Science Matters, but Does it in Economics?

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Science has never mattered in economics, does not matter
and probably never will matter.

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PREFACE

The 2019 COVID pandemic did more than just test our resolve as a nation to deal with a deadly virus, it brought an important debate to a head, namely the role of science in public health. To some, science did not seem to matter. The analysis and recommendations of leading virologists were questioned and oftentimes ignored. For others, it was all that mattered. In 2021, I was invited to give a talk in France on the state of economics. It just so happened that a few years ago, the undergraduate economics student association (Université Laval) had asked me to give a talk on heterodox economics. Entitled *The Scientific Deficit in Economics* it examined the gap between the tributary fields of economics and the mainstream. My talk in France went further and asked whether science mattered in economics? – in short, examining the role of science in contemporary economics. This book is a refinement and extension of that undertaking, focusing on the fields of production theory, distribution theory and consumer theory. In short, it asks and attempts to answer whether science, specifically the laws of contemporary physics and psychology, matters in modern-day economics.

I would like to thank all those who provided comments and criticisms over the last few years. A special thanks to Christophe Faugère of the Kedge Business School for his support.

INTRODUCTION

Cursorily paging through both introductory and advanced textbooks in the field of modern-day economics, one gets the distinct impression that unlike its sister disciplines in the social sciences, economics is a truly scientific discipline, the physics of the social sciences. There, one finds mathematical models, rigorous proofs, data, statistical inference, empirical results and fact-based policy measures. Yet, unlike the pure and applied sciences, puzzles and paradoxes abound in economics. Despite decades of study, events like the Industrial Revolution, the Great Depression and the Productivity Slowdown continue to escape its grasp, casting considerable doubt on the value of the endeavor and raising a number of questions.

One such question is whether science matters in economics. It is generally agreed that economics is an applied science and not a pure one. In general, applied sciences are based on the laws and principles of pure science. A good example is biology where the only laws that are invoked are those of physics, specifically the laws of classical mechanics and thermodynamics. Chemistry is another example where the only laws that are invoked are those of physics.

It is also generally agreed that economics draws from the tributary fields of industrial engineering and psychology, with the former underlying production and the latter, consumption and behavior in general. But, is this the case? Beyond the hyperbole, is production theory truly grounded in the laws of industrial engineering? And is consumption theory grounded in behavioral psychology?

This volume answers these questions in the negative. In short, it is argued that science simply doesn’t matter in economics, has never mattered and will probably never matter. Instead, the field has taken it upon itself to redefine the laws of physics as they relate to work and productivity, and of psychology as they related to human behavior – in short, to carve out a distinct set of laws from physics and psychology.

The evidence is ubiquitous. Nowhere in production theory is there any mention of the laws of classical mechanics or thermodynamics. In their place are principles that oftentimes violate these very laws. Take for example the notion of the marginal product of capital. According to classical mechanics, tools (simple and complex) are not physically productive. Rather, they provide mechanical advantage. Only energy is capable of doing work and thus, of producing. A similar exercise for consumer theory would fail to turn up any of the principles which behavioral psychologists maintain underline behavior.

It is important at this juncture to distinguish science from the scientific method, with the former referring to the body of accepted, empirically-confirmed set of laws/results, and the latter to the methodology of science – hypotheses and tests. Judging from the contents of economic journals and both undergraduate and graduate programs in economics, it is clear that the scientific method is an integral part of the study of economics. Some of the most prestigious journals in the field deal exclusively with economic theory and econometrics.

However, the very use of the scientific method is not in and of itself sufficient to be scientific or to constitute a science when the underlying axioms violate known scientific laws. It's as if chemists were to disregard the existing laws of physics and thermodynamics and formulate a whole other set of laws or basic axioms based on experimentation.

This book examines the evidence. It consists of six chapters on topics ranging from the role of science in general in economics to the trouble with producer theory, to the trouble with distribution theory, as well as to the value of thinking like an economist. Other topics include the enigmatization of growth theory as well as examples of consilient science in the form of humanistic theories of consumer behavior. The latter is included as an example of how elements of the tributary field of psychology can be integrated in a meaningful way into consumer theory.

