itself turns up on the machines. It's embodied in the machine. So all this stuff, it said right back in 1774. That paragraph has far more wisdom than the whole Wealth of Nations.

Nate Hagens (01:20:56):

So this is all kind of testable, although we're on a roller coaster ride. I think there's a possibility, and I know this is a totally separate conversation, that we could lose 20 percent of our energy in coming decades for various reasons.

Professor Steve Keen (01:21:15):

If we're lucky.

Nate Hagens (01:21:15):

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Or more, but let's just say 20 percent. So I would think that would cause a 20 percent or more drop in GDP. What would economists say?

Professor Steve Keen (01:21:28):

They'd say it would cause an 0.8 percent drop in GDP if they use the-

Nate Hagens (01:21:33):

0.8?

Professor Steve Keen (01:21:34):

Yeah. Yeah. That's a strict--

Nate Hagens (01:21:35):

And you think most economists actually believe that?

Professor Steve Keen (01:21:38):

Yep, I do. I've worked with them for long enough to know they swallow this stuff. When you look at the data, change in GDP and change in energy, that's Figure 57 at the moment in my book, it may change. But it's such a one-for-one relationship, it's ridiculous. And yet, they don't even look at it. And when Rudi Bachmann and friends made that comment about the 0.10 percent fall in energy, 0.4 percent fall in GDP, obviously they didn't look at the data and they ridiculed Leontief when Leontief actually reproduces the data.

Nate Hagens (01:22:16):

That would be like the opposite of a Nobel Prize. We should develop something like that.

Professor Steve Keen (01:22:20):

Well, the Nobel Prize is the opposite of a Nobel Prize. You are aware of that.

Nate Hagens (01:22:22):

No, I know. Okay, so there's that.

Professor Steve Keen (01:22:26):

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In economics, yeah. There's synergy.

Nate Hagens (01:22:29):

All right. Big, big picture. Let's move to the stratosphere here. What are the implications of everything that you've said for our modern society and for our future and for our decisions and planning for that moment?

Professor Steve Keen (01:22:43):

The fundamental of grounding is that without energy, there is no GDP. And we have been getting our energy out of fossil fuel forms. And of course with fossil fuels, we generate carbon dioxide. That is causing global warming and that is destabilizing the climate on which our production systems depend. Now we've been blind of that, particularly the economists who are so-called specialists in climate change, William Nordhaus and friends have no idea of this either.

Nate Hagens (01:23:11):

Right. So that's another flaw in the production function is there's not the waste capacity that feeds back in to the biosphere that is our only source of wealth. Because without oxygen and viable ecosystems, we all die.

Professor Steve Keen (01:23:25):

Yeah. No, that's not concluded in the way the neoclassicals think about climate change. And that's why you've got nonsense statements like by Nordhaus for example, saying that it's really, really difficult to find any direct impact, so the expected climate change on the bulk of the economy in the next 50 to 75 years. Now by the bulk of the economy, he meant all of manufacturing. He even included all of mining, services industries, government, et cetera, et cetera. He could see no way in which climate change will affect that. If we get a blanket ban on using fossil fuels because of totally destructive change to the climate in the next five years or so or 10 years, there'll be an incredible plunge in GDP and we're not prepared for it at all.

Nate Hagens (01:24:07):

I think if James Hansen and his colleagues are right, we're going to have a spike in climate warming temperatures in 2024 because we're shifting from the PDO, from La Nina to El Nino on the backs of the sulfur aerosols being reduced as a masking of the

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thermal inertia. So we're going to see. And if we go up a half a degree Celsius next year as they're suggesting, that's going to have massive impacts around the world. And then yes, you're right, people are going to be like, "Oh my god, this is real and our emissions are rising and fossil energy is to blame." But I think most people still don't understand the deep linkage between fossil energy and the size and scope of our economy because they're energy blind.

Professor Steve Keen (01:25:02):

Yeah. And economists have contributed this blindness rather than clarifying, that they are actually absolutely essential.

Nate Hagens (01:25:07):

And on your previous podcast here, this is your third appearance on this show, you predicted that economists, because of their identities and status and built personal situation, they will not change until there's a crisis. So can we anticipate what's going to happen with the environment with oil depletion, though that's going to happen gradually, with what's coming and create some blueprints and break glass in case of emergency plans that are actually based on what a physiocrat might advise the French king, the modern equivalent of that? Can we do that?

