WHY ECONOMICS IS AN EVOLUTIONARY, MATHEMATICAL SCIENCE:

HOW COULD VEBLEN'S VIEW OF ECONOMICS BEEN SO DIFFERENT THAN C. S. PEIRCE'S?

BY JAMES R. WIBLE*

Abstract

More than a century ago one of the most famous essays ever written in American economics appeared in the Quarterly Journal of Economics, "Why is Economics Not an Evolutionary Science?" There Thorstein Veblen claimed that economics was too dominated by a mechanistic view to address the problems of economic life. Since the world and the economy had come to be viewed from an evolutionary perspective after Darwin, it was rather straight forward to argue that the increasingly abstract mathematical character of economics was non-evolutionary. However, Veblen had studied with a first-rate intellect, Charles Sanders Peirce, attending his elementary logic class. If Peirce had written about the future of economics in 1898, it would have been very different than Veblen's essay. Peirce could have written that economics should become an evolutionary mathematical science and that much of classical and neoclassical economics could be interpreted from an evolutionary perspective.

* Department of Economics. Paul College of Business and Economics, University of New Hampshire. Contact: Jim.Wible@unh.edu

The preprint may be cited as follows:

Wible, James R. Why Economics is an Evolutionary, Mathematical Science: How Could Veblen's View Of Economics Been So Different Than C. S. Peirce's? *Journal of the History of Economic Thought* (forthcoming). Preprint at *SocArXiv*, osf.io/preprints/socarxiv

Why Economics is An Evolutionary, Mathematical Science:
How Could Veblen's View of Economics Been So Different than C. S. Peirce's?[1]

> There is the economic life process still in great measure awaiting theoretical formulation. Thorstein Veblen (1898, p. 387)

> Economists of the present day are commonly evolutionists, in a general way....But the habit of handling by evolutionist methods the facts with which their own science is concerned has made its way among the economists to but a very uncertain degree.
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> Thorstein Veblen ([1900] 1919, p. 176)

I. INTRODUCTION

More than a hundred years ago one of the most famous essays ever written in American economics appeared in the *Quarterly Journal of Economics*. In 1898, Thorstein Veblen, wrote what became one of the most widely read critiques of that era, "Why is Economics Not an Evolutionary Science?" In that essay, Veblen claimed the discipline was too dominated by a mechanistic mind set to address the real problems of economic life. Since the world and the economy had come to be viewed from an evolutionary perspective in the aftermath of Darwin's (1859) *Origin of Species*, an intellectual opening was created allowing for the argument that the

[1] I would like to thank Steve Meardon, Robert Dimand, Guy Numa, Karen Conway, anonymous readers and the editor for very helpful comments on earlier drafts of this paper.

increasingly mathematical and abstract economics of English classical and neoclassical vintage, also prominent in American economics, was non-evolutionary and mechanistic. Of course, the overall impression from Veblen's critique was that what passed for mainstream economics in that era was behind the times and not as scientific as it should be. Eight decades later, Kenneth Boulding (1981) authored his own perspective in his *Evolutionary Economics* claiming that Veblen did not understand what an evolutionary science could be. One can make an evolutionary interpretation of neoclassical economics as Boulding has done. Others such as Alchian (1951) and perhaps Friedman (1953), Hayek (1945), and Georgescu-Roegen (1971) may have done so as well in very different ways. What is extraordinary is that Veblen actually crossed paths with a first-rate intellect and scientist who was fashioning an evolutionary conception of economics including mathematical economics long before Boulding, Alchian, Hayek, Friedman, and Georgescu-Roegen. That individual was Charles Sanders Peirce, a Harvard graduate of 1859.

Peirce was a natural scientist, a mathematician, one of the best philosophical minds America has ever produced, and he had an active interest in economics, mathematical economics, abstract mathematics and logic, and evolutionary science and philosophy. Veblen crossed paths with Peirce during the time that Veblen spent at Johns Hopkins University in the early 1880s according to his biographer (Dorfman 1934, p. 41). While at Johns Hopkins, Peirce would extend his emerging ideas on science, evolution, philosophy, and mathematics. By the late 1880s he had created an evolutionary vision of a world accessible with human cognition, mathematics, and mathematically framed sciences. In the early 1890s, Peirce published a now famous set of essays in a new American philosophy journal *The Monist* sketching out some of the broad thematic aspects of an evolutionary and mathematical conception of the universe. The

last essay of that series addressed economic issues in part (1893a) and an earlier one had developed the themes of determinism and mechanism (1892a). While the *Monist* essays would have been accessible to Veblen in his time, Peirce's extensive writings on mathematics and his few pieces on mathematical economics would have been almost prohibitively difficult to obtain without personal contact between Peirce and Veblen. Nonetheless, with more than a century of hindsight, it is becoming clear that one of Veblen's graduate school professors, C. S. Peirce, had a much more mathematical conception of economics than what Veblen did even though both were evolutionary. Whether Veblen should be considered a "student" of Peirce's or as someone who was significantly impacted by him remains.

If Peirce had written an article about the future of economics in 1898 it would have been very different than the one Veblen wrote. Peirce could have written that economics should become an evolutionary mathematical science and that much of classical and neoclassical economics could be interpreted from an evolutionary perspective – and the same for mathematics and mathematical logic. In 1898 Peirce would give his Cambridge Conference Lectures which elaborated his mathematically framed conception of an evolutionary universe which was at the core of his *Monist* essays just a few years earlier. His "preconceptions" of science and philosophy included an understanding of how very abstract mathematics functions in an evolutionary universe. In contrast, in his 1898 essay Veblen's critique is that applications of mathematics and statistics and thus the mathematical economics of his time had become predominantly ill-suited for understanding evolutionary processes. Veblen's ([1908] 1919) position on economics and mathematics did evolve so that a few years later he seems to have backed off to a less categorical interpretation of mathematics and recognized a weak evolutionary aspect to the economics of his time. However, this weak aspect using his own

words from the earlier paper – "is not enough" – to make economics an evolutionary science (1898, p. 394). In that lesser known 1908 article, Veblen seems to reconsider the evolutionary character of mathematics itself. Perhaps surprisingly he recognizes that pure mathematics may not be mechanistic. Before taking that position, Veblen does seem to portray the stance of most applied mathematical scientists of his own time as taking an instrumentalist perspective so that they do not really need to answer more fundamental questions about the meaning of theory and mathematics if their science appears to be making progress in statistical and empirical terms.

II. VEBLEN'S ECONOMICS "IS NOT" AN EVOLUTIONARY SCIENCE ESSAY

For nearly a century C. S. Peirce has been considered as one of the founding influences of institutional economics. In large part this is due to two of the founding figures of institutional economics who crossed paths with Peirce at Johns Hopkins University when they were enrolled as graduate students there in the early 1880s. Both Thorstein Veblen and John Dewey enrolled in Peirce's elementary course on logic but their times at that university did not overlap. Also, Peirce's more advanced students, those more mathematically and logically inclined, took his advanced logic course which was much too rigorous for the other graduate students. Those advanced students were the ones who published a research volume with Peirce (1883a) to mark the tenth anniversary of Johns Hopkins University.[2] It did not include either Veblen or Dewey.

[2] It is the graduate students in the advanced logic class who would be more likely to be considered as Peirce's "students" in the sense of those whose research was actively advised by Peirce.

This fact alone suggests that neither Veblen nor Dewey was highly enough trained in mathematics, science, and logic to appreciate Peirce's more mathematical and rigorous version of pragmatism which he rebranded as pragmaticism in the early 1900s.

Richard Ely also was on the faculty at Johns Hopkins although there appears to be no record of any direct interconnection between Peirce and Ely. At Johns Hopkins, Ely was significantly and adversely impacted by the astronomer/economist Simon Newcomb who had been a mathematics student of Benjamin Peirce, Charles' father, at Harvard. Newcomb was a decades-long acquaintance, critic and opponent of both Charles the son and Ely. Newcomb or even Fisher could have been a foil for Veblen's critique of applied mathematical economics as mechanistic and taxonomic. Veblen apparently never referenced Peirce or Newcomb.

Dewey (1938), near the end of his career and after Peirce had died, did mention and cite Peirce especially in his *Logic: The Theory of Inquiry* and in three reviews of Peirce's newly published collected papers which appeared in the 1930s.[3] By then logic had become much more rigorous as well and had moved beyond the logic that Dewey knew. Many early 20th century economists apparently learned about Peirce from Dewey's lectures at Columbia University. Dewey's course and his reviews appear to be the avenue of connection conveying Peirce's philosophy of pragmatism to a subsequent generation of institutionalists[4].