While the upshot of the book will appear to many to be overly pessimistic, this is certainly not our intention. Rather, we feel that the many failures listed above owe, in large measure, to the failure on the part of generations of scholars to see economics for what it is, namely an applied scientific discipline based on the tributary fields of physics and psychology.

1

SCIENCE MATTERS, BUT DOES IT IN ECONOMICS?

This chapter asks and attempts to answer the question, does science matter in economics? And, by science, it should be understood the basic behavioral science of psychology and the basic hard science of physics. It is argued that, in general, science does not matter in economics. The argument is based on an important distinction, namely that between a pure science and an applied one, with economics being the latter. In virtually all applied sciences, the results/laws of the associated pure sciences are the starting point. Economics, however, is unique in that it ignores its tributary sciences/laws. The reasons for this are examined, and a history of resistance is provided. It concludes by imagining what economics could look like if it followed other applied sciences.

1.1 Introduction

To most, the answer to this question is obvious: of course, science matters? After all, economics is a discipline which is based on the hypothetical-deductive method, one that generates predictions from a set of well-formulated axioms, and proceeds to test them using state-of-the-art statistical techniques (econometrics). It is a discipline that resembles, in its form, basic physics as evidenced by its use of sophisticated optimization techniques, both static and dynamic. The results are published in peer-reviewed, high-caliber journals. In short, the spitting image of a science *à la* Thomas Kuhn, or Karl Popper.

But is it? This account is based on a key presumption, namely that economics is discipline unto itself. That is, it is a distinct field of intellectual endeavor which seeks out a set of laws, a set of regularities. But is this the case? Is economics a pure discipline? In this chapter, we argue that it is not, but rather that it is an applied discipline based on a number of tributary disciplines, notably human psychology/sociology and physics/engineering.[1] Put differently, it seeks to understand the behavior of human beings, both at the individual and aggregate levels, as well as to understand the behavior of physical systems in the economic realm. As such, by definition, it relies on two or more tributary fields, namely psychology/sociology and physics.

In this regard, it is similar/analogous to other applied scientific disciplines like biology and chemistry which are based on the basic, fundamental science, physics—notably classical mechanics and thermodynamics. Another example is engineering which is also based on basic physics. In both cases, the tributary sciences are not only acknowledged, but are an integral part of laws and regularities that together define the discipline. In short, science matters for these sciences.

In this chapter, we claim that this is not the case in economics. In short, science does not matter in economics, and hasn't mattered from the very beginning. By science, it should be understood, the recognition and incorporation of the very elements of the fundamental sciences of physics and psychology. The latter is defined broadly to include neuroscience and neural endocrinology. The chapter is organized as follows. To begin with, we examine the reasons for this as well as the various attempts by economists and non-economists over the course of the past two and one half centuries to integrate basic science into the study of wealth. Second, we show using examples how doing so can provide important insights into a number of puzzles in economics. Lastly, we speculate on the future of science in economics. In other words, while science doesn't matter, will it one day?

1.2 Fundamental versus Applied Science and Why Science Doesn't Matter in Economics

It is generally agreed that the hard sciences are characterized by a unique hierarchy, with physics at the top, and all others, being specific applications. More specifically, classical mechanics, thermodynamics, and kinetics are considered to be the core, or the fundamentals, while biology, chemistry,

[1] Our definition of human psychology/sociology includes neuroscience and neural endocrinology.

engineering, and astronomy as specific applications.[2] A good example of this is biology where the first law, “per se,” is that all living organisms obey the laws of thermodynamics (Trevors and Saier Jr. 2010, 88). The latter, it therefore follows, becomes the starting point of all inquiry. As such, there are no basic biological laws “per se,” only field-specific applications of the laws of thermodynamics (and other sub-disciplines). The same holds true in engineering where the laws of physics, mostly classical mechanics and kinetics, are the starting point.[3]

Is this the case in economics, which after all, is the science of wealth, wealth creation being a material process? The answer, unfortunately, is no. Instead, what we find is an applied scientific discipline that has boldly set out to define a parallel set of laws, ignoring fundamental science. Take, for example, production theory where capital is assumed to be physically productive and moreover, it behaves according to the law of diminishing returns/marginal productivity. Yet, according to classical mechanics, tools (simple and complex) are not seen as physically productive as they are not a source of energy. The same holds for labor, which in an industrial setting, is not physically productive as it too is not a source of energy (i.e. for the underlying material process). In human biology, this is equivalent to arguing that our bones and brain are the source of life, the *vis vitalis* of our existence. Or that in photosynthesis, chlorophyll is an/the energy source.

