The Economic Mind of Charles Sanders Peirce

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Charles Peirce had significant interests in economics. He reworked the mathematical economic models of Cournot and Jevons in the 1870s. He conceived of the transitive axiom of consumer preferences in 1874. Peirce also developed a thesis of the cognitive efficiency of the human mind, abduction. He criticized Newcomb's economic writings. These forays into economics affected the six essays on pragmatism. These interests in economics are integrated with the meaning of the pragmatic maxim in Peirce's 1903 Harvard Lectures.

> "You are not," my friend said, "a special student of political economy..."
> C. S. Peirce, "The Fixation of Belief," 1877, *WP* 3, p. 249

> "Each of us is an insurance company..."
> C. S. Peirce, "Grounds of the Validity of the Laws of Logic," 1869a, *WP* 2, p. 270

1. Introduction

One of the founding figures of American pragmatism, Charles Sanders Peirce, had a much greater interest in economics than is generally known by historians of economics and American intellectual history. During the 1870s, Peirce became keenly interested in the development of mathematical economics especially the works of A. A. Cournot and W. Stanley Jevons. This economic interest continued into the 1880s, when Peirce questioned the economic conesquences of the removal of tariffs on imported sugar. He differed with the analysis of the economic implications of the Spanish Treaty held by supporters of President Grover Cleveland's administration. In the 1890s, Peirce wrote a short critique of Simon Newcomb's *Principles of Political Economy* which had appeared in 1886. Also, during most of his adult life, Peirce was interested in the economic dimensions of scientific research. He was continually aware of the need for additional resources to enhance the precision of the geological research he conducted for the Coast Survey. And economic factors were important economic aspects of his conceptions of science and philosophy. Besides having

an interest in some of the major contributions to economic theory, Peirce also developed a theory of the cognitive efficiency of the human mind. He used the term abduction to refer to this theory. Abduction occurred in the processes of scientific inquiry as well in common sense processes of creatively imagining the future. Peirce held to the thesis that the human mind had evolved so that it could efficiently guess what might happen in the near distant future. Guessing was imperfect and flawed. Human guessing was efficient relative to random generation of forward looking ideas, but it was also quite fallible. Human guesses needed to be tested by experimental means in science or by other methods of experientially based inquiry in the domains of common sense.

One of Peirce's greatest guesses was his application of mathematical logic to evolutionary processes. He called his metaphysical system his "Guess at the Riddle" which was written in 1887 and 1888. The key idea for Peirce was that evolutionary processes went through sequences of development which could be characterized by their logical complexity in terms of a logic of relations. Every process of natural or social development could be characterized as moving from a simple, undifferentiated beginning, to dual, triadic, and more complex stages of relational complexity. Such processes could eventually settle into an end stage of equilibrium, rigidity, and possibly death which could be characterized with dual relations.

Peirce intended that his guess about the relational logic of evolutionary processes would apply in some fashion or other to every branch of philosophy, to every scientific discipline, and to the rational content of ordinary language using semiotics and Boolean algebra. It is with Peirce's relational logic of evolutionary processes and the role of the cognitively efficient human mind in those processes where Peirce differs most from economists of the present day all the way back in time to James and John Stuart Mill.

2. Peirce's Interests in Economics

Pragmatism is generally thought to have originated out of a series of discussions that took place in the early 1870s at an intellectual club which Peirce called the Metaphysical Club. Peirce, William James, Oliver Wendell Holmes, Chauncey Wright, and a handful of intellectually inclined lawyers met to consider and debate philosophical topics. Peirce apparently suggested the name after becoming familiar with a similar club known as the London Metaphysical Society during his trip to Europe in 1870.[1] The Metaphysical Club met in homes in Cambridge, Massachusetts near the campus of Harvard College. From manuscripts which survive to this day, we know that many of the issues debated at the Metaphysical Club were put into draft form by Peirce in the early 1870s. Then in 1877 and 1878, Peirce published six essays in the *Popular Science Monthly* which have become recognized as the founding essays of pragmatism. Collectively, those essays were titled by Peirce as the "Illustrations of the Logic of Science."

There is a second intellectual club which shares the same name as the original Metaphysical Club. In 1879, Peirce joined the faculty at Johns Hopkins University. During one of his graduate classes, Peirce proposed to his students that they start a seminar to present and debate philosophical topics.[2] He suggested the same name as the club that had met in Cambridge, Massachusetts just about a decade earlier. The Johns Hopkins Metaphysical Club had about forty meetings from the early to the mid 1880s.[3] Peirce made several presentations. John Dewey was at Johns Hopkins while Peirce was there. Dewey apparently took Peirce's introductory class on logic but not his advanced class. Dewey is on the roster of those who heard one of Peirce's most famous lectures to the Johns Hopkins Metaphysical Club, his talk titled "Design and Chance" written during the winter of 1883.[4]

With regard to economics, Peirce seems to have had a continuing interest in the development of that subject. During his student days at Harvard, Peirce (1857) wrote an undergraduate essay on gold and gold mining. His interest seems to have been piqued by the gold rush of 1849 in California and another one in Australia. During the 1860s, economically directed comments can be found in several of his writings. However, the episode which shows a mature analytical interest in economics is a meeting of another club which met to discuss mathematics and science. Like the first Metaphysical Club, this club met in Cambridge, Massachusetts during the 1860s and early 1870s. It was called the Scientific Club. The Cambridge Scientific Club met in late December of 1871 to consider what was one of the most advanced books on mathematical economics of its time:

> Charles's father was to address the Cambridge Scientific Club on 28 December 1871 on the application of mathematics to certain questions in political economy, such as price and amount of sale, and the conditions of a maximum. Charles undertook to prepare diagrams for his father to exhibit at that meeting, and these were mailed to Cambridge on or about the 19th. (Fisch 1984, p. xxxv)

On 28 December 1871 the Cambridge Scientific Club met to consider the now famous book *Researches into the Mathematical Principles of the Theory of Wealth* by A. A. Cournot. At that point in time, Cournot's work was available only in French. Peirce and his father Benjamin were both conversant in French. Previously, Benjamin has participated in the translation of Laplace's *Analytical Mechanique* into English. Peirce also later wrote two of the essays on pragmatism in French before they were translated into English.

Letters and manuscripts survive from this Cournot-focused episode of the Cambridge Scientific Club.[5] There is a letter to his wife Zina, one to Simon Newcomb, and another to his father Benjamin from December 1871. In the letter to Zina from Washington, D. C. dated 17 December 1871, Peirce tells her that he has spent his evenings studying political economy. In the letter to Newcomb

also dated 17 December 1871, Peirce discusses profit maximizing equations for competition and monopoly and holds that the demand curve facing a competetive firm would be a linear constant. Peirce (1871b) penned a postscript to the letter stating: "This is all in Cournot." The real gem is the letter to Benjamin. In that letter written on 19 December 1871, Peirce presents equations which discuss the decision-making problem of two duopolists. Peirce uses his own notation which has made it difficult for historians and philosophers unacquainted with Cournot's work to identify the significance of the equations. Once the notation is related to Cournot's, it is easy to see that Peirce analyzed and discussed Cournot's profit maximizing equations for duopoly with his father.[6] Peirce realizes that the whole point to Cournot's comparison of monopoly and competition is a mathematical demonstration that the price charged by the monopolist should be greater than the price charged by competitive producers.[7]

Peirce explored mathematical economics in two other manuscripts in the early 1870s. In "Calculus of Wealth" also dated to 1871, he further explores profit maximization for competition and monopoly. From a manuscript in 1874, "On Political Economy," there is an unusual statement of the consumer axiom of transitivity. Peirce called it the first axiom of political economy. Last there is a letter to an attorney by the name of Conger who inquires whether calculus can be applied to psychology. Peirce responds that psychology is not sufficiently developed for such an application. Instead, Peirce asserts that calculus could be applied to political economy. He also concludes by maintaining that the principles of the economy should be studied from the vantage point of a logic of relations like that found in his long 1870 paper on Boolean algebra, "Description of a Notation for a Logic of Relatives."