Mentions of a connection between Veblen and Peirce seem to have begun with Veblen's biographer, Joseph Dorfman. It was Dorfman (1934, p. 41) who notes that Veblen reported

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[3] For Dewey's writings on Peirce that could have influenced American economists see Dewey (1923, [1925] 1984, [1932] 1982, [1935] 1982, and [1937] 1982).

[4] Rutherford (2011, pp. 224, 234-235) notes prominent institutionalists who studied with Dewey.

taking Peirce's class in a letter when he appealed for a scholarship at Johns Hopkins University. More substantively, Dorfman in that same passage also claims that Veblen took several key ideas from Peirce – his conception of the function of human thought and habits of action, a conception of guiding principles, and his philosophy of inquiry. The topic of a possible connection between Peirce and Veblen would be raised again by Alan Dyer. It was Dyer (1986) who asserted that Veblen learned his view of the imaginative creativity of the scientific process from Peirce. Then came an article by Robert Griffin (1998) with an apt title – "What Veblen Owed to Peirce ...." Griffin recognized that there may be no direct evidence connecting Peirce and Veblen. Griffin (1998, p. 734) wrote: "Unfortunately, Veblen wrote nothing about Peirce and never referred to him." Nevertheless, Griffin still asserted that Veblen may have been influenced significantly by Peirce. Among other possibilities, Griffin maintained that Veblen's conception of adaptation came from the philosopher Immanuel Kant and was very similar to Peirce's pragmatic maxim. Also from Griffin is the claim that Peirce's method of tenacity for fixing human beliefs has an analogue in Veblen's explanation of why economists may tenaciously hold their beliefs. Closer to the present, Hall and Whybrow (2008) have maintained that the idea which may have most significantly impacted Veblen was Peirce's conception of continuity in evolutionary processes.

Casting the net a bit wider, other prominent figures in institutional economics such as Commons (1934, p. 150), Tool (1979, p. 23), Gordon (1980, p. ix), Gruchy (1947, p. 250), and Rutherford (1990, p. 402) mentioned Peirce as a founding influence making institutional economics different from neoclassical economics. Rutherford noted that Peirce's method focused on the very long run and did not focus on short-run instrumental applications of science that many institutionalists would like to assert. In the 1990s is found one of the strongest statements relating Peirce to institutional economics and Veblen:

> [T]he foundations of institutionalism consist primarily of the analytic method of Peirce. Dewey is recognized by institutionalists – in large measure because of his influence on Ayres – as a primary source of the self-correcting, evolutionary continuum. Clearly, however, many of Dewey's ideas originated with Peirce, as did those of Commons, and some of those of Veblen. Thus, the basic tools of institutional method are rooted in the works of Peirce (E. E. Liebhafsky, 1993, p. 750).

As mentioned, the lives of Thorstein Veblen and C. S. Peirce intersected briefly at Johns Hopkins University probably in the fall of 1881. Fisch (1986, p. li) tells us that Peirce had only three students for both his introductory and advanced courses in logic for the fall of 1881. The other students were registered for the advanced class so Veblen could have been Peirce's only student or one of three if the other two enrolled in both courses. Veblen spent only part of the academic year at that university and applied for a scholarship to continue his studies there. However the scholarship was not granted which led to Veblen moving to Yale University where he took a doctorate in philosophy under Noah Porter and was strongly influenced by William Graham Sumner and his views of evolutionary social processes (Dimand 1998, pp. 450-452). Sumner was also an advisor to Irving Fisher and seems to have suggested that Fisher (1892) write his dissertation on mathematical economics. While at Hopkins, Veblen had studied economics with Richard Ely. At Yale, as he was nearing the end of his graduate study, Veblen wrote a critique of Kant's *Critique of Judgment* which was his first publication.[5] After a period

[5] Biographical details come from Dorfman's (1934) biography of Veblen which also summarizes and contextualizes many of his research contributions.

of transition, Veblen went to Cornell where he crossed paths with J. Lawrence Laughlin who was in charge of the economics program. Laughlin would eventually become chair of the department of economics in a new university, the University of Chicago and Veblen went with him.

At Chicago, Veblen taught some courses on economics and agricultural economics and began to assist in the editing of a new academic journal, the *Journal of Political Economy*. During this period, Veblen's publications reflected both his philosophical and economic interests. Veblen wrote with a sharp, critically observant attitude about the consumption patterns of the very wealthy and how different they were from those of most workers and farmers in society. He wrote about how women dressed and how their adornments signaled their status in society. He even wrote about sports as an activity of the leisure class. He also wrote about the difference between pecuniary and industrial motives and investment versus financial accumulation. In the late 1890s, he published his ideas in grander form as his first book, *Theory of the Leisure Class* ([1899a] 1994). At nearly the same time, Veblen published four essays on the nature of science and economic science in the *Quarterly Journal of Economics*. The first essay was the now famous "Is Not" article and the others were three installments of the nearly equally well-known "Preconceptions of Economic Science" ([1899b] 1919, [1899c] 1919, [1900] 1919). A fifth essay on the same general themes appeared in 1908, "The Evolution of the Scientific Point of View." Another important work for Veblen's views on mathematical economics in this time frame is *Theory of Business Enterprise* (1904).

Veblen's "Why is Economics Not an Evolutionary Science?" or, hereafter truncated to the simpler "Is Not" essay, begins immediately with a characterization of another social science that had become evolutionary in his considered opinion, anthropology. In the opening sentences Veblen proclaimed that an innovative evolutionary version of anthropology would have impacts

on other social sciences. Veblen held that evolutionary anthropology could revolutionize the other social sciences in the future. By relative comparison, the science of economics was in a backward state. Veblen (1898, pp. 373, and 374-375) claimed: "economics is helplessly behind the times, and unable to handle its subject matter in a way to entitle it to standing as a modern science;" and, "Economics is not an evolutionary science – by the confession of its spokesmen...." While both classical and neoclassical economics considered consumption and production from a limited process perspective, the psychological processes of consumption and the sequential processes of production in economics were inherently mechanical and thus not evolutionary. Regarding economics more generally, Veblen (1898, p.384) claimed: "The outcome of the method, at its best, is a body of logically consistent propositions concerning the normal relations of things – a system of economic taxonomy."

One of the major problems of this taxonomic science is its conception of the human agent. It has an outdated psychological and anthropological conception of human nature which had been accepted generations ago. Its view of human nature is "passive" and "inert" (p. 389) and it also inherently adopts mechanistic characteristics such as a quiescent state of equilibrium and mechanistic calculation:

> The hedonistic conception of man is that of a lightning calculator of pleasures and pains, who oscillates like a homogeneous globule of desire of happiness under the impulse of stimuli that shift him about the area, but leave him intact. He has neither antecedent nor consequent. He is an isolated, definitive human datum, in stable equilibrium except for the buffets of impinging forces that displace him in one direction or another....When the force of the impact is spent, he comes to

> rest....the hedonistic man is not a prime mover. He is not the seat of a process of living....(Veblen 1898, pp. 389-390).

Of course the preceding quote, besides indicating many mechanistic attributes of individuals and economic processes, is a lightly veiled criticism of the emergence of mathematical economics. The preceding comments raise one of Veblen's most significant criticisms of neoclassical economics. Mathematical utility theory might address many of the highly repetitive facts of life, but it does not deal with the economy or its decision makers in a more fundamental and deeper way in the context of a life process. If economics is to be a science, it has to be a science of the life process.[6] This means at the individual level, the economist needs a psychology of the individual life process: "The economic life history of the individual is a cumulative process of adaptation of means to ends that cumulatively change as the process goes on, both the agent and his environment being at any one point the outcome of the past process" (p. 391). At the social level the life process of the community is one of cumulative development: "All economic change is a change in the economic community ....The change is always in the last resort a change in habits of thought" (p. 91). Near the end of the essay, Veblen essentially provides a definition of economics:

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[6] This theme was later taken up by Nicholas Georgescu-Roegen (1971) who was quite mathematical. Of course Mitchell was more comfortable with the use of mathematics and statistics in economics than Veblen. Mirowski (1981) notes the ambiguous role of mathematics in institutional economics.

> ....an evolutionary economics must be the theory of a process of cultural growth as determined by the economic interest, a theory of a cumulative sequence of economic institutions stated in terms of the process itself....It must be a theory of the economic life process of the race or the community (Veblen 1898, pp. 393-394).