Admittedly, this is surprising given the proximity of economics to process engineering where fundamental science constitutes the starting point. Both disciplines have the same objective, namely understanding the material processes that together account for the World’s wealth. This then begs the question, why? Why has economics ignored fundamental science, and why does it continue to do so? In other words, why does science not matter? In the next section, we offer a number of reasons, ranging from the

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[2] Physics is the most basic science because it studies the most basic phenomena. In biology and chemistry, for example, you study things that move - in physics, you study motion itself. In biology and chemistry, you make use of the concepts of force, heat, etc. - in physics, force, heat, electricity, etc. http://batesville.k12.in.us/physics/PhyNet/AboutScience.

[3] Similarly, plant biologists don’t reinvent the basic laws of thermodynamics/classical mechanics. Life scientists don’t reinvent the Krebs Cycle. Process engineers don’t ignore classical mechanics/kinetics. Astrophyscists don’t ignore Newton’s laws.

evolution of the discipline, to the various controversies that have marked its history, to the very way in which knowledge is publicized (i.e. via journals).

1.3 Why Has Economics Ignored Its Tributaries?

Why is it that dialogue across what are related fields is, for all intents and purposes, non-existent in economics? Why haven't process engineers teamed up with growth theorists to understand the intricacies of past (and hopefully future) growth? Why have the very people who have a firsthand understanding of the very processes underlying growth been left out, not even consulted? Why have behavioral psychologists been absent from consumer theory? Why is behavior as modeled in economics orthogonal to any and all work in psychology, to the point that dialogue is virtually impossible? In this section, we present a number of non-mutually-exclusive reasons, from the early history of the discipline, to the ideology and propaganda of the 19th century, to the medium of diffusion of results (journals as opposed to books), to the creation of a Nobel prize.

1.3.1 Tabula Rasa

The first reason we advance is the very history of the discipline, namely that it predates its fundamental, tributary disciplines. Economics has a history that dates back to the mid-18th century, a time when psychology and thermodynamics were non-existent. Moreover, early work such as Adam Smith's "An Inquiry into the Nature and Causes of the Wealth of Nations" was about the newly-discovered, Watt steam engine (fire power). As such, when Smith was confronted with the daunting task of describing the effects of the steam engine on wealth, he had to resort to primitive notions, couching his analysis in what was a Paleolithic, labor-centric view of production, one that focused on labor. This became known as the classical theory of production, with a single factor input, namely labor. Chapter 1 of the Wealth of Nations enumerates the various ways in which specialization (code for the adoption of the steam engine/fire power) increases labor productivity.

From a purely Newtonian point of view, this was absurd, as the steam engine would for all intents and purposes, replace labor as the source of work, transforming it into a mere organizational factor input, overseeing the workings of machinery—-what Alfred Marshall would, a century later, refer to as machine operatives. That this be the case is not surprising as Smith, a moral philosopher, was not a natural philosopher (i.e. schooled in Newtownian physics). Not helping matters was the fact that steam/fire power as a force was not well understood—in fact, not understood at all. It would take a century before thermodynamics, the science of heat, would do so.

However, economics or political economy could not wait. The introduction of the steam engine/fire power and its widespread adoption in the 19th century with all the associated problems and challenges, obviated the need for a science, however imperfect or unscientific. Among the most pressing problems were the business cycle and the apparent failure on the part of England to make a successful transition to the new, higher GDP in response to the steam engine. Rather than greater wealth, the steam engine ushered in periods of higher unemployment and misery.