Professor Steve Keen (01:25:55):

I think it's incredibly late timing to be doing that, but as you know, we depended on fossil fuels for about 85 percent of our energy, and that hasn't changed much in the last 20 years. It's gone down to some extent for some time because of growth in fossil fuel production, decline in hydroelectric, which that's the main form of renewables even now is hydroelectric. It's not wind and solar. Potentially, we're going to see quite serious climate catastrophes is coming our way. Most of the climate scientists I'm in touch with are scared about are a global famine caused by a collapse in food output from one of the wheat belts or corn belts of the world, and that then leading to social breakdown because suddenly we haven't got the food we need. Or wet-bulb catastrophe is the other one, which would hit third world countries more than it would hit Westerners probably.

(01:26:54):

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But something which is catastrophic, which causes a massive collapse in population, and then leads to probably rogue behavior by governments around the world then, because we haven't managed to even reach an agreement to phase out fossil fuels, the last COP-out meeting. It'll be every country for itself in what could be a very chaotic environment, will be a very chaotic environment if we see something like a global famine.

Nate Hagens (01:27:22):

So you're saying that we shouldn't look to the neoclassical economists who are the current economic shaman and cheerleaders of our cultural narrative of the early 21st century? We shouldn't look to them to change their minds and chart a different course?

Professor Steve Keen (01:27:40):

They will be the most shocked and most confused by what happens completely. They're useless. They've led us astray. It's just been a cascade of errors right back to Smith, as I've said, that led us to the situation, but the last people that have any understanding of the physical role of production on the planet are economists, and the were last ones who realized the dangers of climate change are also economists. So I would just like to kick them out of the room. They don't belong here.

Nate Hagens (01:28:04):

I tend to agree, but let me play devil's advocate. There are a lot of bright pro-future young people in college, in graduate school, in postgraduate. Couldn't some of them take the kernels of truth bombs that you've been laying out here and contribute to the science and understanding and translate between what you're saying and the traditional neoclassical economics departments around the world? I suspect your answer is going to be no, because their boss and the people that gets the funding are the tenured economists and they're not going to fund this sort of research. Or what do you think?

Professor Steve Keen (01:28:47):

No, it's a waste of time. I mean, some of the young ones are worth reaching to say, "Look, for God's sake join Rethinking Economics, fight against your curriculum." But fundamentally, if you want people to give you guidance right now, it's going to be the

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engineers and they're the ones we should be... Get the engineers to look at it. The first thing an engineer is going to look at is the energy supply. That's just the nature of training of engineers. It's all about how you use energy and how you direct it to produce useful outcomes rather than blowing things up. So the engineers are the ones we need to rely upon, and we should have been getting them to build the alternative technologies in the last 40 or 50 years rather than me getting a lot of them to go off and work out as financial engineers instead and give us speculative bubbles in real estate and shares. We've had a huge misdirection of our intelligence for the last 40 or 50 years. And again, economists are to blame for that.

Nate Hagens (01:29:45):

When does your book come out and what's it called?

Professor Steve Keen (01:29:49):

Hopefully it'll be coming out. It depends upon the publisher's process, of course, but hopefully by March, I would say. And the title is going to be Rebuilding Economics From The Top Down.

Nate Hagens (01:29:59):

Well, I've read the energy chapter and it is quite compelling, Steve, I mean, you and I talk about what's going on now in the world, but I didn't know a lot of the things that you have dug up by reading these original papers. You also told me that most people in economics don't even read these original papers, so thank you.

Professor Steve Keen (01:30:21):

No, they never go back and read the original. Yeah.

Nate Hagens (01:30:22):

Originals. It's just shareable.

Professor Steve Keen (01:30:24):

Yeah.

Nate Hagens (01:30:25):

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This was a little bit of a Sherlock Holmes treatment of the history of the production function and the complete absence of energy in describing our wealth and productivity. And yet, energy is embedded in everything including the labor and capital functions. Do you have any closing words for listeners who might be a little shell shocked by this conversation?

Professor Steve Keen (01:30:53):

Just the main thing comes down to how economists, by not understanding energy, have trivialized the dangers of climate change. So we're likely to see that striking this decade. I mean, we both know the potential 0.5 degree increase in global temperatures out of both El Nino plus the hypothetical role of leaving the sulfur emissions has been masking some increase in global temperatures. That should cause absolutely chaotic weather probably starting in the next northern summer. So it's going to be brutally soon that this starts happening, and we have to prepare as soon as possible so all the XR activists dial it up, engineers start realizing we have to, as soon as possible, start producing whatever alternative system we can work out to reduce the amount of carbon we're putting into the atmosphere as soon as possible. That's the most important thing to have some potential to hang onto human civilization over the next two decades. If we don't do it, it's back to the Stone Age.

Nate Hagens (01:32:03):

Thank you, Steve, as always. To be continued, my friend, and good luck with your book.

Professor Steve Keen (01:32:07):

Thank you.

Nate Hagens (01:32:08):

And all your future sleuthing.

Professor Steve Keen (01:32:11):

Indeed.

Nate Hagens (01:32:12):

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