Two years after "On Political Economy," Peirce would author his only published piece devoted mostly to economic analysis. In 1877, Peirce wrote his "Note on the Theory of the Economy of Research." It was published in 1879 with the Coast Survey papers for 1876. In the "Note" Peirce created a utility model of the costs and benefits of increasing the precision of scientific research. By the mid 1870s, Peirce had conducted a great deal of experimental research. He had observed the stars in the Milky Way galaxy for the Harvard Observatory. This resulted in his authoring his best known scientific monograph *Photometric Researches*. He was the Assistant in Charge of the pendulum experiments for the Coast Survey. In that capacity, he directed numerous pendulum experiments in Europe and the United States. Also, Peirce made numerous investigations into human factors and scientific instruments which affected the reliability and accuracy of scientific instruments. The "Note" represents the benefit or utility of greater precision in scientific observation as a function of the degree of probable error.[8] Utility would increase as probable error was reduced. Probable error is the 19th century analog of a confidence interval in statistics. Cost was considered to rise as probable error was reduced as more resources were devoted to greater precision in scientific research. The mathematics of the "Note" resembles the presentation of utility theory in Jevons's *Theory of Political*

Economy which first appeared in 1871. Also, Peirce's graphical interpretation of a two project version of his theory of research is quite similar to Jevons's version of a consumer's marginal utility for two goods. This can be seen in Figure 1 which exhibits the graphs of both Peirce and Jevons.[9]

Figure 1
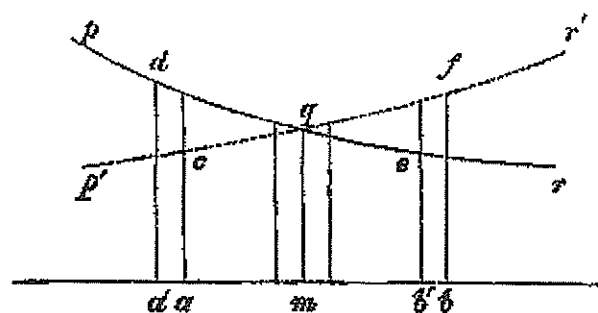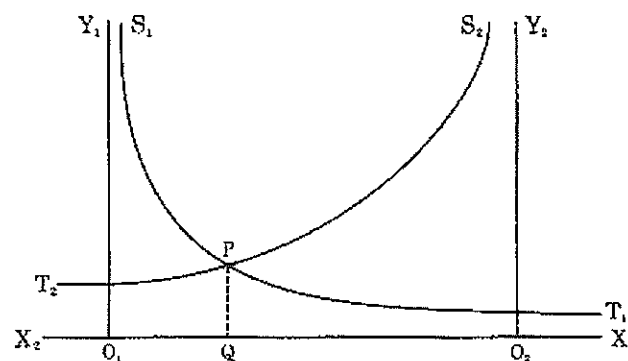Peirce and Jevons's Bi-directional Diminishing Marginal Utility Graphs

FIG. 5.

Top figure is Figure 5 from Jevons's Theory of Political Economy, p. 97. Bottom figure is from Peirce's "Note on the Theory of the Economy of Research."

In the mid 1880s, Peirce would debate the significance of free trade with the editor of the *New York Post* and *The Nation*.[10] Using the conceptions of relative prices and relative cost, Peirce held that the Spanish Treaty which would remove tariffs on sugar would lower the price of sugar in New York City. The editors of the *Post* and *The Nation* maintained that price in the market in New York would be changed but only to a negligible degree. Peirce's comments clearly reflect ideas from the works of Cournot and Jevons on relative prices and international trade that Peirce surely would have read during the 1870s.

While Peirce would never again deal with economics in as much detail as he had in the 1870s, it would continue to draw his interest. Besides the letters on free trade and the Spanish Treaty, in the last three decades or so of Peirce's life there are several more episodes of interest with regard to economics. In testimony before Congress in the late 1880s, Peirce (1885c) testified on weights and measures with regard to the minting of coins in precious metals. In the 1890s, he authored a critique of Simon Newcomb's *Principles of Political Economy*; he provided an economic criticism of the methods for reconstructing the works of Aristotle and Plato; and he disagreed with utilitarian theories for the punishment of criminals.[11] In the Harvard lectures of 1903, Peirce offered a mathematical model of the profit maximizing insurance firm as an example of the meaning of the term probability.

3. Economics and the Original Essays on Pragmatism

What do we make of Peirce's interest in economics in the 1870s? One possibility would be that Peirce's interest in mathematical economics could be interpreted to be an oddity – or an isolated intellectual interest entirely separate from his science and philosophy. The other possibility would be that economics is intimately interconnected and interwoven throughout Peirce's contributions to other disciplines. In this view, one would expect to see economic or economically minded comments in many of his philosophical and scientific writings. A close reading of Peirce's six essays on pragmatism shows that economic ideas have a significant presence in those essays.

The most extensive economic comments can be found in the first essay, "Fixation of Belief." In that essay, Peirce (1877) uses economics to illustrate three of the four methods that have been used to establish belief in human thought. The example of single minded commitment for or against free trade is portrayed as one of the most important examples to illustrate the method of tenacity. Peirce believes that views for or against free trade are decided without much use of data and once a position is taken, the position is maintained without reservation in the face of conflicting information and opinions. A second method for fixing belief is the idea that there are a priori reasons for preferring one system of ideas over another. Peirce held that if there were two or more alternative systems of belief, that some would adopt one system of belief and others the alternative. Peirce regarded such a choice as a matter of taste. Since

Peirce had read Jevons on utility theory and human preferences, one can certainly see that an economic critique was being offered in regard to this type of choice. A third method of belief is one of authority. It is portrayed as one which becomes quite rigid and inflexible and by implication obviously inefficient. The last method for fixing belief is the scientific method. Peirce clearly held that scientific methods were more efficient than other methods. He maintained that scientific methods would waste fewer resources and conclusions would be attained more directly by following the logic of scientific methods.