Similarly, the quest to understand markets (demand and supply) could not wait for a comprehensive theory of consumer behavior based on universally-agreed-upon principles/regularities of human behavior (i.e. psychology). Instead, stylized theories were advanced, the best example being utility theory. The point is that what could be referred to as the economics imperative could not and did not wait for there to be a well-developed set of fundamental sciences, one describing the behavior of physical systems (i.e. production) and the other, describing the behavior of human systems.

1.3.2 The Labor Theory of Value and the Problem of the Existence and Stability of Equilibrium

This, however, raises an interesting question, namely that while it is true that economics predates the fundamental fields, why were their insights not incorporated at a later date? In other words, why did economics not evolve, why did it not update itself? The answer, we argue, lies with two developments, namely the rise of radical economics in the early-to-mid 19th century with Karl Marx as its main proponent, and second, the resulting allegation that private market economies were inherently unstable, and more importantly, contained the seeds of their own destruction. Both of these were instrumental in the widening divide between economics and fundamental science, notably thermodynamics.

Karl Marx's magnum opus, *Das Kapital* published in1867 was a turning point of sorts, as it turned classical production theory on its head. If labor was the only productive factor input, then it stood to reason that the owners of labor were the only ones entitled to the spoils. In short, profits were a form of theft. This followed from the fact that capital was not physically productive. The classical response was swift, coming with the publication of William Stanley Jevons' *The Theory of Political Economy* in 1872 were capital was simply decreed to be productive. Using the language of thermodynamics, it was decreed to be physically productive, complete with a marginal productivity, thus justifying profits as legitimate, both physically and legally. The result was neoclassical production theory based on two, non-physically-productive factor inputs.

This, we maintain, *de facto* stifled progress in the field as it provided the long-sought legitimization of profits not as a form of theft, but as being earned or merited. Any and all critiques were dismissed outright, as they constituted a clear and present threat to the established order.

Another factor that *de facto* stifled progress was the problem of equilibrium, specifically general or macroeconomic equilibrium. One of the key predictions of radical economics was the inevitability of overall, systemic collapse. According to Karl Marx, capitalism contained the seeds of its own destruction. Given the recurrent downturns in U.K. GDP throughout the 19^{th} century, some greater than others, this became a going concern. Clearly, the onus was on classical and neoclassical economists to prove, mathematically or otherwise, that private market economics could reach a full-employment equilibrium, one that was unique and most importantly, stable. From the late 19^{th} century onwards, the quest to prove that such an equilibrium existed would occupy the thoughts of leading figures such as Leon Walras and Vilfredo Pareto.

However, as their work makes clear, the task was far from obvious. In short, to arrive at such a proof, the starting point had to be simple, namely excess demand functions that were analytical. And this required a simple model of consumer and producer behavior. This would continue to be the case in the 20^{th} century when new methods from topology would be used (Brouwer and Kakutani's fixed-point theorems).

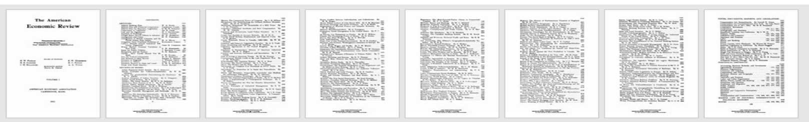
As has been the case in all highly-formalized work involving advanced optimization techniques, the starting point had to be as simple as possible. This, we argue, has contributed to stifling even further, the emergence of more consilient models of consumer and producer behavior. Put differently, mathematical elegance and tractability pre-empted more realistic approaches to consumer and producer behavior. A case in which formalization acted and continues to act as a constraint on progress.

Moreover this had a rather pernicious effect on first principles. Specifically, the profession reverse-engineered, as it were, the results of GE analysis to first principles—consumer and producer theory. Simple max U(x) and max π(q) became the standard in microeconomics, thus pre-empting any and all refinements. After all, anything other would negate GE analysis and results.