Elsewhere in the essay he had summarized more broadly and simply: "Any evolutionary science, on the other hand, is a close-knit body of theory. It is a theory of a process, of an unfolding sequence" (p. 375). Besides classical and neoclassical economics not being evolutionary, two schools of economics were portrayed as also falling short. Neither the economics of the German Historical School nor Austrian economics had met the standards of being an evolutionary science. While the German Historical School emphasized data about real economic processes, they had not created a theory of anything or developed a consistent body of knowledge (Veblen 1898, p. 375). The historical view is pre-Darwinian (p. 388). The fault of the Austrian school was not in viewing economics as a process. Rather its view of human nature is mistaken and not adequate for considering the individual in a life process (Veblen 1898, p. 389).

While Veblen is clear that he does not regard economics as an evolutionary science, at the end of the "Is Not" essay he actually offers, however briefly, a richer more complex way to advance his argument. As noted in the latter paragraphs of the "Is Not" essay, Veblen had conceded that two schools of economics, the German historical and the Austrian, might have weak evolutionary process aspects which still fall short of an evolutionary standard. Then in the last paragraph, Veblen suggests a more extensive generalization of that argument. Putting the

finishing touches on the "Is Not" essay, Veblen again twice conclusively argues that economics is not an evolutionary science. However, between those two "is not" passages comes the newly fashioned "is-not-enough" argument which would become the major theme for several articles to follow:

> The premises and the point of view required for an evolutionary economics have been wanting....Even if it has been possible at any time to turn to the evolutionary line of speculation in economics, the possibility of a departure *is not enough* to bring it about.... This has been the situation in economics. (Veblen 1898, pp. 394-395, italics added for emphasis).

Perhaps Veblen realized that there were many mainstream economists of his own time who thought of themselves as evolutionary thinkers. Certainly Newcomb (1879a, 1879b) portrayed himself as an evolutionary thinker and defended that new theory in *The North American Review*. Veblen seems to have realized that the "is" versus "is not" dichotomy of his 1898 essay would not carry the day and persuade the most prominent economists of the insufficiency of their point of view. Veblen's much more elaborate "is not enough" theme would become the over-arching thesis running through his three "Preconceptions" articles which appeared in quick succession in the *Quarterly Journal of Economics* two in 1899 and the last in 1900. There he again argues that mechanistic conceptions of science and theory distort economic science. In the three "Preconceptions" articles, Veblen would recount the history of economics from the Physiocrats through Smith to the utilitarians of classical and neoclassical vintage portraying how mechanistic ideas had come to dominate the most fundamental concepts

of economic science. Then he would argue that the evolutionary aspect of the economics of Alfred Marshall, the most prominent theorist of his time, "is not enough" to make his theoretical perspective evolutionary. In "Preconceptions III," Veblen ([1900] 1919, p. 173) criticizes Marshall's work claiming that it remains: "an inquiry directed to the determination of the conditions of equilibrium" and; "It is not in any eminent degree an inquiry into cultural or institutional development as affected by economic exigencies or by the economic interests of men whose activities are analyzed and portrayed." Summarizing regarding Marshall's contribution, Veblen ([1900] 1919, p. 173) claims: "it is the movement of a consummately conceived and self-balanced mechanism, not that of a cumulatively unfolding process or an institutional adaptation to cumulatively unfolding exigencies." Thus Marshall's famous work "is not enough" of an evolutionary line of inquiry to be considered as having attained the status of an evolutionary science.

III. APPLIED BUT NOT PURE MATHEMATICS IS MECHANISTIC AND INSTRUMENTAL

In important ways Veblen's views on mathematics would continue to evolve. Certainly he would continue to develop his sharp strand of claims about the mechanistic character of applied mathematical science and economics. But he also would offer another, broader quite reflective strand of thought regarding the non-committal and instrumental character of applied mathematical research and he would also assert a very strong claim that pure mathematics is not mechanistic. Additional comments from Veblen on the mechanistic character of both science and mathematical economics would come in his *Theory of Business Enterprise* (*TBE*) (1904). Then, more reflective comments would come in the 1908 essay, "Evolution of the Scientific Point of View." Curiously the main story of Veblen's more detailed comments on mechanistic

aspects of mathematical economics come in footnotes.[7] The footnotes on mathematics are so extensive that they could form the core of a separate article on mathematical economics and may prove just as significant in understanding Veblen. Veblen's more explicit notes on mathematics deserve as much attention as the main text and the notes could eventually bring us what may be a surprise, Veblen's view that pure mathematics is not mechanistic.

Shortly after publishing the three "Preconceptions" essays, Veblen's *TBE* (1904) provides one of his most elaborate explications of how economics is substantially mechanistic. The last chapter titled "Civilization and the Machine Process" constructs a detailed narrative of how human society dominated by machine industrial processes comes to have its cultural attitudes become quite mechanistic. Mechanistic conceptions of cause-and-effect and before-and-after become ever more prominent and come to govern conceptions of social process more generally and especially the mind set of science. Veblen (1904, n. 1, pp. 366-367) remarks that the organized quantification of commerce spawned the idea of quantifying the laws of nature and this impetus eventually resulted in a new empirical philosophy with "its most perfect product, Positivism."[8] Earlier in *TBE* Veblen had made one of his most direct statements connecting mathematical economics with utilitarianism. Here the clear implication is that mathematical economics is similarly mechanistic: ".... the use of the differential calculus and similar

[7] Regarding Veblen's use of notes, his biographer, Joseph Dorfman comments on their extensive use at the end of his book on imperial Germany. There Veblen's use of notes is so extensive that Dorfman (1934, p. 330) maintains "they form almost a book of their own."

[8] Veblen (1904, n. 1, pp. 366-367) attributes this point to Sombart.

mathematical expedients in the discussion of marginal utility theory and the like .... are valid to the full extent only if this hedonistic psychology is accepted" (Veblen [1900] 1919, p. 157, n 5).

While Veblen's critique of mathematical economics is sharp and consistent in terms of his opposition with regard to mechanism, that criticism needs to be balanced with the realization that he did not reject all uses of mathematics in economics. Veblen did make limited use of mathematics. He did employ algebraic notation for some topics in *TBE* (1904). In chapter five, "The Use of Loan Credit," and again mostly in the notes, Veblen did construct several algebraic formulations of relevant topics. One is an equation for how long it takes capital to "turnover" (p. 95, n. 5), another is an inequality for illustrating how credit reduces the time for turnover (p. 96, n. 5), and there are several algebraic fractions about credit extension (p. 100 and n. 1). One gets the impression, that these brief uses of algebra would not change his view about the superficial, mechanistic nature of applied mathematics in most science and economics. These equations on mathematical aspects of finance might also reflect his awareness of Irving Fisher's contributions to understanding the role of capital in the economy (see Dimand 1998, p. 454).

Returning yet again to the last chapter of *TBE*, Veblen provides a simple encapsulatng thought for succinctly portraying the mechanistic character of economics and applied mathematical sciences. He sees scientists in many disciplines behaving like engineers. A few pages after commenting on the spread of commercial accounting as a source of the mechanistic character of science, Veblen maintains that scientists practice their craft more like engineers:

> The scientists are learning more and more consistently to think in the opaque, impersonal terms of strains, mechanical structure, displacement, and the like;

> terms which are convertible into the working drawings and specifications of the mechanical engineer (Veblen 1904, p. 371).

This suggests that Veblen wanted economists to rise above the more limited intellectual role of the engineer who knows practice and action but does not contemplate a more fundamental conceptual/theoretical framework for understanding why things happen the way they do.

Veblen's second strand of more detailed and nuanced criticisms of mathematics and mathematical economics would come just a few years later in 1908. Nearly a decade after his four *QJE* articles were published, Veblen wrote a fifth essay on the nature of science which was presented in California in 1908 – the aforementioned "Evolution of the Scientific Point of View." In this essay Veblen's comments on mathematics again would appear in long footnotes. In the first, nearly three-page note on the role of mathematics in science, Veblen appears to be objecting to what seems to be the a-theoretical character of applied mathematics and statistics. Recall that he had asserted that an evolutionary science has a cumulative causal sequence at its core in the "Is Not" essay. Here Veblen again raises the matter of causality. He maintains that most scientists deny that a conception of causality and related ideas like "efficiency, activity, and the like....can legitimately enter, into their work" ([1908] 1919, p. 33, note 2) and, "This attitude seems to particularly commend itself to those who by preference attend to the mathematical formulations of theory…." Those individuals seem particularly devoted to working out the details of the theory. Veblen's argument seems to be that those who would formulate scientific inquiry in mathematical terms do seek to strip it of any more fundamental interpretation but for variation in quantitative magnitudes:

> [E]ssentially statistical materials – with which scientific inquiry is occupied are of this non-committal character, and that the mathematical formulations of theory include no further element than those of idle variation….causation is a fact of imputation, not of observation....nothing further than non-committal variation can be expressed in mathematical terms. A bare notation of quantity can convey nothing further (Veblen [1908] 1919, p. 34, note 2).