Another essay with obvious economic content is "Doctrine of Chances." Here Peirce (1878b) maintains that narrowly interpreted self-interest is not rational. One's life span is limited so that the accumulation of wealth makes no sense because it will be given up eventually:

> ... death makes the number of our risks, of our inferences, finite and so makes their mean result uncertain. The very idea of probability and of reasoning rests on the assumption that this number is indefinitely great. We are thus landed in the same difficulty as before, and I can see but one solution of it. It seems to me that we are driven to this, that logicality inexorably requires that our interests shall *not* be limited. They must not stop at our own fate, but must embrace the whole community.... To be logical men should not be selfish; and, in point of fact, they are not so selfish as they are thought. The willful prosecution of one's desires is a different thing from selfishness. The miser is not selfish; his money does him no good, and he cares for what shall become of it after his death. (Peirce 1878b, *WP* 3, pp. 283–84)

Peirce also comments on the nature of an insurance firm and gambling. These comments are an extension of his interest in probability and random sampling techniques. In the history of statistics, Peirce is considered the first philosopher and scientist to have a clear understanding of scientific sampling.[12] In the middle of the 19th century, astronomy and geodesy were the sciences which were most concerned with making inferences from large sample sizes. Physics and chemistry were focused on smaller scale phenomena which could be summarized with relatively simple mathematical formulas containing quantifiable coefficients. In the economy, Peirce focused on the insurance firm as an enterprise which took advantage of predictable large scale patterns of social phenomena. He viewed the insurance firm as a stochastic enterprise. If the firm estimated the probabilities of insured events accurately, it would survive. If not, it would fail and go bankrupt.[13]

Turning from insurance to broader topics in "Doctrine of Chance," Peirce (1878b) asserted that the long run was the statistical long run when probabilities would change. He maintained that most patterns of phenomena were stable for finite periods of time. Even if the period of time was unimaginably long by human standards, every pattern giving rise to scientifically stable results would

eventually be broken. The same was true of an insurance company and by inference all economic processes. Whatever patterns of stable economic phenomena were apparent during some period of economic history, those patterns were sure to change at some point in the future. Peirce thought that knowledge of probabilities and their limitations would require cooperation among those in the economy or those in science. One individual could not develop such knowledge in isolation. In a stochastic world where probabilities matter, empirical knowledge and scientific outcomes needed to be shared. In such a world, Peirce regarded selfishness as illogical and the utilitarian focus on pleasure and pain as misguided.

Of the four remaining six essays on pragmatism, two of them — "Deduction, Induction, and Hypothesis" and "The Probability of Induction" — are devoted to explaining the rules of logic and their application to probability. These essays contain a much richer picture of science than essays that economists tend to read on scientific method such as Friedman's (1953) well known essay on positive economics written in the early 1950s. Another essay is devoted to synthesizing a view of the world from the parts of the nature that were being discovered in science and mathematics. That essay is titled, "Order of Nature." Peirce's (1878d) world is one which could be conceived as collections of objects and processes. Those collections of objects and processes could be characterized with patterns of properties and outcomes. Patterns and properties of outcomes create distinctions which can be distinguished and differentiated. These distinctions and differentiations would endure for some scale of time so that mathematics and the tools of science and probability could be used to study those collections, their processes, and their properties. In "Order of Nature," Peirce held that our universe is not one of pure chance. Our world is a mix of order and chance. The mix of order and disorder exhibits path dependence, so that there is a continual growth of order and diversity in our universe. Also, created patterns of order and disorder constrain future patterns of order and disorder. This is another manifestation of path dependence. Whether the growth of order and pattern continues indefinitely with or without ultimate bounds is beyond the present state of human and scientific knowledge.

The most famous of the six essays on pragmatism is the second one "How to Make Our Ideas Clear." If one looks for economics in terms of recognizable theory and applications then it would appear that this is the least economic of the six essays. But appearances can be deceiving. If the philosophical ideas about scientific method are restated in economic terms, then this may be the most economic of the essays on pragmatism. In philosophical terms, Peirce (1878a) takes a theme from Descartes about how ideas can be clarified. Without going into the details, Peirce offers a philosophical version of the scientific method which is presented in three of the last four essays of the *Popular Science Monthly* essays on pragmatism. He tells us that ideas are clarified by their sensible effects. But these are not the isolated uninterpreted inputs that empiricists and later positivists would imagine. In previous writings

to be considered in the next section of this essay, Peirce had held that general ideas not derivable from sense experience need to be related to a conception of sensible effects. Generalized abstractions such as those found in inferences, hypotheses, and mathematical and philosophical concepts provide a context for interpreting what is sensible in observation. Sensible ideas are those with forward looking consequences. The reliability of forward looking knowledge has been one of the central questions of philosophy.

In another article that will be considered subsequently, an 1869 article, "Grounds of the Validity of the Laws of Logic," Peirce (1969a) differed with Kant's framing of the nature of forward looking knowledge. Peirce no doubt was informed of Hume's scepticism with regard to Kant.[14] Peirce held that synthetic a priori or forward looking knowledge without uncertainty is impossible. Kant used the term synthetic a priori knowledge to describe human knowledge relevant to the present and the future. Peirce held that the meaningful question is how any kind of forward looking knowledge is possible even if it is not known a priori.

Peirce also disagreed with the most prominent empiricists of his day, James and John Stuart Mill. Peirce held that the general concepts that scientists, mathematicians, and common people used to anticipate the future were too general to be derived solely from the inputs of the senses. In "How to Make Our Ideas Clear," Peirce held that the clearest forward-looking ideas were those that could be stated logically and also had real sensible consequences. Such forward-looking propositions often took the form of conditionals. They could take the following form: This is what would happen or would be true, if certain investigative actions were taken and the conditional context surrounding previous observations of those actions remained unchanged. He put it in the form of the pragmatic maxim:

> Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object. (Peirce 1878a, *WP* 3, p. 266)

Economists should recognize this conditional mode of reasoning since economic models are applied and interpreted with the same reasoning process of conditional interpretation.

It should be clear from the preceding comments, that Peirce's interest in economics is intertwined with the six most famous essays of American philosophy. The economics of Cournot and Jevons and classical economists such as Malthus, Ricardo, Smith, and James and John Stuart Mill influenced Peirce's conception of pragmatism. There is no better way to make this point, than to maintain that an economic essay should be added to the group of six founding essays on pragmatism. Obviously the essay of reference is Peirce's "Note on the Theory of the Economy of Research." Peirce scholar and biographer Max Fisch

has commented that Peirce's "Note" needs to be placed along side the other six essays. Fisch also tells us that Peirce intended to write more than six essays for the "Illustrations of Logic" series. He also speculates that Peirce could have easily written a less technical version of the "Note" for the *Popular Science Monthly*.[15] Given Peirce's interest in economics as exhibited in the writings surrounding the Cambridge Scientific Club in 1871 and then in the economic comments in the six essays on pragmatism, an important conclusion can be drawn. Fisch's comments about the importance of economics and the "Note on the Theory of the Economy of Research," are surely understated. The science and philosophy of the Metaphysical Club is certainly intertwined with the economics of the Cambridge Scientific Club.

4. From Logic and Hypothesis to Abduction, Efficient Cognition, and Guessing

There is another economic hypothesis for which Peirce is well known which lies outside of the domain of economics as it has been configured since Adam Smith. Peirce held that the human mind had evolved to become an efficient anticipator of the future. Efficient for Peirce was defined relative to an alternative. The human mind could create guesses about future consequences which were more accurate than conceptions of the future generated by chance. This is Peirce's thesis of cognitive efficiency. He labeled this process with the term abduction and explained it with a theory of guessing. One of Peirce's most encompassing guesses regarded the broadest patterns of the natural world since its creation. Peirce called this his "Guess at the Riddle." Peirce hypothesized that the universe began in a purely stochastic state of absolute chance without order or pattern, then something happened which began the growth of order and pattern, and such growth continues to the present day. Somewhere along the way, sufficient order and pattern appeared to allow for the laws of nature. Subsequent growth and development allowed for the appearance of the larger structures of the cosmos such as galaxies and solar systems. Even later stages of development created earth-like environments where life and intelligence could embark on a path of order and pattern. At some point in this process, humans with large brains appeared. Putting their superior brain power to good use, humans began reflecting on the patterns and properties of the natural and social environments in which they found themselves. Ideas, language, and cognitive constructs began to grow towards greater complexity, accuracy, and utility. For Peirce, human cognition had evolved in concert with the patterns, properties, and processes in which human populations were embedded. Their cognitive constructs, while prone to error, were better than ideas taken at random. One needed to constantly inquire whether the ideas used to conceive of problems and circumstances were relevant, accurate, and efficient.