1.3.3 The Decline of Pamphlets/Treatises/Volumes and the Rise of Scholarly Journals

For most of its history, the findings in economics were diffused through either pamphlets or books. In fact, most of that which today constitutes the core curriculum in modern economics originated in pamphlets or books, not in journal articles. While this to most will appear or seem irrelevant or inconsequential, we believe that it has an important bearing on the evolution of economics. Specifically, journal articles are not, in general, conducive to Kuhnian-like paradigm shifts in thought, owing in large measure to the length and purview of the contents. In short, journal articles are more conducive to the propagation of, the refinement of, and the testing of the canons of the field/science. For example, in economics, articles on consumer theory seek to validate, refine, or extend the basic utility maximization model. To my knowledge, there is not one article that single-handedly changed the course of a field or the profession itself.

Figure 1.1
American Economic Review 1911 Table of Contents



Historically, economic journals evolved from being a combination of book reviews and short articles/comments to exclusively devoted to the latter. Take, for example, the American Economic Review, founded by a group of politically-minded scholars, which in its early years devoted more space to book reviews than it did to articles. Figure 1.1 shows the contents of the inaugural volume of the American Economic Review. What is particularly noteworthy is the fact that of the seven pages of content, six and one-half are book reviews, the other half being articles. In other words, it accorded more importance, in so far as the advancement of the field was concerned, to new ideas/concepts than it did to refinements of existing ones. The same was true of the Journal of Political Economy whose inaugural number contained 36 book reviews and 24 articles.

This changed in the post-WWII period when the focus shifted away from book reviews, over to journal articles exclusively. One could argue that this was the result of two developments, namely the rise of Keynesian macroeconomics and the publication of Paul Samuelson's Foundations of Economic Analysis, both of which served to provide the field with a pseudo-scientific set of laws. Both became the reference and thus starting point for work for years to come. Interestingly, neither had anything to do with fundamental science, despite the highly mathematical nature of *Foundations of Economic Analysis*.

This shift had the unfortunate effect of stifling progress in what could be referred to as economic fundamentals. Today, consumer theory remains largely unchanged as does the theory of the firm. While economics has witnessed the introduction of new, more sophisticated optimization techniques (duality etc.), the core has remained largely unchanged. Few leading journals are prepared to take risks, with the result that little progress has been observed. Add to this the fact that the gatekeepers (i.e. the editors) have a stake in the existing paradigm and you get a form of sclerosis, where journals essentially reproduce existing knowledge.

1.3.4 A Nobel-like Prize in Economics

Perhaps the crowning achievement of the economics profession in so far as its scientificity is concerned was the creation in 1968 of a Nobel prize in economic sciences. For one, it *de facto* consecrated economics as a bona fide science, distinct from all other social sciences (moral philosophy), thus dissipating any and all doubts as to its "scientific" status.

However, considering the various laureates and their contribution, what stands out is the lack of connection with the other scientific Nobel prizes—that is in physics, chemistry and medicine. In many cases, prizes given in medicine could well have been given in chemistry or physics, and vice-versa, a testimony of the universal nature of science (fundamental and applied). For example, the 1997 prize in Medicine, awarded to Paul Boyer for his research on ATP, could well have been awarded in chemistry or physics for that matter.

Despite the fact that wealth creation is a material processes, like all other material processes in the known universe, no such collegiality exists in economics. Not one of the prizes in economics could have been awarded in the other three scientific categories. One could argue that this is evidence that science does not, *de facto,* matter.

1.4 Science Matters: A Litany of Missed Opportunities

Over the course of the past two centuries, there have been a number of attempts by political economists and non-specialists to invoke/infer elements of basic science into the core of economic analysis. In this section, we examine a handful of these, ranging from Charles Babbage's 1832 masterpiece "On the Economy of Machinery and Manufactures," to 1921 Nobel Prize laureate (Chemistry) Frederick Soddy's attempt to rewrite production theory, "Cartesian Economics." The discussion will be organized around two themes, namely contributions that were ignored altogether, and those that were ignored for ideological reasons, the latter including Karl Marx's incursions into the realm of engineering.

1.4.1 Charles Babbage's On the Economy of Machinery and Manufactures 1832

Perhaps the earliest attempt at invoking basic science as a guide to understanding industry was that of Charles Babbage in 1832. In *On the Economy of Machinery and Manufactures,* he provided detailed scientific descriptions of the new power drive technology that was steam power.