Veblen continues with his critique of mathematical research methods. He claims that scientists who adopt mathematics prefer to substitute a conception of a mathematical function for the more metaphysical notion of causality. This seems to be something of an instrumentalist argument. Veblen suggests that scientists who embrace such a mathematical functionalism or instrumentalism place a limit on the theoretical interpretations that could be offered by the scientist about what may be driving the patterns found with mathematics and statistics:

> The connection between his [the scientist's] premises, hypotheses, and experiments, on the one hand, and his theoretical results, on the other hand, is not felt to be of the nature of a mathematical function..... Consistently adhered to, the principle [of mathematical] "function" or concomitant variation precludes recourse to experiment, hypotheses or inquiry – indeed it precludes "recourse" to anything whatsoever. Its notation does not comprise anything so anthropomorphic (Veblen [1908] 1919, p. 35, note 2).

Veblen's point of view seems to be that evolution provides a qualitative, philosophical framework for the deepest conceptions of science and economics which is stifled by mechanistic applications and interpretations of mathematics and statistics.

Also in the 1908 article, after that first long mathematical note and many pages later is found a second significant, but shorter note ostensibly on the limitations of the use of mathematics in science. Here Veblen notes that in ancient times, mathematics played a very prominent role in inquiry. However, next comes something of a surprise with regard to basic mathematics. Veblen's critique of applied mathematical science and economics certainly raises a question whether his mechanistic critique is equally germane to what most call "pure" mathematics:

> Now mathematics occupies a singular place among the sciences, in that it is, in its pure form, a logical discipline simply: its subject matter being the logic of quantity.... Its generalisations are generalisations of logical procedure, which are tested and verified by immediate self-observation. Such a science is in a peculiar degree, but only in a peculiarly degree, independent of the detail-discipline of daily life, whether technological or institutional.... nor need the state of institutions or the state of the industrial arts seriously color or distort such analytical work in such a field. Mathematics is peculiarly independent of cultural circumstances, since it deals analytically with mankind's native gifts of logic, not with the ephemeral traits acquired by habituation (Veblen [1908] 1919, p. 52, note 3).

Here near the end of Veblen's detailed comments on applied mathematics we have an extraordinary qualification. While much if not all of the applied mathematical sciences of his time including economics are mechanistic and taxonomic, Veblen does recognize that mathematics by itself is not inherently mechanistic. Mathematics in its more pure form is so different than the applied mathematics of the sciences that it cannot be distorted by mechanistic cultural influences or "the state of the industrial arts" (p. 32, n. 3). This does leave us with an unanswered question. While recognizing that pure mathematics is quite independent of mechanistic cultural influences, he makes no mention of whether an evolutionary philosophical conception of mathematics is possible. Veblen does seem to imply that the level of abstraction in mathematics may be so strong that it could be interpreted as being quite independent of the life processes of the individual and society. However this exclusion of pure mathematics from his mechanistic critique of the applied mathematical sciences provides an opening to consider Peirce's evolutionary philosophy of mathematics which would encompass both pure and applied mathematics and of course economics and mathematical economics.

IV. PEIRCE'S INDETERMINISM AND EVOLUTIONARY THEORY: MECHANISM AS ONE OF SEVERAL EVOLUTIONARY PROCESSES

Although Veblen might not have known it, another view of science, mathematics, and economics that would be evolutionary at its core was beginning to emerge in the hands of his former Johns Hopkins professor, C. S. Peirce. But Veblen, like most of us over the past century, had almost no way of knowing where Peirce's ideas were headed. Like Veblen, Peirce would not have wanted scientists and economists to function like engineers in their processes of investigation and inquiry. In the years when Veblen and Dewey were at Johns Hopkins, in a

public lecture Peirce had expressed sentiments in some respects foreshadowing those which would later come from Veblen. Peirce was concerned that scientists were trained and educated too narrowly resulting in a mechanistic outlook:

> But in my judgment there are scientific men, all whose training has only served to belittle them, and I do not see that a mere scientific specialist stands intellectually much higher than an artisan. I am quite sure that a young man who spends his time exclusively in the laboratory of physics or chemistry or biology, is in danger of profiting but little more from his work than if he were an apprentice in a machine shop (Peirce 1882, WP 4, p. 380).

Both Veblen and Peirce seem to take an evolutionary point of view as a point of departure for both science and philosophy and thus by implication economics. Veblen's rationale seems to be that the newest, best, and latest sciences are evolutionary, therefore one needs to take an evolutionary point of view to be up to date and for economics to be scientific. In comparison, Peirce's evolutionary views would not begin with Darwin's contributions, with Kant's philosophy, or evolutionary anthropology. Peirce begins with a natural philosophy or theory of creation as a continuous, cumulative process since time began. According to Karl Popper (1972, pp. 212-213), Peirce was the first modern indeterminist. An indeterminist is someone who takes the position that random homogeneity is a better hypothesis of cosmic origin than its opposite, mechanism. Mechanism is the cosmological hypothesis that the universe was created with complicated and precise patterns of order from the very beginning with chance being a fringe or secondary property of phenomena. For the indeterminist, all order and pattern

is created by the processes of evolution which began at the very beginning of the present order of space and time. Indeterminist chaos comes first followed by pockets of mechanistic-like order. Before the "big bang" hypothesis, scientists of Peirce's day called this conception of origin, the nebular hypothesis. In Peirce's time, the nebular hypothesis was the thesis that our Milkyway galaxy had begun as a cloud of primordial dust and then by processes of accretion driven by gravitation and other evolving natural forces, the elements, stars, planets, and other heavenly bodies were created. Peirce's father Benjamin had co-founded the Harvard Observatory and was America's best lunar astronomer in the mid-19th century. Newcomb succeeded Benjamin as America's foremost lunar astronomer. Before that, Charles (1878f) also was employed briefly at the Harvard Observatory, took measures on hundreds of stars in the galaxy, and was the first to conclude that it took the shape of a disc. From these activities alone, one can conclude that Peirce had a sharp conception of indeterminism and evolution of astro-physical processes on a grand scale.

It is also known that Darwin's *Origin of Species* published in 1859, triggered a consideration of evolution beyond the astrophysical and biological domains to the social and epistemological levels. The impact of Darwin's work was so profound, that a group of young men began to meet in Cambridge Massachusetts from the late 1860s into the 1870s to explore the intellectual and scientific impact of those ideas. This meeting of now famous individuals called themselves the Metaphysical Club. The most prominent members were Peirce, William James, and Oliver Wendell Holmes. Their meetings have been chronicled in many articles and a book of that title by Menand (2001). The Metaphysical Club is considered to have been the birthplace of the ideas which later became known as pragmatism. The meetings of the Metaphysical Club led Peirce to write a series of essays elaborating the philosophical, scientific, and mathematical-

statistical aspects of a new conception of human knowledge. Peirce's "Illustrations of the Logic of Science," those six essays published in 1877 and 1878, are still viewed as the most classic essays on pragmatism. Peirce separately published another essay in 1879, his "Note on the Theory of the Economy of Research." That article applies Jevons-like mathematics and graphics of marginal utility to the allocation of funds to two or more research projects for the purpose of getting the greatest increment in accuracy across all research projects (Wible 1994). A draft of that essay precedes the "Illustrations" articles and the noted Peirce scholar, Max Fisch, has maintained that the "Note" should be considered as a seventh essay on pragmatism. Peirce actually met Jevons in the early 1870s.

While he was an instructor at Johns Hopkins University in the early 1880s, it is believed that Peirce assigned the "Illustrations" articles in his logic classes that would have been attended by Veblen and Dewey.[9] In his elementary logic class for the non-mathematical graduate students, Peirce may have emphasized the more philosophical articles – the first two articles of the series, "Fixation of Belief" (1877) and "How to Make Our Ideas Clear" (1878a), and the last, "Deduction, Induction, and Hypothesis" (1878e). The remaining articles offered either an applied or algebraic mathematical perspective.[10] While Veblen may have read and heard lectures

[9] He also started a philosophy seminar for faculty and graduate students and gave it the name of the "Metaphysical Club" as well (Brent 1998, p. 129).

[10] Two were on general ideas about probability and statistics. "Doctrine of Chances" (1878b) and "Probability of Induction" (1878c) were the third and fourth articles of the series. The fifth article, "Order of Nature," was written from a qualitative, mathematical perspective where Peirce

on the more philosophical essays, those three on a mathematically framed and probabilistic conception of our world may have been less emphasized. At least, the stream of ideas coming from those three articles seems to be missing from Veblen's conception of science, social science, and economics. Similarly a conception of astrophysical evolution and cosmology so important for Peirce, seems to be missing from Veblen's writings.