Peirce's theory of efficient human cognition seems to have arisen from his interest in logic and the logic of inference in science. Relatively early in his adult life, Peirce distinguished a third logical process which was different from deduction and induction. This third process was called hypothesis at first. Later it was termed abduction. Deduction was a mode of inference based on the syllogism. One reasoned from a general premise to a specific conclusion. Induction exhibited reason in the opposite direction. One reasoned from specific observations of human sensation to inductive generalizations. For Peirce, hypothesis was quite different. A proposition suggesting a logical relation with regard to the patterns of entities and/or processes was stated. This proposition was not yet a widely recognized generalization so it would not be wise to use it deductively. Also, it exceeded anything that would be warranted as an inductive generalization. For Peirce, an abduction typically began as a guess termed an hypothesis about what is or what would be the case if certain conditions under which the guess was made were indeed met. The hypothesis at best was only weakly supported by inductive evidence and propositionally stated as a general statement. However, until a process of inquiry was pursued and appropriate scientific evidence was found to support the statement, the hypothesis would be viewed as contingent and provisional. Peirce was aware of the logic of falsification so he knew that evidence in support of an hypothesis would not prove that it was true. In the context of his evolutionary view of the universe rooted in his knowledge of astronomy and geodesy, Peirce held that even the longest known stable patterns of our world would eventually be altered. Solar systems are created and destroyed over very long eras of time so all laws of nature as we know them could be different. What an abductive hypothesis did was allow the use of human cognition in creatively exploring a more complex variety of patterns of social and natural phenomena than induction and deduction would permit. Logically guided cognition is the most precious forward-looking neuro-psychological endowment that humans can have in Peirce's view.

Some of Peirce's earliest comments on inductive knowledge come from his 1869 article, "Grounds of the Validity of the Laws of Logic." This article was the last of a series of three articles on cognition that appeared in the *Journal of Speculative Philosophy*. Here Peirce (1869a) was concerned with how any reliable inductive knowledge was possible. Instead of the uniformity of nature which was presupposed by most empiricists like J. S. Mill, Peirce held that our world was a mix of order and disorder which could be approached with the laws of probability. In such a world, he rephrases Kant's assertion about how empirical knowledge is possible:

> According to Kant, the central question of philosophy is "How are synthetical judgments *a priori* possible?" But antecedently to this comes the question how synthetical judgments in general, and still more generally, how synthetical reasoning at all is possible at all. When the answer to the general problem has been obtained, the particular one will be comparatively simple. This is the lock upon the door of philosophy. (Peirce 1869a, *WP* 2, pp. 267–268)[16]

Almost simultaneously with "Grounds of the Validity of the Laws of Logic," Peirce published two book reviews which add significant details to his theory of cognition. In one review, Peirce (1869b, *WP* 2) sets out to review James Mill's *Analysis of the Phenomena of the Human Mind*. His review is titled, "The English Doctrine of Ideas." The psychological doctrine of abstract ideas to which James and John Stuart Mill and many other English-speaking economists adhered in the 19th century is known as British associationism. Associationism is the thesis that abstract ideas are created by the associations of sensations stimulated by events in the empirically observable, external world. In this review, Peirce takes great pains to question James Mill's strong defense of associationism. Mill defends the associationistic assertion that all ideas are copies of sensations and that even the order of ideas which one has is a copy of the order of sensations from which the ideas originated. Also at issue is a notion of a general idea such as resemblance which James Mill held was a product of sensory experience. Peirce crafts his criticism in the following way directing his comments toward J. S. Mill:

> Stuart Mill is gravely mistaken in supposing that his father's rejection of resemblance as a guiding principle of association was an unimportant part of his theory. Association by resemblance stood in the way of his doctrine that the order of ideas is nothing but the order of sensations, and to grant the mind a power of giving an inwardly determined order to its ideas would be to grant that there is something in the mind besides sensations and their copies. (Peirce 1869b, *WP* 2, p. 306)

Peirce obviously sees James Mill's view as flawed and argues for the opposing view that the mind brings something independent of sensation to experience. As one example, Peirce takes an idea which is at the center of James Mill's position which Peirce believes is inconsistent with Mill's own position. Peirce holds that: "The doctrine that an idea is the copy of a sensation has obviously not been derived from exact observation" (Peirce 1869b, *WP* 2, p. 306). Then Peirce considers another example which would be difficult for either James or John Stuart Mill to reject. Stemming from his interest in science, mathematics, and logic, we should not be surprised to find Peirce suggesting the very conception of inference as an idea which is independent of sensation. He attributes his view of the significance of a conception of inference to one of the founders of modern psychology, Wilhelm Wundt. Peirce (1869b, *WP* 2, p. 307) believes that it is Wundt who has shown "that every train of thought is essentially inferential in its character." Peirce believes that James Mill's version of associationism is too simple being unable to account for generalized ideas such as resemblance, reflexive reflection, and scientific or logical inference.

   Peirce's critique of Mill's view of logic and inference was continued in another book review published early in the next decade. This piece is one of the earliest writings suggesting that Peirce was thinking about economic aspects of

inquiry. In a review titled, "Educational Text-books, II," published in the *Nation* in 1872, Peirce (1872, *WP* 3) criticized many of the textual materials used for educational purposes in the 1870s. The critique begins by focusing on a problem with a star atlas which Peirce maintains has been constructed on the wrong principles. Then, after commenting on other texts in physics, psychology, and deductive logic, Peirce critiques the conception of hypothesis in yet another textbook, one on deductive logic.[17] Here Peirce maintains that the author of one of the texts has assumed John Stuart Mill's conception of hypothesis which Peirce believes is erroneous. His critique of Mill's view of hypothesis is very similar to his criticism of the notion of inference mentioned above.[18] In this text book review, Peirce first criticizes Mill for an unclear conception of what a scientific hypothesis is:

> A scientific hypothesis is usually defined (and is defined by Mr. Mill) as the supposition of a circumstance which, by the action of known laws (or a generalization of known laws), would result in facts such as have been observed. It is also common to use the term scientific hypothesis to denote a very doubtful conclusion of science. These two meanings are apt to be confounded, and Mill has plainly confounded them.... (Peirce 1872, *WP* 3, pp. 4–5)

Then, about half a page later, Peirce rephrases his critique regarding a conception of inference as including more than sensations and he raises economic aspects of science. What is so interesting about this passage, is not only do we have Peirce criticizing the logical conception of a scientific hypothesis by Mill, one of the best known economists of the 19th century, Peirce also provides an economic critique of Mill:

> A hypothesis, therefore, does not differ from any other inferential proposition; and the only thing to be considered in reference to its admissibility is the actual evidence upon the matter. Mr. Mill's view is that a hypothesis is not something inferred, but something taken as the basis of enquiry; so that the question is not what the existing evidence is, but what evidence is forthcoming. Here two questions must be distinguished: the first, in reference to what a man may logically do; the second, as to how he may best economize his scientific energies. Now a man may investigate the truth of any proposition whatever, and if he makes no false inference there is nothing illogical in his procedure. But he will be very unwise to spend a large portion of his life putting anything to the test which can hardly be true or which can hardly be false. (Peirce 1872, *WP* 3, p. 5)

   Within just a few years, Peirce began to broaden his concern for efficiencies that logic provides for inquiry and the crucial role of hypothesis in

exploring new conceptions of things to a thesis of cognitive efficiency. In "Order of Nature," written in 1878, Peirce maintains that the mind of man is efficiently adapted to its surroundings. He claims:

> 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. 319)[19]

In the remainder of the paragraph, Peirce goes on to claim that science depends on general ideas of time, space, and mass. With these general conceptions in hand, Peirce believes that scientific discovery is possible and that it happens more often and more quickly than was understood in his day.