Consider, for example, the following excerpt where classical mechanics is used to illustrate the contribution of wind, water, and steam.

> Of those machines by which we produce power, it may be observed, that although they are to us immense acquisitions, yet in regard to two of the sources of this power, the force of wind and of water, we merely make use of bodies in a state of motion by nature; we change the directions of their movement in order to render them subservient to our purposes, but we neither add to nor diminish the quantity of motion in existence. When we expose the sails of a windmill obliquely to the gale, we check the velocity of a small portion of the atmosphere, and convert its own rectilinear motion into one of rotation in the sails; we thus change the direction of force, but we create no power....The force of vapour is another fertile source of moving power; but even in this case it cannot be maintained that power is created. Water is converted into elastic vapour by the combination of fuel. (Babbage 1832, 15)

Interestingly, he devoted a whole chapter to speed or what he referred to as "velocity." Chapter 4, entitled "Increase and Diminution of Velocity," showcased using industry-specific examples the role of increased speed as a key feature of mechanization.

> In turning from the smaller instruments in frequent use to the larger and more important machines, the economy arising from the increase in velocity becomes more striking. In converting cast into wrought iron, a mass of metal, of about a hundred weight, is heated almost to white heat and placed under a heavy hammer moved by water or steam power. This is raised by a projection on a revolving axis; and if the hammer derived its momentum only from the space through which it fell, it would require a considerably greater time to give a blow. But it is important that the softened mass of red-hot iron should receive as many blows as possible before it cools, the form of the cam or projection on the axis is such, that the hammer, instead of being lifted to a small height, is thrown up with a jerk, and almost the instant after its strikes a large beam, which acts as a powerful spring, and drives it down on the iron with such velocity that by these means about the double the number of strokes can be made in a given time. (Babbage 1832, 26)

Whereas previous writers referred to specialization, Babbage provided a detailed account of the role of power in material processes in general, and the role of steam power in U.K. manufacturing. Further, he perspicaciously was the first to formalize the role of rotary motion/power in material processes, alluding to the importance of velocity or put differently, machine speed. To Babbage, science mattered. Unfortunately, Babbage did not matter to political economy as evidenced by his absence from the overall record.

1.4.2 Frederick Soddy's 1924 Cartesian Economics

Another early 20th-century dissenter was British Nobel-prize laureate chemist Frederick Soddy, who after his pioneering work with Ernest Rutherford on atomic transmutation turned his attention to economics, largely in response to the alleged "misspecification" of production theory, more to the point, to the absence of energy from the analysis. The gist of his critique can be found in the following allegory:

> At the risk of being redundant, let me illustrate what I mean by the question, How do men live? by asking what makes a railway train go. In one sense or another the credit for the achievement may be claimed by the so-called 'engine-driver', the guard, the signalman, the manager, the capitalist, or share-holder, or, again, by the scientific pioneers who discovered the nature of fire, by the inventors who harnessed it, by Labour which built the railway and the train. The fact remains than all of them by their united efforts could not drive the train. The real engine-driver is the coal. So, in the present state of science, the answer to the question how men live, or how anything lives, or how inanimate nature lives, in the sense in which we speak of the life of a waterfall or of any other manifestation of continued liveliness, is, with few and unimportant exceptions, By sunshine. Switch off the sun and a world would result lifeless, not only in the sense of animate life, but also in respect of by far the greater part of the life of inanimate nature. The volcanoes, as now, might occasionally erupt, the tides would ebb and flow on an otherwise stagnant ocean, and the newly discovered phenomena of radioactivity would persist. But it is sunshine which provides the power not only of the winds and waters but also of every form of life yet known. The starting point of Cartesian economics is thus the well-known laws of the conservation and transformation of energy, usually referred to as the first and second laws of thermodynamics. (Soddy 1924, xi)

In short, according to Soddy, energy is the cornerstone of all human activity, including production. Labor, capital, information, technology etc.

are all accessory inputs, necessary for but not the actual source of wealth. Despite much promise, the proposed Cartesian economics, based on the laws of basic physics (mechanics and thermodynamics) failed to make inroads into mainstream economics.