Keeping Veblen's access to Peirce's writings in mind, another set of Peirce's essays were published in the early 1890s in *The Monist*. At that point in history, *The Monist* was a new philosophical journal and as such it would not be unreasonable to have expected that Veblen, having earned a doctorate in philosophy, would have had at least a passing familiarity with it. Certainly the last article of the series, "Evolutionary Love" (1893a), contains a sharp and cutting criticism of the free market economics exhibited in a well-known textbook of that era, Newcomb's (1886) *Principles of Political Economy* (*PPE*). Those comments suggest that Peirce was aware of the conflicts between the Old and New Schools of economics in the late 1880s at nearly the same time as the American Economic Association was being founded. Newcomb was the chief exponent of the "Old School" of free market economics as so articulated by Richard Ely (1884). Ely had created a "New School" of political economy which he thought was more up to date and scientific than the "Old School." Ely and Newcomb conducted a contentious debate over the nature of economics as a science in several of the most prestigious publications in America during that era. Newcomb admired John Stuart Mill and his *PPE* is essentially a Millian text book for American collegiate economics. In "Evolutionary Love,"

(1878d) uses simple algebraically framed entities to talk about the stochastic origins of the cosmos and how chance is fundamental to the order and pattern of our universe.

Peirce criticized the limited view of the self and self-interest found in Newcomb's *Principles*. Since Peirce was writing during the severe recession of the early 1890s, he asserted that economics was wrong not to recognize the economic impact of such a deep contraction and he predicted an even worse event in the 20th century.

In another of *The Monist* essays of the early 1890s, Peirce did present a considerable critique of mechanism and determinism in science and philosophy in an article that Veblen could have read due to its relative accessibility. In "The Doctrine of Necessity Examined," Peirce argued that mechanical processes and forces had limits which reveal that chance operates at a more fundamental level in natural processes:

> Those observations which are generally adduced in favor of mechanical causation simply prove that there is an element of regularity in nature, and have no bearing whatever upon the question of whether such regularity is exact and universal, or not....Try to verify any law of nature, and you will find that the more precise your observations, the more certain they will be to show irregular departures from law. ....Trace their causes back far enough, and you will be forced to admit they are always due to arbitrary determination, or chance (Peirce 1892a, EP 1, p. 304-305).

Returning to the last essay of *The Monist* series, besides nature changing by processes of chance and mechanical forces there was a third fundamental aspect of evolutionary process. In "Evolutionary Love," Peirce clearly identifies three, not two, significant aspects or strands of evolutionary processes. Evolutionary processes change and evolve not just by chance and mechanical forces, but also by higher purposes. As was his penchant for nomenclature, these

three core strands of evolutionary processes were given Greek names to provide some sharper nomenclature for the ideas. Evolution by chance was termed, tychisim; evolution by mechanical force or necessity was termed anancism; and evolution by higher purposes, agapism:

> Three modes of evolution have thus been brought before us; evolution by fortuitous variation, evolution by mechanical necessity, and evolution by creative love. We may term them *tychasitc* evolution, or *tychasm*, *anancastic* evolution, or *anacasm*, and *agapastic* evolution, *agapasm* .... All three modes of evolution are composed of the same general elements. Agapasm exhibits them most clearly....tychasm and anancasm are degenerate forms of agapasm (Peirce 1893a, EP 1, p. 362).

The interesting thing is that one might have expected someone like Veblen with a doctorate in philosophy to at least mention a major article series on evolutionary processes written by his former graduate school professor. No such references can be found. Also, Peirce's conceptualization of evolutionary processes including his critique of the mechanical conception of determinism seems to be missing from Veblen's work. Veblen's silence stands in sharp contrast to William James who lauded Peirce's evolutionary views as found in *The Monist* in the early 1890s and in that aforementioned series of lectures given in Cambridge a few blocks from the Harvard campus in 1898 (Ketner and Putnam 1992, pp. 8-12). In those lectures, Peirce (1898, p. 267) would outline what he would call his "mathematical cosmology" In contrast to Veblen, Peirce regarded mechanical forces as part of an evolutionary perspective. While some mechanical forces might be reversible and not exhibit cumulative causation, some could show

evolutionary features. Machines wear out and many mechanistic forces in other domains weaken and fade away. Also some mechanistic processes could have catastrophic evolutionary consequences (Peirce 1891, p. 290). As an astronomer, Peirce (1898, p. 174) was aware that heavenly bodies or stars might on occasion have intersecting trajectories and could collide thus irreversibly altering the evolutionary path of solar systems and life processes on a grand scale. Also, Peirce as an indeterminist portrays mechanical processes as being nested within more qualitative evolutionary processes. Thus mechanical forces are and have considerable evolutionary consequences.

V. PEIRCE'S PRAGMATICISM: TURNING TO MATHEMATICS, SEMIOTICS, LOGIC, AND ABDUCTION

Given Peirce's conception of three modes of evolutionary processes including mechanical forces, it is clear that Peirce would not have characterized mechanical processes as categorically non-evolutionary. Thus Peirce did not characterize the many various sciences of his time as being evolutionary or non-evolutionary based on the degree of their focus on mechanistic forces whether in nature or society. Here we have an important sense in which Peirce likely would not have formed a criticism of economics as being predominantly mechanistic as Veblen did in the "Is Not" essay. Peirce's ideas on mechanism and indeterminism were so sharp that he could have easily redirected them towards economics. Instead he argued that economists' conception of self-interest did not rise to the higher levels of human purpose. Self-interest needs to be more other-regarding which would stem from the agapastic strand of evolutionary processes. Also, in contrast to Veblen who seemingly turned

away from mathematics and its relevance for science, statistics, and economics, Peirce turned in the opposite direction toward mathematics. Now as noted previously, Veblen did assert that pure mathematics was independent of and consequently exempt from the cultural mechanistic mindset that had so distorted economics and the sciences. In some sense, Veblen did leave an opening for an evolutionary philosophy of mathematical economics perhaps like Peirce's although he did not take that position explicitly. The same year that Veblen would criticize the use of applied mechanistic mathematics in economics, Peirce would assert the primacy of mathematics among the sciences and also for philosophy: "I would classify the sciences upon the general principle set forth by Auguste Comte, that is, in order of abstractness of their objects .... At their head I would place Mathematics" (Peirce 1898, p. 114). In those same lectures, Peirce (1898, p. 267) claims: "The subject of mathematical metaphysics, or Cosmology, is not so very difficult, provided it be properly expanded and displayed." [11]

Peirce had always had a prominent mathematical strand to his outlook. In nearly every article or lecture series, he often authored a mathematically themed essay that provided parallel mathematical conceptualization to other lines of thought and argument. For example, "Order of Nature"(1878d) is the most mathematically themed essay of the "Illustrations" series from the 1870s. Similarly his 1903 Harvard "Lectures on Pragmatism" were authored with mathematical themes in the background and a separate mathematical lecture, possibly never delivered, was

[11] Apparently the only other figure to take a mathematical approach to philosophy was the British mathematician Alfred North Whitehead who was actually at Harvard and reading Peirce's manuscripts as they were being edited into his *Collected Papers*. See Murphey (1993, p. 295).

written to elaborate those mathematical ideas (Peirce 1903b). In the first Harvard lecture, Peirce did use the calculus of the profit maximizing insurance business as an illustration of pragmatism working through multiple lines of calculus that must have been extremely annoying to William James. Peirce is recognized as one of the co-founders of mathematical logic around the turn of the 20th century so his conception of mathematics was much broader and much more advanced than many of his contemporaries such as Veblen and James (and even Newcomb) who thought of mathematics in terms of advanced calculus and applications to physics. Peirce's (1870) best "mathematical" piece was a long essay on the use of relational logic authored in 1870. That date is important for it means that thereafter one must always bring an abstract, algebraic sense of mathematics to any conceptual application by Peirce to any subject in science and philosophy and especially in economics. It is also 38 years before Veblen ([1908] 1919) recognized that pure mathematics was independent of the mechanistic cultural forces of his time. Also it is important to note that Peirce's 1870 "Logic of Relatives" paper preceded his most famous six "Illustrations" (1877-78) essays and the "Note on the Theory of the Economy of Research" (1879). This means we should read these most famous six "illustration" articles with the lens of abstract, relational mathematics where appropriate. We also know that Peirce was intrigued with Cournot's duopoly equations (Peirce 1871, Wible and Hoover 2015), that he formulated a version of the axiom of transitivity in terms of consumer preferences (Peirce 1874), and that he used a profit maximizing model of the insurance firm to illustrate pragmatism in the first Harvard lecture (Peirce 1903a, Wible 2014).