Five years later, in "A Theory of Probable Inference," Peirce (1883b) would further extend his theory of efficient cognition to guessing. First, he argues as he had in "Order of Nature," that the mind is well adapted to comprehend some if not many of the patterns of the phenomena which human beings experience:

> Although the universe need have no peculiar constitution to render ampliative inference valid, yet it is worth while to inquire whether or not it has such a constitution; for if it has, that circumstance must have its effect upon all our inferences. It cannot any longer be denied that the human intellect is peculiarly adapted to the comprehension of the laws and facts of nature, or at least of some of them.... (Peirce 1883b, *WP* 4, p. 445).

In the very last section of this essay, Peirce constructs an additional illustration of the difference between an induction and an hypothesis. He imagines a "strange being" from some remote part of the universe coming to the United States and being presented with a United States Census Report. He believes that such an intelligent being would make many inductions from the array of data so presented. At some point, this strange being would come across data for rainfall and illiteracy. Using maps from the Coast Survey for the United States, Peirce illustrates that winter rainfall tends to occur in places where illiteracy is very high. An inductive inference would be that there is some partial connection between the amount of rainfall in winter and illiteracy. But such a partial explanation is unsatisfactory for Peirce. At this point, he argues that an investigator with a human mind would inquire about the causes of rainfall and illiteracy so that appropriate conceptions could be created and intelligent questions could be asked. But Peirce's strange being is not adapted to the section of the universe where humans live and is unable to make greater sense of the facts of rainfall and illiteracy. In one of the last paragraphs of the paper, Peirce

fashions these ideas into a theory of guessing. This would become an important notion for him in both science and philosophy. Regarding the ability of the human mind to understand nature through a process of guessing, he writes:

> Nature is a far vaster and less clearly arranged repertory of facts than a census report; and if men had not come to it with special aptitudes for guessing right, it may well be doubted whether in the ten or twenty thousand years that they may have existed their greatest mind would have attained the amount of knowledge which is actually possessed by the lowest idiot.(Peirce 1883a, *WP* 4, pp. 449–450)[20]

5. Are There Two Conceptions of Rationality in Peirce's Thought?

The preceding depiction of Peirce's interest in economics could be interpreted as suggesting two distinct conceptions of rationality. As economists have defined it since the Marginalist Revolution of the late 19th century, rationality is a process of either utility or profit maximization. Consumers and firms are similarly rational but with different objective functions and constraints. The Marginalist Revolution was concerned with developing economic theory using calculus and reinterpreting economic theory in a way that would be consistent with calculus. Before that, wealth accumulation was considered the principal motive of economic activity. In contrast to economists, others such as philosophers have conceived of rationality as a matter of intelligibility. What is it that allows a human being to communicate rationally with another human being? Peirce had a lot to say about intelligibility and he applied his insights to economics as well.

It should be clear that Peirce understood the aims of the Marginalist Revolution. He actually created and solved a utility optimizing model in his "Note on the Theory of the Economy of Research" and he worked through profit maximizing equations for monopoly, competition, and duopoly as Cournot had done. These interests in mathematical economics were noted previously. In general, Peirce was intrigued with the project of making economics a mathematical discipline and he understood that there would be limitations imposed on an understanding of human behavior with such an approach. Peirce's expresses this dual minded awareness for what economic theorists were doing with mathematics in a definition that he prepared for the *Century Dictionary*:

> No theory in the positive sciences can be supposed to satisfy every feature of the facts.... If this is necessary even in physics, it is far more indispensable ... in political economy. Here the sane method is to begin by considering persons placed in situations of extreme simplicity, in the utmost contrast to those of all human society, and animated by motives and by reasoning powers equally unlike those of real men. Nevertheless, in this way alone can a base be obtained from which to proceed to the consideration of the effects of different complications. Owing to the

necessity of making theories far more simple than the real facts, we are obliged to be cautious in accepting any extreme consequences of them, and to be also upon our guard against apparent refutations of them based upon such extreme consequences. (Peirce 1902c, *CP* 7, pp. 60–61)

But Peirce was also concerned that individuals were capable of rationality more broadly interpreted as basic intelligibility in their economic affairs. The ability to reason with a syllogism was a key aspect of intelligibility for Peirce. Throughout Peirce's writings there are numerous references to logic and transitivity. One can find such a reference in the manuscripts that were written while the Cambridge Metaphysical Club was meeting in the early 1870s. Transitivity can be found in Peirce's long piece on Boolean algebra which appeared in 1870. There are also references to transitive aspects of economic affairs. But the one which is most interesting is a description of transitivity in relation to an ordinary syllogism and measurement. In an essay written while at Johns Hopkins, "A Theory of Probable Inference," Peirce (1883b) asserts that transitivity is one of the most basic aspects of a syllogism:

> For the existence of ordinary syllogism, all that is requisite is that we should be able to say, in some sense that one term is contained in another, or that one object stands to a second in one of those relations: "better than," "equivalent to," etc. which are termed *transitive* because if *A* is in any such relation to *B* and *B* is in the same relation to *C*, then *A* is in that relation to *C*. (Peirce 1883b, *WP* 4, p. 410, italics in original)[21]

Such reasoning implies that Peirce thought that the qualitative properties of a very young universe – before the properties of space, time, and nature had settled into rigid patterns – could be described with a logic of mathematical relations. It is also a universe which was intelligible since the logic of a syllogism could be applied in a world with order even though it did not have the rigid order that would permit quantification and measurement.

Turning to economic applications, Peirce made some very interesting transitive interpretations of economic behavior. In one of the manuscripts as mentioned previously, one can even find a statement of what theorists now call an axiom of consumer preference. In "On Political Economy," Peirce wrote down his First Axiom of Political Economy:

> The dependence of demand on price arises from this fundamental proposition. The desire of a person for anything has a quantity of one dimension, and a person having a choice will take that alternative which gives him the greatest satisfaction. In other words if a person prefers A to B and B to C he also prefers A to C. This is the first axiom of Political Economy. (Peirce 1874, *WP* 3, p. 176)

More than a decade later, in a passage interpreting one of his metaphysical categories, Peirce again uses a transitive economic example illustrating the logical complexity of creative, on-going processes. Peirce wants to argue that some things cannot be reduced from a triadic complexity to being a compound of two dual relations. The example of gift-giving is found in many places in Peirce's writing, and it may be his favorite example of irreducible triadic complexity:

> To make this clear, I will first show it in an example. The fact that A presents B with a gift C, is a triple relation, and as such cannot possibly be resolved into any combination of dual relations. Indeed, the very idea of combination involves that of thirdness, for a combination is something which is what it is owing to the parts which it brings into mutual relationship. But we may waive that consideration, and still we cannot build up the fact that A presents C to B by any aggregate of dual relations between A and B, B and C, and C and A. A may enrich B, B may receive C, and A may part with C, and yet A need not necessarily give B to C. For that, it would be necessary that these three dual relations should not only coexist, but be welded into one fact. Thus, we see that a triad cannot be analyzed into dyads. (Peirce 1887–88c, *WP* 6, pp. 174–175)

