General Equilibrium Theory and the search of its empirical endorsement: Henry Ludwell Moore

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"I hope that you flourish in Probabilities"
– Letter from Francis Ysidro Edgeworth to Karl Pearson, 11 September 1893.

"The economist is like a scion of a noble race who is proud of his honorable descent and not a little ashamed of his own scant achievements"
– Henry Ludwell Moore, *Synthetic Economics*, 1929.

Abstract

The article analyzes an attempt to make the Walrasian model statistically operative: the approach developed by the American Henry Ludwell Moore in the early twentieth century. Thus, the paper explores the dissemination of Walrasian theory in the immediately post-Walras generation. From the analysis of some reviews, this study also aims to evaluate how the academic community received Moore's work on walrasian theory. The paper has a twofold perspective: 1) the analysis of the relationship between Walras and Moore, mostly through their exchanged letters, in which we highlight Walras' attempts to spread his theory in the New World and; 2) theoretical inquiry, exploring the work developed by the American. We conclude that the main analytical tool used by Moore was the treatment of data using a secular trend. As this trend is empirically derived, according to Moore, there is a transition from a purely rational construction to a real and dynamic situation. Hence, in the author's works, this transition from a static analysis to a dynamic analysis was intrinsically related to the empirical basis of the theory. Moore also tried to demonstrate that the formulation of the general moving equilibrium allows for the empirical test of the productivity theory of distribution. We will also provide some space to discuss the general climate at Columbia University – where Moore was a professor – regarding the application of statistics in the social sciences. Additionally we will make particular considerations about the parallel development of pure statistical theory. Finally, we will draft some related comments about the original Walrasian theory.

1. Introduction

With the process of axiomatization of the general equilibrium theory, that culminated in the publication of Arrow, Debreu and McKenzie's seminal articles in 1954, researchers distanced themselves from the attempts of empirical verification of the system. This article aims to analyze a work in which the Walrasian equilibrium model was adapted in a form that it could be empirically tested. This work is the theoretical construction of

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the American Henry Moore, developed in the early twentieth century. Thus, the paper explores the dissemination of Walrasian theory in the immediately post-Walras generation. From the analysis of some reviews, this study also aims to evaluate how the academic community received Moore's work on walrasian theory. Looking at the reception of the endeavor, from reading the reviews, it is possible to analyze the limitations of the work not based on the degree of development of contemporary economic and statistical theory, but from the state-of-the art of the respective theories at the time. Further, we also aim to delineate the relationship between this specific theoretical development with the rest of Moore's work. The paper has a twofold perspective: 1) the analysis of the personal relationship between Walras and Moore, mostly through their exchanged letters, in which we highlight Walras' attempts to spread his theory in the New World and; 2) theoretical inquiry, exploring the work developed by the American author.

Regardless of controversies about the paternity of disciplines[2], there are numerous references in the literature addressing the importance of Moore at the beginning of statistical economics. G. J. Stigler (1962, p. 1) argued that no other author was so influential in developing the subject[3]. Epstein (2014, p. 13), writing a history of econometrics, chose Moore as the first author to be approached, and pointed out that "modern econometrics really began with an analysis of the labor market by the American Henry L. Moore". Le Gall (1999) asserted that Moore pioneered at least two questions: the application of spectral methods in economics and introducing celestial bodies as a source of economic fluctuations[4]. Boumans and Dupont-Kieffer (2011, p. 26) also indicated that in the literature Moore appears as the "quintessential pioneer" of early-twentieth-century econometrics. One last example is G. J. Stigler (1954). Discussing the history of empirical studies of consumer behavior, the article described that "Moore was the single most influential economist in the popularization of statistical demand analysis" (G. J. Stigler, 1954, p. 112).

Despite of references in the literature regarding his importance, not all quotes about Moore have a positive content. Spanos (2006, p. 16), for example, asserted that "some of the crucial weaknesses of the current textbook approach can be traced back to Moore". Wulwick (1992, p. 182) also pointed out that he is often portrayed as a "bungler", while Le Gall (1999), that he is pictured as a "raving madman". Epstein (2014) mentioned that, after some criticism, Moore started to avoid as much as possible professional meetings. Also, in an interview, Samuelson, speaking about Moore, told that "H.L. Moore was a strange man, who had some psychiatric problems later in his life" (Freedman, 2010, p.

[2]Mirowski (1990) discusses the genealogy of econometrics and Moore, pointing out the artificiality of the title of founder of a given branch of knowledge.

[3]However, Stigler pointed out this influence is not for priority or excellence, since in both cases Moore was not superior to the French Marcel Lenoir (G. J. Stigler, 1954, p. 112).

[4]Some works that address the theory of economic oscillations developed by Moore are Morgan et al. (1990), Klein and Klein (1997) and Raybaut (1991).

166). Ambiguously, when referring to Moore, Douglas (1939, p. 104) pointed he out as "that lovable and nervous genius".

Apart from these selected examples from the literature, the importance of Moore's work might still be evidenced by using some citation data. Quandt (1976), making a quantitative study of the academic literature on economics, showed that during the 1930s, Moore is the third most cited economist in a sample of eight selected journals[5]. Moore, in number of citations received, is only behind Marshall and Keynes, and ahead of authors such as Pigou, Hansen, Robbins, and Schumpeter (Quandt, 1976, p. 754)[6].