While all of the mathematical conceptions suggested above apply to nearly all phenomena and enable various scientific disciplines, mathematics, and philosophy and even

language, Peirce did bring this all down to the level of the individual. In contrast to Veblen, Peirce authors a sketch of the individual in an evolutionary world. Peirce began with the notion that concepts are shaped by human experience in the world. Basic human needs give rise to counting, geometry, and relationally structured patterns of concepts which allow human survival to become more dependable. Peirce traced the idea of evolution shaping the rise of abstract human conceptions to Galileo and his idea of "*il lume naturale*" (1891, EP 1, p. 287). As more elaborately expressed, he asserts:

> It seems incontestable, therefore, that the mind of man is strongly adapted to the comprehension of the world; at least, so far as this goes, that certain conceptions, highly important for such a comprehension, naturally arise in his mind; and, without such a tendency, the mind could never have had any development at all (Peirce 1878d, WP 3, p. 318).

Peirce's conception of how intelligent human individuals learned from the environment and others around them led him to semiotics, to a logical process he called abduction, and to new interpretations of abstract mathematics and logic. Here Peirce held that there are three main processes of reasoning: induction, deduction, and abduction. While everyone knows the intuition of induction and deduction, abduction is different. Abduction (also called hypothesis and retroduction by Peirce) is the logic of contingently guessing the future. An abduction is an explanation, which if it were true or accurate, could account for some unexpected surprise.

Abduction is the logic of anticipating the future and it is at the core of future-oriented expectations for Peirce.

The relational thought processes of the individual, so important for mathematics and science (and also language), are initiated from the very beginning if not very early in human life. Peirce provides an interesting comment on how the human process for forming hypotheses originates. A young child soon after birth would begin the simplest of relational comparisons. The comment comes in the context of his sketching out aspects of the three modes of logical reasoning and also the idea that human thought occurs in signs:

> Thus we have in order of strength, Deduction, Induction, Hypothesis [abduction]....Yet it is hypotheses with which we must start; the baby when he lies turning his fingers before his eyes is making a hypothesis as to the connection of what he sees and what he feels. Hypotheses give us facts. Induction extends our knowledge. Deduction makes it distinct (Peirce 1865 WP1, p. 283).

In the second Harvard Lecture, Peirce (1903a EP 2, p. 155) would maintain that in human perception we have the possibility of "cognizing a *relation*." Thus the baby in the crib is beginning to cognize a relation which is further understood as occurring through a semiotic process. What the baby experiences as different or external comes through the very primitive thought process of thinking in signs. In the late 1860s, in one of his first article series in the *Journal of Speculative Philosophy*, Peirce (1868, WP 2, p. 173) claimed that "All thought, therefore must necessarily be in signs ....From this proposition that *thought* is a *sign* it follows

that every thought must address itself to some other, must determine some other, since that is the essence of a sign:" He would even hold that: "Logic itself is a study of signs" (Peirce 1898, p. 146). In 1894, Peirce would theorize that there are three basic kinds of signs. Icons are entities which imitate some important feature of whatever is represented. Indices are aspects or entities which direct attention to something due to a physical connection or act. Symbols are the most general form of signs and they are entities which have acquired a meaning due to their use. Words, speeches, phrases, books, and libraries are examples of symbols (Peirce 1894, EP 2, p. 5).

From general ideas about semiotics, Peirce turned to conceiving of mathematics as a semiotic process. While the process of relational, semiotic cognition may begin very early in human life, it also occurs in the most advanced and complex of human cognitive processes such as mathematics. Broadening beyond the primitive semiotic processes of the young child, Peirce comments about how pervasive signs are in human thought and experience starkly claiming: "All things, forms, symbols are symbolizable" (Peirce 1865 WP 1, p. 282). Peirce would especially focus on mathematics. Mathematics is a very powerful semiotic process. He begins with those likenesses which have a physical resemblance – pictures, statues, works of art, and architecture. Then he asserts that mathematical reasoning depends on an iconic sense of likeness which enables new aspects to be identified:

> The reasoning of mathematicians will be found to turn chiefly upon the use of likenesses, which are the very hinges of the gates of their science. The utility of

> likenesses to mathematicians consists in their suggesting, in a very precise way, new aspects of supposed states of things (Peirce 1894, EP 2, p. 6).

What this means is that mathematics is largely a process of the very abstract use of iconic reasoning associated with equations and graphs. Semiotic processes of all varieties facilitate the growth of human knowledge and they grow complex versions of symbols as well (Peirce 1894, EP 2, p. 10). Focusing more closely on mathematics whose representations are mostly considered as icons in Peirce's semiotics, this whole line of thought was extended to systems of relations which are represented in equations and diagrams:

> The hypothesis of the mathematician is always the conception of a system of relations. In order that they may be reasoned about mathematically, these relations must be conceived as embodied in some kind of objects, but the character of the objects, apart from the relations, is utterly immaterial. They are always made as bare, skeleton-like, or diagrammatic as possible (Peirce 1895a, PM, p. 46).

Perhaps the best summary comment we have about mathematics from Peirce is his conclusion: "In the procedure of *all* mathematics whatsoever, the observation of diagrams plays a great part ...." (Peirce 1903b [2010], p. 69). Peirce would describe the role of diagrams and their function as icons in describing the role of creating mathematical reasoning:

> The mathematician begins his work by making a diagram or scheme.... A diagram is a figure whose parts are connected according to a prescription or rule; and any figure whose parts are so connected is as good as any other, except that one is preferable which makes the prescribed connections most prominent, and features not prescribed the least prominent. Allow me to call the mathematician's diagram or scheme an *icon*. Then an *icon* is a mere figure of connected units.... (Peirce 1889, WP 6, pp. 258-259).

Near the end of his active intellectual life Peirce would go on to link mathematics with expectations. In the context of elaborating his conception of abduction he turned to the instance when one encounters a truly unanticipated and surprising event. When something wholly surprising or new and unexpected is encountered, one tries to imagine a hypothetical explanation about why the unexpected event would have occurred. A contingent and hypothetical explanation then establishes an expectation – that when the same contingencies and circumstances occur again – that the previously experienced surprising event should happen again. The transition from expectations to mathematics is with a diagram. If one can make a diagram which captures the main lines of relational linkages as the surprising situation was perceived to unfold, then mathematics is possible. More specifically, it is the logical diagram that facilitates a transition to mathematics (Peirce 1902b, CP 2, pp. 79-80). In another section of the "Minute Logic" Peirce explicitly claims an important role for mathematics. Mathematics facilitates extensions and elaborations of the key creative insights coming from an abduction:

"There will be a mathematical logic just as there is a mathematical physics and a mathematical economics.... Mathematics is engaged solely in tracing out the consequences of hypotheses [or abductions and expectations]" (Peirce 1902a, CP 1, pp. 112-113).

Just a few years later in one of his last published articles, Peirce would extend his interpretation of the significance of his forward-looking semiotic and evolutionary philosophy of mathematics. Humans have evolved a fundamental capacity for relational reasoning coupled with sharp semiotic representation skills including mathematics. What Peirce seems to suggest is that the relational-semiotic powers of the human mind -- when extended by language, mathematics, diagrams, inquiry, and expectations -- form an extraordinary resource. This point is made essentially by identifying humanity's most evolved evolutionary trait as the many aspects of abductive guessing: "Our faculty of guessing corresponds to a bird's musical and aeronautic powers; that is, it is to us, as those are to them, the loftiest of our merely instinctive powers...." (Peirce 1907, CP 7, p. 34). Our ability to make useful representations of the patterns of things and processes encountered in an evolutionary world external to our bodies may be the "loftiest" of our instinctive powers. For Peirce, mathematics itself is a cumulative evolutionary process created by humans who are themselves embedded in cumulative evolutionary processes both at the individual and social levels and these features can be related to nearly every aspect of the life processes of humanity.