In comparison, exchange is a quadruple relationship which can be decomposed into triadic relationships. In the very next sentence, Peirce juxtaposes the logical points just made about gift-giving with a comparison to economic exchange. His goal is to show that the more complex logical relationships of market exchange can be reduced to triads:

> But I will now show by an example that a four can be analyzed into three. Take the quadruple fact that A sells C to B for the price D. This is a compound of two facts: 1st, that A makes a certain transaction, which we may name E; and 2nd, that this transactions E is a sale of C for the price D. Each of these facts is a triple fact, and their combination makes up as genuine a quadruple fact as can be found. (Peirce 1887–88c, *WP* 6, p. 175)

Gift-giving and exchange are not the only economic examples that Peirce used to illustrate his theory. Another economic example can be found in one of the manuscripts from the summer of 1886, "First, Second, Third." The concepts of ends and means are significant to economists. Ends are the ultimate aims and values that are thought to be behind the patterns of choices that are made in the economy every day. The means to achieve these ends are thought to be limited so that individuals face these limits in their own circumstances as well. In discussing his metaphysical categories in "First, Second, Third," interspersed among other examples one finds a consideration of ends, means, and the nature of a contract. In remarks discussing the three categories, Peirce writes:

The beginning is first, the end second, the means third. A and B the parties of the first and second make a contract; that contract, C, is what brings them into relation, and herein lies its essence. (Peirce 1886d, *WP* 5, p. 305)

What is so interesting about the preceding passages is that Peirce is conceiving of economic activity in terms of logical relations largely before mathematical economics had been created and certainly before it was formalized as a system of axioms and postulates from the 1920s through the 1950s. In the history of mathematics, Peirce is recognized as one of the early contributors to the formalization of mathematics. Peirce's 1870 piece and several others on Boolean algebra and the logic of relations are recognized for their contributions to the creation of the new field of mathematical logic. But Peirce began to think about the philosophical implications of mathematical logic. Instead of advocating the formalization and logicizing of various scientific disciplines, Peirce applied logic and the logic of mathematical relations to the theory of evolution and human cognitive intelligibility. For Peirce, human cognition had evolved to help us interpret patterns in the natural and social environment. With reference to economics, a rational human being capable of transitive logic could reason and make use of the inferences that take the form of a syllogism. Such reasoning capabilities would make qualitative choices and comparisons possible. For Peirce, such logical comparisons as found in the consumer axiom of transitivity and the logical relations found in ordinary exchange as quadruple logic of relations were prior to any quantitative depiction of economic activity. The implications of all of this for economic theory could not be more profound. Peirce's broad conception of rationality as the intelligibility of logical relations led him to formulate consumer preference, exchange, gift-giving and other economic activities such as contracting as matters of logical relations. In his treatment of profit maximization, Peirce also seems to emphasize the logic of first order conditions as important logical properties even when data is unavailable to provided a numerical solution for profit maximization. Such logical relations are conceptually prior to their description with a framework of scientific quantification for Peirce. This is the reverse of the way economic theory is typically taught.

Usually economic theory is presented as having developed with quantitative conceptions of utility first. When no unit of interpersonally measurable utility could be found, a logical interpretation of consumer choice was created using axioms and postulates to assure that a utility function could be integrated using the techniques of calculus. The historical caricature of economics presents the search for a quantifiable theoretical framework and unit of analysis as happening first and logically prior to what followed. What followed was an algebraic approach to consumer theory when the limitations of a quantitative framework were encountered. But Peirce would never have done things this way. He developed a relational and logical interpretation of human cognition in

the context of evolutionary processes which emphasized the primacy and efficiency of qualitative relational comparisons. This qualitative conception of rational intelligibility was logically prior to the quantitative, optimizing theories of rationality as utility and profit maximization that he encountered as he read economists Cournot, Jevons, and others. Of course the mathematical economics of utility theory has embedded logical relations which are consonant with his general conception of relational efficient cognition. For Peirce a qualitative logic of relations is more fundamental than optimization. Theoretical talk of maximization is warranted only in so far as its logical properties are the same as those of a conception of rationality in terms of a logic of relations. Peirce was an evolutionary thinker of the first rank and for him quantitative reasoning is embedded within a more general relational logic of transitive, syllogistic reasoning. Again, this is the opposite of what is taught in almost all advanced economics texts and graduate theory classes for the past half century.

6. Peirce's Stochastic View of the Individual

While Peirce's interests in the economics of Cournot and Jevons and the efficiency of human cognition are really quite extraordinary, there is another economic dimension which is just as interesting and deserves greater emphasis. This is Peirce's philosophical and scientific interest in an insurance company. This interest was noted previously when discussing the essays on pragmatism. Peirce's theory of an insurance company may actually present a stochastic theory of individual rationality. This is in stark contrast to the way economic theory has been developed and presented for much of the twentieth century. The theories of the consumer and the firm as developed since the Marginalist Revolution are considered to be both deterministic and focused on quantitative units of measure. While utility theory failed to ever find a stable unit of measure, the theory of the firm required only a fairly stable currency, such as the American dollar or the British pound, as a unit of measure.[22] Most countries have such a unit and an elaborate framework for dealing with inflation has been developed in macroeconomics to deal with the gradually changing value of a currency unit. In standard microeconomic theory, the rational individual is depicted as behaving consistent with a deterministic, rational optimizing process modeled with applied calculus. Mathematical versions of economic rationality as maximization provide the analytical motivation for behavioral equations summarizing the most important determinants of human economic behavior. To these behavioral equations a stochastic element is added with an error term implying that there are limitations to the deterministically based theory. Then data can be collected and the theory can be tested against the evidence. Regressions or other statistical programs can be run, results can be obtained, and test statistics can be examined to see how well the theory fits with the data.

However, Peirce would have begun with a qualitative, relational, and syllogistic conception of rationality as intelligibility. His transactors would have

the capability of reasoning about economic processes with a mathematical logic of relations before they would make quantitatively based decisions or conceive of maximization.

While Peirce was intrigued with some of the most important foundational contributions to deterministic microeconomics, this did not stop him from formulating a stochastic theory of individual decision making. Through out his life, Peirce was intrigued with the insurance company. Peirce's comments on an insurance company from "Doctrine of Chances" are noted above. The reason for this is that an insurance company needed to be a good estimator of probabilities to earn a profit and to stay in business. An insurance company plays a special role in Peirce's philosophy of science. The profitability of an insurance company depends on accurately appraising the demographic characteristics of the policy holders and their insurance claims relative to the premiums they are willing to pay.