1.4.3 F.G. Tryon

To many observers in the early 20th century, the U.S. was in the midst of an industrial revolution, one to which the economics profession appeared to be oblivious. F.G. Tryon of the Institute of Economics (Brookings Institution) was among the first to point to the incongruity between production processes as modeled in economics and those observed in early 20th-century America.

> Anything as important in industrial life as power deserves more attention than it has yet received by economists. The industrial position of a nation may be gauged by its use of power. The great advance in material standards of life in the last century was made possible by an enormous increase in the consumption of energy, and the prospect of repeating the achievement in the next century turns perhaps more than on anything else on making energy cheaper and more abundant. A theory of production that will really explain how wealth is produced must analyze the contribution of this element of energy.
>
> These considerations have prompted the Institute of Economics to undertake a reconnaissance in the field of power as a factor of production. One of the first problems uncovered has been the need of a long-time index of power, comparable with the indices of employment, of the volume of production and trade, of monetary phenomena, that will trace the growth of the factor of power in our national development [Tryon (1927),281].

1.4.4 Technocracy as Defined by Howard Scott

In little time, this incongruity reached academia, specifically Columbia University where a group of engineers, known as the Technocracy Alliance outrightly rejected mainstream approaches to understanding wealth (essentially neoclassical production theory), arguing that they ignored mechanics, thermodynamics, process engineering and with the state of the art regarding material processes in general.[4]

Foremost in the minds of the "dissidents" was the fact that while America's capacity to produce wealth was increasing, actual wealth appeared to be stagnant, prompting various calls to action. One such call came from the engineering department at Columbia, where Walter Rautenstrauch and Howard Scott launched the technocracy movement. In short, it contended that mainstream economics in general and production theory in particular were irrelevant, not to mention incomplete and unscientific, and in need of a major overhaul. The latter would be grounded in thermodynamics in general and in energy in particular. In short, while perhaps not fully aware of it, the Technocrats were attempting to steer economics back on to a course similar to that taken by thermodynamics in the 19th century, one based on the scientific underpinnings of material processes in economics.

For example, in *Introduction to Technocracy,* by Howard Scott, published in 1933, the first 10 pages contained a rendition of basic applied physics, thermodynamics and kinetics. This would then constitute the basis of the new science of wealth, one based on the laws of physics.

> The eighteenth century say the introduction of the powered machine, which was first conceived as an extension of the hand operations of craftsmen. The close of the nineteenth century witnessed the machine process occupying a dominant place in the technological scheme and reshaping men's habits and methods of thinking., The turn of the century marked the introduction and the accelerating rise, under guidance of science of the modern, continuous technological processes of production. In this new industrial order, the machine was no longer conceived as an extension of the hand tool; it became a moving mechanical element in a sequence of events, the course and rate of which had been arranged and ordered in strict accordance with the exact quantitative calculations of science. Men in the fields of scientific inquiry and technological research, the same as those directly engaged in technological employment, gradually ceased to think in terms of workmanlike efficiency of a given cause working to like effect: they began to think in terms of process. (Scott 1933, 8)

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[4] While the Technocracy movement went through a number of iterations, organization-wise, our analysis will refer to the movement in general.

As mentioned, the driving force was the view that energy-related innovations (electric unit drive in particular) had increased America's ability to produce without a concomitant increase in income and expenditure, leading to stagnation, unemployment and a full-blown depression. The movement offered both a detailed diagnosis of the problem as well as a series of corrective measures/reforms (an energy monetary standard, guaranteed income). It, however, lost much of its appeal with the rise of Keynesian economics, which provided a less radical fix. In short, animal spirits replaced the energy shock as the cause of the depression.