VI. PEIRCE AND VEBLEN ON MATHEMATICS AND EVOLUITONARY PROCESSES

At this point, there may be additional concerns about Peirce's and Veblen's views of evolutionary processes that deserve further comment. In this regard, there are several fundamental concerns and a sharp difference or two which invite further consideration. In taking up such concerns and differences, some perspective can be gained by returning to the quotes from Veblen at the beginning of this essay. There in the first quote, Veblen (1898, p. 387) remarks that there is much in life process "awaiting theoretical formulation." One would imagine that this comment surely was about the future direction of the economy and economics as a science. However, one could make a similar point about other important lines of inquiry such as the theory of evolution itself and conceptions of mathematics. During and after the 1890s, both of these areas of theory and thought would undergo substantial expansion and revision. Even contemporaneously with Veblen, Peirce was deeply involved with expanding evolutionary ideas and creating an evolutionary conception of mathematics and scientific inquiry. He wrote voluminously about these topics from the mid-1880s through his last publications and writings around 1908. In contrast, Veblen extensively applied his conception and understanding of evolutionary economic and social processes from an anthropological and sociological perspective. Dorfman (1949, p. 436) in characterizing significant influences on Veblen's evolutionary ideas suggests that they may have come from his study of Kant as well: "Veblen fell into another movement that was causing a storm in the intellectual world of Europe, but hardly a ripple in America….It's proponents held that Kant had glimpsed the true doctrine of evolution…." With regard to the evolving nature of core aspects of Veblen's theoretical dichotomies Dorfman (1949, p. 437) notes that: "After 1891 Veblen's views underwent no

fundamental change." Of course Veblen's evolving conception of mathematics, as elaborated above, would seem to be an exception to this broad characterization by Dorfman.

One major concern is whether Peirce and Veblen's theories of evolution are fundamentally compatible and then whether any differences or similarities would affect their views of mathematics. Veblen seems to have left an opening for an evolutionary approach to mathematics. A significant question is whether Peirce's conception is one that could be paired with Veblen's conception of evolutionary economic processes. Both men write about very different aspects of evolutionary processes. Veblen seems to assume certain core conceptions or key ideas as constituting the core of an evolutionary theory and then he applies those principles to economics, the economy, and society. Peirce creates fundamental philosophical, scientific, and mathematical conceptions of evolutionary inquiry and then turns to many specialized topics within mathematics, science, philosophy, and economics. Beyond these differences one way to begin juxtaposing their views is to consider each in terms of a theory of abstract ideas. Veblen's conception of abstract ideas seems to be more implicit while Peirce's are more explicit. What might be regarded as Veblen's view of abstract ideas seems to be left ungeneralized and implicitly embedded in the details of his elaborate themes regarding various social and economic processes. Clearly he seems to have some more general but incompletely articulated conception of how abstract ideas are created and change in evolutionary processes. Perhaps he is drawing on Kant and the Kantian philosophical tradition on these matters. Veblen also may be reacting against British empirical psychology of associationism as a theory of abstract ideas. In all of this, nothing was said explicitly about abstract mathematical ideas. What Veblen has written about mathematics seems quite secondary to his other more fundamental contributions about

economics, social processes, and possibly abstract ideas more generally. Thus for Veblen, it does seem that his views of evolutionary processes and mathematics are somewhat separable.

In contrast for Peirce, abstract mathematical ideas are elevated to the core of his conception of philosophy, science, and human inquiry in an evolutionary world and economy. Peirce essentially took a mathematical turn across nearly every key aspect of his various lines of thought and inquiry and especially his conception of abstract ideas. Regarding a conception of abstract ideas, his semiotic conception of all thought and then his conception of how to reason with abduction added to deduction and induction suggests an understanding of abstract ideas more generally and separate from mathematics. Turning back to mathematics, Peirce's views are so well developed and Veblen's so fragmentary that this becomes one aspect where Peirce could dominate. Certainly Veblen is consistent in his criticism that applied mathematics is subject to a mechanistic interpretative bias. His evolutionary interpretation seems to be that the mental processes and habits of applied mathematical scientists in his time are strongly dominated by a sort of intellectual, mechanistic path dependence stemming from cultural influences emanating from commerce, industry, and accounting. This is more an evolutionary sociological critique than a theory or philosophy of mathematics. Veblen's critique seems to suggest that applied mathematical scientists of his time did not know much about the history and philosophy of mathematics and the degree to which it could be non-mechanistic. In contrast, Peirce (1892-93) was keenly interested in the history and philosophy of mathematics and science and lectured on those subjects in the Lowell Lectures of 1893.

Besides his interrelated conceptions of mathematics and pragmaticism, Peirce did develop his conception of evolutionary processes in a more general way that is different than

Veblen. Like Veblen Peirce had studied Kant. Early in his life, Peirce was significantly influenced by Kant mostly from his father who tutored him on the logical flaws of philosophers including Kant (Brent 1998, p. 57). But Peirce moved beyond or surpassed Kant in important ways. His semiotics, his conception that all thought is in signs while not inconsistent with Kant seems to be somewhat novel. Also, Peirce's emphasis on relational thinking as beginning with the young child and continuing into mature reasoning processes and especially with mathematics, logic, abduction, and inquiry is quite significant. Then, at some point Peirce began to think of Kant's metaphysical categories in relational terms in a way that Veblen did not. Again in the Cambridge Conference Lectures of 1898 he writes:

> But Kant, as you may remember, calls attention to sundry relations between one category and another. I detected some additional relations between the categories, *all but* forming a regular system, yet not quite so. Those relations seemed to point to some larger list of conceptions in which they form a regular system of relationship (Peirce 1898, p. 124).

These innovations are then fashioned by Peirce into his own metaphysical theory of relational categories which have gained the attention of many philosophers. Peirce's evolutionary philosophy is much more comprehensive than Veblen's.

In this regard consider the central role of pure and applied mathematics and relational conceptions in Peirce's evolutionary philosophy. Indeed it is possible that some might argue that Veblen was silent on most of the elaborate intellectual positions created by Peirce including

his mathematical turn and thus his ideas may not be in direct contradiction to Veblen's evolutionary ideas. Of course, Veblen almost certainly had no idea of the full development of Peirce's evolutionary mathematical philosophy. Similarly, Peirce is silent on most of the evolutionary positions taken by Veblen about economics, social processes, and institutions. It is likely that Peirce might have viewed Veblen as an economic philosopher more than a scientist. In essence, both were silent regarding the matters on which the other elaborated. This complementarity of silence on the many differing aspects of their positions on evolution could constitute the gist of a mutually consistent or non-contradictory interpretation of their views taken together. Even so, one can imagine that Veblen, as an extraordinarily independent thinker, would not have wanted to be intellectually dominated by Peirce's evolutionary ideas nor Peirce by Veblen. The same might be true of contemporary institutionalists and admirers of Veblen.

Consider the case of Peirce's life-long friend, William James, whose psychology and pragmatism mostly was admired by Veblen. Peirce tried to teach James the rudiments of pure mathematics with its philosophical implications in exhaustive correspondence but simply was overwhelmed by Peirce's excursions into detailed, abstract mathematical and logical subjects (Peirce 1897-1919). In a nutshell, James did not see the need to make mathematical conceptions so central to his evolutionary philosophy. James encouraged Peirce to develop his theory of evolutionary philosophical categories separately without reference to the mathematical matters. James (1903) wrote Peirce that he had a "bad head for logic and mathematics." But Peirce did not do so. My sense is that if Veblen were to express sentiments regarding Peirce's evolutionary mathematical categories and his related mathematical conception of pragmatism, they might have paralleled the types of reservations James expressed. James just could not embrace what

Peirce was offering. At times, Peirce's insistence on his mathematical evolutionary perspective sharply angered and antagonized James. The mathematical themes of Peirce's first Harvard lecture in 1903 so angered James that after the first lecture he would not return for the remaining six lectures and opposed their publication.

Evolutionary though Peirce's contributions were, it is hard to imagine that Veblen, either wholesale or even in large stretches, would have adopted Peirce's mathematically conceived evolutionary philosophy and pragmatism without extensive critically minded reservations of his own. By way of comparison, we are now just learning of another major historical figure who was interested in Peirce's conceptions of inquiry, logic, and probability in the early 1900s, none other than Frank Ramsey (Misak 2016). Even as he was interacting with Keynes, Russell, and Wittgenstein, Ramsey was reading some of Peirce's writings. Ramsey obviously had a more mathematical and logical mind than either Veblen or James. In this regard, one should not expect that Veblen ever would have conducted a Ramsey-like inquiry into Peirce's writings. That would have been out of character for Veblen.