From "Grounds of the Validity of the Laws of Logic," Peirce characterizes the validity of induction relative to truth in the following way:

> From this it appears that we cannot say that the generality of inductions are true, but only that in the long run they approximate to the truth... in the long run our errors balance one another. In fact, insurance companies proceed upon induction; – they do not know what will happen to this or that policy-holder; they only know that they are secure in the long run. (Peirce 1869a, *WP* 2, pp. 268–269)

On the next page of the essay, Peirce further qualifies his assessment of how an insurance company can make valid inductions. He actually states that in some respects *we can all be thought of as facing the problems that an insurance company faces*:

> ... we know that, by faithfully adhering to that mode of inference [induction], we shall, on the whole, approximate to the truth. *Each of us is an insurance company*, in short. But, now suppose that an insurance company, among its risks, should take one exceeding in amount the sum of all the others. Plainly, it would then have no security whatever. Now, has not every single man such a risk? (Peirce 1869a, *WP* 2, p. 270, italics added for emphasis)

Given these comments about insurance and probability, it is not surprising that Peirce would make some interesting comments about probability in the *Popular Science Monthly* essays. If the pragmatic maxim is now regarded as the most important single contribution of those essays, it should be interesting to note that Peirce paraphrased the maxim in terms of probability in "Doctrine of Chances:"

> *To get a clear ideas of what we mean by probability, we have to consider what real and sensible difference there is between one degree of probability and another.* (Peirce, 1878b, *WP* 3, p. 279, italics added for emphasis)

Then in "Order of Nature," he turns to the theme of how synthetic knowledge is possible that we have considered above. His answer is sampling:

> *In the last of these papers we examined the nature of inductive or synthetic reasoning. We found it to be a process of sampling.* (Peirce 1878d, *WP* 3, p. 312, italics added for emphasis)

In 1903 when he returned to Harvard to give his famous lectures on pragmatism, Peirce continued to present an insurance company as one of his main examples of the meaning of pragmatism and the pragmatic maxim. The first lecture is titled, "The Pragmatic Maxim," by the editors of collection of essays put out by the Peirce Edition Project. That collection is titled, *The Essential Peirce*. In that lecture, Peirce quotes his own pragmatic maxim from "How to Make Our Ideas Clear." The concept which he chooses to clarify at this point is the meaning of the term probability. His first example is a game of chance which he also had discussed in other writings. The second example is an insurance company. He begins in the following way:

> The theory of probabilities is full of paradoxes and puzzles. Let us, then, apply the maxim of pragmatism to them.
> In order to do this, we must ask, *What is meant by saying that the probability of an event has a certain value, p*? According to the maxim of pragmatism, then, we must ask what practical difference it can make whether the value is *p* or something else. Then we must ask how are probabilities applied to practical affairs. (Peirce 1903, p. 136, italics in original)

What follows next in Peirce's lecture is the example of an insurance company which Peirce had considered as early as the late 1860s. To the meaning of a probability in terms of the pragmatic maxim he gives this response:

> The answer is that the great business of insurance depends upon it. Probability is used in insurance to determine how much must be paid on a certain risk to make it safe to pay a certain sum if the event insured against should occur. Then, we must ask how can it be safe to engage to pay a large sum if an uncertain event occurs. The answer is that the insurance company does a very large business and is able to ascertain pretty closely out of a thousand risks of a given description how many in any one year will be losses.... (Peirce 1903, p. 136)

Immediately after presenting the pragmatic maxim, the pragmatic meaning of probability, and taking up the insurance firm as an example, Peirce launches into the calculus of the profit maximizing insurance firm. He actually solves for the first order condition that will describe the optimal price and number of insurance policies for the insurance firm. Apparently, he actually went through the solution of the optimization problem for his audience at Harvard. He solves for the partial derivative which describes how much price should be lowered if the insurance company wants to sell one more policy. After the derivation of the partial derivative, he makes these comments:

> This is the problem of insurance. Now in order that probability may have any bearing on this problem, it is obvious that it must be of the nature of a *real fact* and not a mere *state of mind*. For facts only enter into the solution of the problem of insurance. And this must evidently be a fact of statistics. (Peirce 1903, p. 137)

7. Conclusions

Charles Sanders Peirce had a long, significant, and unusual interest in the discipline of economics. He read and applied in a creative way some of the most advanced mathematical economics of the 19th century especially that of Cournot and Jevons. It is clear that he had reworked and interpreted Cournot's models of monopoly, duopoly, and competition and Jevons's model of utility maximization in the 1870s. It is also apparent that Peirce's forays into mathematical economics affected his conception of pragmatism. The six essays on pragmatism, the founding contributions to American philosophy, need to be read with Peirce's keen interest in economics kept in mind.

Peirce also developed a thesis of the cognitive efficiency of the human mind, emphasizing the qualitative and relational nature of human rationality defined broadly as a conception of intelligibility. This thesis was termed abduction by Peirce and was explained by his theory of guessing. Peirce applied this broader, relational conception of human rationality both to scientific inquiry and common sense. Also, it was extended to economics and appears to be the reason why he conceived of the transitive axiom of consumer preferences in 1874 and other relational interpretations of basic economic concepts such as exchange and contracting in the 1880s.

All of these interests in economics are integrated in one of his last discussions of the meaning of the pragmatic maxim in 1903. There he returns to mathematical economics and provides a qualitative and quantitative interpretation of the meaning of the term probability for an insurance firm. Peirce had a broader, qualitative conception of human rationality which he applied to economists conceptions of rationality as optimization. The logical, relational properties of human decision making are more fundamental and logically prior to quantitative conceptions of economic rationality for Peirce. This is precisely

the opposite of the way in which most economists conceive of those two conceptions of human rationality. Peirce also places the individual in the context of an evolutionary world. This is a context which economists still mostly do not adopt explicitly.

NOTES

1. Many of the biographical details can be found in Brent's (1998) biography and in several biographical essays of Houser. For philosophical overviews of Peirce's pragmatism see Hausman (1993), de Waal (2001), and Fisch (1984).

2. One of Peirce's graduate students, Christine Ladd-Franklin (1916) tells the story of the creation of the Johns Hopkins Metaphysical Club.

3. Houser (1986, p. lxvii) tells us that the Metaphysical Club was reorganized at its fortieth meeting to reflect the reorganization of the philosophy department.

4. Before Dewey came to Johns Hopkins, Thorstein Veblen had enrolled as a graduate student. Veblen apparently enrolled in Peirce's introductory class on logic. Veblen left Johns Hopkins for Yale where he studied with Noah Porter. Presently we have no indication that Veblen became involved with the Johns Hopkins Metaphysical Club, or that he was further influenced by Peirce. Veblen and Dewey's student days at Johns Hopkins apparently did not overlap.

5. For bibliographic details see the section of the bibliography devoted to the economic papers related to the Cambridge Scientific Club.

6. There is an extensive chapter on Peirce and the December 28th meeting of the Cambridge Scientific Club in my monograph on Peirce's interest in economics. See Wible (2006).

7. In the letter, Peirce also realizes that price may be a decision variable as well. He realizes that Cournot has inverted the profit maximizing equations solving them in terms of quantity for the purpose of mathematical tractability.

8. Peirce "Note" is discussed in Wible (1994).

9. A biographer of Peirce, Joseph Brent (1998, p. 79), tells us that Peirce met Jevons on a trip to Europe in 1870 on behalf of the Coast Survey. On that trip, Peirce passed through England and was carrying some off prints of his soon to be published articles on logic and mathematics. Both De Morgan and Jevons received the off prints and Jevons apparently was quite impressed by them. Given Peirce's keen interest in the mathematical economics of Cournot, it would seem obvious that Peirce had familiarized himself with Jevons's *Theory of Political Economy* as well. Also, given Peirce's high level skills as both an applied and theoretical mathematician, neither Cournot's *Researches* nor Jevons's *Theory* would have posed much of a challenge to his mathematical abilities.

10. See Peirce's three writings with economic themes in 1884 and 1885.

11. For a critique of Newcomb, see Peirce's (1893a) essay "Evolutionary Love" which is part of *The Monist* Metaphysical Series of philosophical articles. This is Peirce's second most famous set of articles on philosophy. See also, Peirce (1892d and 1901). Peirce (1902a, 1902b) solicited a grant from the Carnegie Foundation to revise his views of the economy of research.