Such boldness, especially from non-practitioners, was met with great resistance from the profession. For example, University of Chicago economics professor Aaron Director, in a pamphlet entitled, *The Economics of Technocracy,* seriously doubted its usefulness, arguing that mainstream economics and production theory was better suited to analyze the issues it sought to address. To begin, he summarized Technocracy in terms of six points:

> 1-The importance of energy: —Through the expenditure of energy we convert all raw materials into products that we consume and through it operate all the equipment that we use." This, of course, has always been familiar to us, except that it was stated in terms of work, and not of energy. The great merit of the latter term is the possibility of dragging in the Law of Conservation of Energy and this marrying physics to the social mechanism.
>
> 2-Energy can be measured, and the unit of measurement is always the same, while the dollar varies from time to time.
>
> 3-The chief distinction between our society and that of all previous societies isthe much greater amount of energy which can be generated. This has always been recognized by the designation of our civilization as the machine era.
>
> 4-With every increase in the amount of mechanical energy the need for labor decreases.
>
> 5-The present depression marks the end of an era, since the increase in mechanical energy has at last become so great that, regardless of what happens, the need for human labor will rapidly decline.

> 6-Does it follow, therefore, that the price system must break down, and that only the engineers can run a mechanical civilization. (Director 1933, 8)

He then proceeded to re-examine, using standard neoclassical analysis, each of these points. In keeping with the 19th-century tradition of equating energy with machinery, the shock was cast in terms of "technical progress," and not of energy deepening. This was then followed by a Ricardian-inspired analysis of the effects of "technical progress" on costs, wages and prices. Competition, he argued, was a sufficient condition for full employment.

> On the other hand, the technocrats maintained that a more scientific utilization of existing equipment would result in a much larger product: "It is only necessary to insist that the number of engineers in industry far outweigh the number of economists, and if these engineers are to run industry in the future, they should be competent to point out methods of improving efficiency. It is not enough to hide behind a barrage of words. It should be patent to the most critical observer that the one thing which the individual enterprise under competitive conditions does strive for is to reduce its cost, regardless of the consequences on employment.' (Director 1933, 16)

Having concluded that "technical progress is not incompatible with full employment," he proceeded, in Chapter VII, to debunk the view that the Great Depression was the result of energy-based technological change. This, metaphorically speaking, is where the gloves came off. First, he, in the tradition of Say and Ricardo, ruled out underincome. Output, he argued, is identically equal to income, whether in the form of money or in kind.

> If there were no commercial banking system, the national income would be distributed for consumption goods and the production of additional equipment in accordance with the desires of the community. The output of industry is equal to the income of the laborers employed in it and of the property owners whose capital is invested in it. Clearly, if entrepreneurs borrowed funds directly from the income receivers, they could not continue to produce capital equipment in excess of the amount which income receivers were willing to save. (Director 1933, 21)

In short, according to Director, Technocracy offered nothing new, and, more importantly, was riddled with the most elementary of oversights and errors. Energy was nothing new, and, more importantly, presented no particular challenge to mainstream political economy. Technological progress, in this case, electric drive, increases, in a commensurate fashion, income, wages and profits. The causes of the Great Depression, he argues, lie elsewhere, notably in "the war, the resulting debts, and tariffs."

1.4.5 Nicholas Georgescu-Roegen's The Entropy Law and the Economic Process 1971

Nicholas Georgescu-Roegen's *The Entropy Law and the Economic Process* is another example of basic science at the core of economics. Its premise is straightforward, namely that thermodynamics is based on two laws: the first law states that energy is neither created nor destroyed in any isolated system (a conservation principle). The second law of thermodynamics – also known as the entropy law – states that energy tends to be degraded to ever poorer qualities (a degradation principle).

Georgescu-Roegen argued that the relevance of thermodynamics to economics stems from the physical fact that man can neither create nor destroy matter or energy, only transform it.

The usual economic terms of production and consumption are mere verbal conventions that tend to obscure that nothing is created and nothing is destroyed in the economic process – everything is being transformed.

He recognized that capital as defined in economics was not physically productive. Rather, that role was assumed by energy. In Georgescu-Roegen's terminology, energy may have the form of either a stock factor (mineral deposits in nature), or a flow factor (resources transformed in the economy); but never that of a fund factor (man-made capital in the economy). Hence, in response to Robert Solow's 1974 claim that capital could be substituted for energy, he argued that such a substitution is physically impossible.

Unfortunately, his message was lost on production theory which remained unfettered (i.e. neoclassical). While entropy, or the degredation of matter is today recognized, especially in ecological economics, the role of negentropy in production continues to be ignored.