Even though Veblen like James may not have had a mathematical mind quite like Peirce's, it is still significant that Veblen seems to have become aware of the difference between applied and pure mathematics. This suggests his view of mathematics might be more knowledgeable than is commonly believed. Veblen may have had mathematical abilities greater than what has been recognized in the history of economics. His older brother Andrew who taught mathematics and would become head of the department of physics at the University of Iowa found a position for him teaching mathematics at a local academy in Madison, Wisconsin just before he attended Johns Hopkins (Dorfman 1934, p. 36). His biographer actually notes that

Veblen may have shared the raw mathematical talent exhibited in the abilities of close relatives such as Andrew and his son Oswald. Regarding Thorstein's innate mathematical aptitude Dorfman wrote that:

> Veblen described himself…. as a mutant ….declaring that in the Veblen family this mutant strain showed markedly in mathematics. Veblen said he could extract the eighth root of a number without computation on paper, and his nephew, Oswald Veblen, was able to go into fields where even expert mathematicians could not follow (Dorfman 1934, pp. 318-319)"

Oswald, took his doctoral degree in mathematics at the University of Chicago in the foundations of geometry while Veblen was at Chicago (Dyson 2012, p. 20).[12] Compared to Thorstein but not unlike Andrew and Oswald, Peirce of course was not just aware of the new abstract mathematics of his time. Peirce was deeply interested in the new mathematical logic, non-Euclidian geometry, topology, set theory, and computation. For Peirce, issues from pure mathematics such as continuity and the consistency of sets were also relevant to the foundations of calculus. Unless those problems were addressed, all of the disciplines which depend upon applied calculus might be called into question as well.

[12] Oswald also played a prominent role in founding both the mathematics department at Princeton University and the Institute for Advanced Study, and then, in hiring Einstein and Von Neumann in the 1930s.

Beyond evolutionary and mathematical conceptions, there is one specific aspect of Peirce's interest in mathematics and economics which might give pause to Veblen and institutionalists. One is Ricardo. Mathematics was changing remarkably when Veblen made his critique that mathematical economics was too mechanistic. Except for a few long footnotes Veblen did not more broadly characterize mathematics. In contrast Peirce was actively engaged with the new abstract mathematics of the late and early 20th centuries. This difference between the two men can be sharpened by an awareness of what Peirce thought about Ricardo. Ricardo of course has the reputation of being perhaps the most abstract of 19th century classical economists. Most historical and institutionalist economists were and have been quite critical of Ricardo in that regard. In contrast, Ricardo was really Peirce's favorite economist and he embraced the high level of abstraction in Ricardo's work (Eisele 1979). Peirce (1893b, CP 4, p. 87) thought highly of the abstract character of Ricardo's theory of rent. Seemingly looking for an economic and empirical counterpart of mathematical induction, Peirce (1890 WP 8, p. 21; 1893b, CP 4, p. 83) identified what he called Ricardian inference. When the economist notices that parcels of land need to be placed in order of their relative productivity and that rent is earned on the most productive parcel, then the economist is engaging in abstract relational comparison of what has been observed (Hoover and Wible 2019). For Peirce, this relational comparison within a collection of observations is crucial for creating a mathematical, relational conception of economic activity at the level of the individual. Now Peirce's interpretation of the mathematical significance of Ricardo's theory of rent with Ricardian inference, is unique to him. There is no

doubt that such a high view of Ricardo would stand in sharp contrast with those economists who considered themselves historical, evolutionary scientists and thus quite critical of Ricardo.[13]

Now return to the second quote from Veblen at the beginning of this essay. As Veblen remarked regarding economists of his own time, one can raise the same matter about today's economists early in the 21st century. Like Veblen ([1900] 1919, p. 76), one might consider whether, "Economists of the present day are commonly evolutionists in a general way" and thus whether the evolutionary aspects of their research methods are still quite limited to "a very uncertain degree?" Would Peirce's ideas raise the evolutionary character of economics if they were applied in a critical and careful way to today's arrays of economic ideas? We are just beginning to assimilate Peirce's evolutionary mathematical philosophy even though his death was more than a century ago. Perhaps the most important question raised here is whether Peirce's evolutionary philosophy of mathematics would be of any interest either to today's institutionalist or mainstream economists. Institutionalists seem to prefer non-mathematical modes of inquiry but for an exception or two such as Mitchell and Geogescu Roegen. Mainstream economists who know anything about the history of economics and mathematics likely would associate Peirce with institutional economics and not with mathematical economics and econometrics. Whether either school would reconsider its views of mathematics,

[13] Another matter is general equilibrium theory. General equilibrium theory needs to be contextualized from the perspective of an evolutionary and mathematical conception of science and philosophy. Peirce's evolutionary mathematical philosophy may be much better suited for this endeavor than Veblen's (Wible 2017).

mathematical economics, and econometrics in light of Peirce's evolutionary mathematical conception of inquiry, science, and economics is an open forward-looking question. Of course both schools of economics might learn something by reconsidering their views of mathematics and scientific inquiry from a Peircean perspective. But one should not pre-judge or prescribe how Peirce's mathematical conception of inquiry would or should be received by any contemporary research community in economics broadly considered. One can hope that further consideration of Peirce's evolutionary mathematical conception of science and economics might move us toward a more integrative conception of economic science and the history of economics and thereby advance a more integrative understanding of this vast array of human endeavors known as economic science.

VII. CONCLUSIONS

It is time to reconsider briefly the main question motivating this inquiry. How could economics be an evolutionary mathematical science for Peirce when for Veblen it was not? The clearest answer is that Peirce had developed an evolutionary, relational, and semiotic philosophy of mathematics and science which apparently was unknown to Veblen. Peirce's conception of the sciences begins with mathematics and an evolutionary cosmology. Veblen's conception of the social sciences begins with evolutionary anthropology and perhaps with Kantian evolutionary ideas. Veblen in his famous 1898 essay claims that economics "is not" an evolutionary science. This position led to his claim that a mechanistic mind set had come to pervade the theory and practice of many sciences and especially economics and that it was not evolutionary. In economics much of the problem emanated from the development of subjective marginal utility

theory as a replacement for the labor theory of value. Marginal utility theory according to Veblen was especially susceptible to mechanistic interpretation including its mathematical formulations with calculus. By 1904 Veblen was writing that mechanistic attitudes had become so strong in the applied mathematical sciences of his day that most scientists including economists functioned more like engineers than open minded inquirers. However by 1908 this position may have softened a bit. At that point in time Veblen offered two more nuanced and perhaps surprising themes about mathematics. First he seems to have shifted to more of an instrumentalist position regarding scientific research shaped by applied mathematical conceptions of inquiry. He came to recognize that many scientists and economists remained skeptical about taking strong mechanistic or evolutionary interpretations of their research. Second, Veblen actually took the position that pure mathematics was independent of any mechanistic cultural influence. Ostensibly this position on pure mathematics came after Veblen recognized that mathematics was not interpreted mechanistically in ancient times. But Veblen did not offer a theory or philosophy of how a non-mechanistic or even an evolutionary interpretation of mathematics might be attained. He did seem to leave an opening for an evolutionary philosophy of mathematics.

Again, probably unknown to Veblen, but at the same time he was asserting economics was not an evolutionary science, his former graduate professor C. S. Peirce was fashioning an evolutionary, relational philosophy of mathematics and the sciences. This is why Peirce's conception of economics and mathematical economics around 1898 and the turn of that century would have been so different than Veblen's. It is also why Peirce could conceive of economics in an evolutionary way with an evolutionary philosophy of mathematics. Peirce had created a

semiotic, relational philosophy of mathematics and human cognition which could then be used to construct a semiotic, relational and mathematical understanding of natural and social phenomena in an indeterministic, evolutionary world. In this context, Peirce also brought this semiotic philosophy of mathematics and science to his interpretation of economics. This is why his conception of economics and mathematical economics is both evolutionary and mathematical and why he would have written a very different essay about economics than Veblen.

Even though both were evolutionary theorists, Peirce and Veblen have starkly contrasting conceptions of evolution. Peirce developed his evolutionary and mathematical philosophy of inquiry much more comprehensively than did Veblen and Veblen applied what he knew of evolutionary processes to many aspects of economy and society which Peirce did not. One needs to be cautious about simply asserting that their views fit together one way or another. Such a positon would require considerable care. Is Peirce's evolutionary and mathematical perspective compatible to some degree with Veblen and institutionalist conceptions of economics? Is Peirce's mathematical evolutionary conception of science and inquiry relevant to the mathematically-dominant mainstream of contemporary economics? Is it too much to hope for the prospect of meaningful progress along both lines of inquiry? These are knotty, thorny, and significant questions and leave many possibilities for further research. Peirce was a mathematical evolutionary scientist and philosopher and Veblen was an evolutionary but mostly non-mathematical economist and social critic. They were professor and student at least in a minimal way. How interesting it might have been if each had seriously considered the ideas of the other in 1898 when they were both actively engaged with significant evolutionary contributions to human inquiry. While they did not do so then, much might be learned from each

if we take their separate contributions seriously in a new way and juxtapose them one against the other.

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