12. See Hacking (1990).

13. Peirce (1878b, *WP* 3, pp. 283), in "Doctrine of Chances," puts it this way:

"But whether a gambler plays in this way or any other, the same thing is true, namely, that if he plays long enough he will be sure some time to have such a run against him as to exhaust his entire fortune. The same thing is true of an insurance company.... But calculations of expectations leave out of account the circumstance now under consideration, which reverses the whole thing. However, I must not be understood as saying that insurance on this account is unsound, more than other kinds of business. All human affairs rest upon probabilities, and the same thing is true every where. If man were immortal he could be perfectly sure of seeing the day when everything in which he trusted should betray his trust, and, in short, of coming eventually to hopeless misery. He would break down, at last, as every great fortune, as every dynasty, as every civilization does. In place of this we have death."

14. There are three articles in the series and they are considered to be focused on cognition. See Peirce (1868a, 1868b, and 1869a).

15. See Fisch's undated chronological data slip titled "Economy of research and 'Illustrations of the Logic of Science'" which is in the collection of the Peirce Edition Project at Indiana University Purdue University at Indianapolis.

16. For Peirce, induction is flawed especially when considered with reference to the historic philosophical and scientific aim of finding statements which are universally true. But all is not lost if universal truths are difficult to ascertain. There are prospects for finding reliable patterns of knowledge with limited validity. Individuals can learn about the external world to a limited degree. Peirce reverses his thinking and analyzes the question in the opposite way. If the majority of inductions were false, then human conduct would not be possible. Peirce asserts that, while induction may not be universally valid, it is also not extraordinarily deceptive:

"The other question relative to the validity of induction, is why men are not fated to light upon those inductions which are highly deceptive. The explanation of the former branch of the problem we have seen to be that there is something real. Now, since if there is anything real... it follows necessarily that a sufficiently long succession of inferences from the part to whole will lead men to a knowledge of it, so that in that case they cannot be fated on the whole to be thoroughly unlucky in their inductions. This second branch of the problem is in fact equivalent to asking why there is anything real...." (Peirce 1869a, WP 2, p. 269)

17. Peirce criticizes Thomas Fowler's Deductive Logic which was published in 1871. See Writings of Peirce (WP 3, p. 543) for a complete reference.

18. This general critique was revised later and again directed toward Mill in one of the essays on pragmatism, "Deduction, Induction, and Hypothesis," in the late 1870s.

19. The quote continues: "How are we to explain this adaptation? The great utility and indispensableness of the conceptions of time, space, and force, even to the lowest intelligence, are such as to suggest that they are the results of natural selection. Without something like geometrical, kinetical, and mechanical conceptions, no animal could seize his food or do anything which might be necessary for preservation of the species." (Peirce 1878d, WP 3, p. 319)

20. Peirce broadens his theory of guessing in the sentences that follow: "But, in point of fact, not man merely, but all animals derive by inheritance (presumably by natural selection) two classes of ideas which adapt them to their environment. In the first place, they all have from birth some notions, however crude and concrete, of force, matter, space, and time; and in the next place, they have some notion of what sort of objects their fellow-beings are, and of how they will act on given occasions." (Peirce 1883a, WP 4, pp. 449–450)

21. The quotation continues with Peirce arguing that syllogisms could be meaningful in a universe which is yet so unstable that quantitative measurement and the formulation of a probability ratio are impossible. In such an unstable universe, one world could be nested within a second and that second world within a third, etc. This pattern of nesting could be formulated in a transitive logical relationship. Syllogisms and reasoning about such a world would be possible. However, science would be impossible in such an unstable universe because no stable unit of measure is possible:

"The universe might be all so fluid and variable that nothing should preserve its individual identity, and that no measurement should be conceivable; and still one portion might remain inclosed within a second, itself inclosed within a third, so that a syllogism would be possible. But probable inference could not be made in such a universe, because no signification would attach to the words "quantitative ratio." For that there must be counting; and consequently units must exist, preserving their identity and variously grouped together." (Peirce 1883b, WP 4, p. 410)

22. Certainly the theory of the firm can be formalized and stated in axiomatic terms, but this is rarely done because it is not as necessary but for one exception. For choice under uncertainty, decisions are represented with an expected utility function even when firms are involved.

PEIRCE REFERENCES USING ABBREVIATIONS

The following abbreviations are used in the bibliography of Peirce's writings:

WP   Writings of Charles S. Peirce, 6 volumes, Indiana University Press
EP   The Essential Peirce, 2 volumes, Indiana University Press
CP   Collected Papers of Charles Sanders Peirce, 8 vols., Harvard University Press
HP   Historical Perspectives on Peirce's Logic of Science, ed. Carolyn Eisele, 2 vols.
NEM   New Elements of Mathematics by C. S. Peirce, Carolyn Eisele, ed., 4 vol.
1984 to 2000. Writings of Charles S. Peirce: A Chronological Edition, vols. 1–6, 1857–1890. Many editors. (Bloomington: Indiana University Press).
1992 and 1998. The Essential Peirce, 2 vols., ed. Nathan Houser and Christian Kloesel and the Peirce Edition Project. (Bloomington: Indiana University Press).
1931–35, 1958. Collected Papers of Charles Sanders Peirce, vols. 1–6, ed. Charles Hartshorne and Paul Weiss, 1931–35; vols. 7–8, ed. Arthur Burks, 1958 (Cambridge, MA: Harvard University Press).
1985. Historical Perspectives on Peirce's Logic of Science: A History of Science, ed. Carolyn Eisele (Berlin: Mouton Publishers).
1976. New Elements of Mathematics by C. S. Peirce, ed. Carolyn Eisele (The Hague: Mouton Publishers).

1857. "The Immediate Effects of the Discovery of an Extensive Gold Mine," Harvard College essay written on April 26, 1857, part of manuscript 1633A, pp. 17–19, Peirce Edition Project, Indianapolis.

The Journal of Speculative Philosophy Series 1868

1868a. "Questions Concerning Certain Faculties Claimed for Man," WP 2, pp. 193–211.
1868b. "Some Consequences of Four Incapacities," WP 2, pp. 211–242.

1869a. "Grounds of Validity of the Laws of Logic: Further Consequences of Four Incapacities," *WP* 2, pp. 242–272.
1869b. "The English Doctrine of Ideas," *WP* 2, pp. 302–307.
1870. "Description of a Notation for the Logic of Relatives," *WP* 2, pp. 359–429.

Papers Related to the Cambridge Scientific Club 1871–74

1871a. "[Letter to Melusina Fay Peirce]," in Brent (1998, p. 89).
1871b. "Letter to Simon Newcomb," in Baumol and Goldfeld (1968), pp. 186–87.
1871c. "[Letter to Benjamin Peirce]," *NEM*, pp. 553–554.
1871d. "Calculus of Wealth," *NEM*, pp. 551–552 .
1873. "Letter, Peirce to Abraham B. Conger," *WP* 3, pp. 109–10.
1874. "[On Political Economy]," *WP* 3, pp. 173–76.

1872. "Educational Text-books, II," *WP* 3, pp. 1–7.

Popular Science Monthly Series 1877–78 "Illustrations of the Logic of Science"

1877. "The Fixation of Belief," *WP* 3, pp. 242–257.
1878a. "How to Make Our Ideas Clear," *WP* 3, pp. 257–276.
1878b. "The Doctrine of Chances," *WP* 3, pp. 276–289.
1878c. "The Probability of Induction," *WP* 3, pp. 290–305.
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