In addition to the general references that the literature makes about Moore, there are also the references associating the American to the walrasian theory – either evidencing the intellectual approach or the distance between the two. Schumpeter is one author relating the American professor to the Walrasian theory. In his 1954 book, he told that "In the United States, Walras acquired two-first rank followers, Fisher and Moore, but was practically ignored by the rest of the profession" (Schumpeter, 2006, p. 796). Another work to point out the relationship between Moore and Walrasian theory is Jolink and Knot (1993). The authors asserted that despite the hostility suffered by Walras by economists, engineers and mathematicians, "the Walrasian dream of a mathematical economics was revived at the turn of the century by Henry L. Moore" (Jolink & Knot, 1993, p. 166). In other work, Jolink (2006, p. 70) pointed out that the Walrasian theory was largely ignored in the early decades of the twentieth century, but possibly the most important *trait d'union* was found at Columbia University, given Moore's work[7]. Ingrao and Israel (2005) also claim that Moore was Walras' first and most convinced follower among American economists, however "Moore's respectful but decided *breakaway* from the original Walrasian programme in favour of an inductive approach is a further sign of the isolation imposed by a quirk of fate on the author of the *Éléments*" (Ingrao & Israel, 2005, p. 107). Another author who suggested a distance of Moore from the theory of general equilibrium is Epstein (2014, p. 14), who stated that "Moore increasingly came to view himself as a kind of rebel in economic theory. His admiration for the neoclassical analysis of the labor market did not extend to the full model of general equilibrium". Therefore, the present work will also allow us to analyze with more detail the relationship between one of the first researchers in statistical economics and Walras and walrasian

[5]American Economic Review, Journal of Political Economy, Quarterly Journal of Economics, Economic Journal, Economica, Econometrica, Southern Economic Journal and the Review of Economics and Statistics.

[6]We also did a brief quantitative analysis using data from Google Scholar, the most complete bibliometric basis for the period. From a search for "statistical economics", until 1930, ranking the data by the index provided by Google, the first two most important works given by the search are 1) Moore's 1911 book, *Law of Wages* and; 2) Moore's 1908 paper, Statistical Complement of Pure Economics. More information about the Google's rank calculation is given in Harzing (2010, p. 22).

[7]This work dealt with the reception of the walrasian theory by the early econometricians. The conclusion is that such reception was lukewarm. Walrasian theory was discussed only to illustrate the relevance of the changes suggested by the founders of econometrics (Jolink, 2006).

theory.

This paper is divided into three sections, apart from this introduction. The following part will explore the relationship between Moore and Walras, highlighting attempts to disseminate Walrasian theory in the United States and in the English language. The second section will deal with Moore's Walrasian theory, which, according to the American, could be empirically verified, as already indicated. This section will also provide space to discuss the general climate at Columbia University – where Moore was a professor – regarding the application of statistics in the social sciences. We will also make particular considerations about the parallel development of pure statistical theory. Finally, as pointed out, Moore's work will be further presented and evaluated taking into account the reviews available at the time. The last section presents the concluding remarks of the paper.

2. The personal relationship between Henry Moore and Léon Walras[8]

It dates from mid-1898 the first mention made to Moore in Walras correspondences. An unidentified employee of Briquet et Fils, a Geneva-based bookstore, informed the Frenchman that there was a young foreigner, probably one of his disciples, who was strongly insisting on obtaining a photograph of the Professor. Unsure if Walras would allow it, the representative then wrote to him, asking if they could provide the photo and, if so, which one could be given. Without getting an answer from Walras – he never answered the bookstore – the employee repeated the question again a few days later in another correspondence, adding that he knew that the young man was an American and his name was H. L. Moore. Moore also left his address with the seller, in case the bookstore could mail the request to the United States (Jaffé, 1965, p. 24-5).

Five years later, in 1903, discovering through a publication of the American Economic Association that Alvin Saunders Johnson, an economist and later professor at Chicago and Stanford, wrote a paper on income distribution, Walras sent to him the *Eléments d'économie politique pure*, with some additional comments on Saunders' publication. Johnson replied that he would admit advantages in the mathematical approach to economic theory. The American also wrote that Walras would likely be interested to know that a Columbia member, Professor H. L. Moore "a devoted disciple of Cournot" gave a course of mathematical economics in the previous semester, and that this course aroused much interest among PhD students (Jaffé, 1965, p. 229).

Coincidentally, in the same month of this letter from Johnson, Moore, who was in Geneva, wrote to Walras and asked if he could meet him personally. The American at

[8]As noted earlier, this session is based on the exchanged letters between Walras and Moore, available in William Jaffe's compiled *Correspondence of Léon Walras and Related Papers.*

the time was writing in the history of economic thought[9] and then went to Europe to retrieve a Cournot's manuscript. His interest in Walras was twofold: he was the first to pay due respect to the French economist and one of the few who developed his method. He concluded his letter, however, pointing out that "aside from the Cournot interest, I should steem it a privilege to know you" (Jaffé, 1965, p. 230).

The two professors then met a few days later at Clarens, Walras' residence. Walras recommended that, apropos of the publication of Cournot's manuscript, Moore could talk to Charles Gide[10] or with Gabriel Tarde (a task that Moore later reported that he had no opportunity to do). Moore also insisted that Walras would consider elaborating an autobiography (Jaffé, 1965, p. 233).

Few months later, Walras mentioned to Moore that a recent event[11] had made him actually consider writing some autobiographical notes, and that he would let him know when he was done. The Frenchman also reported that he read the *Papers and Proceedings Series* of the *16th annual meeting of the American Economic Association* and that Fetter's work, "The Relations between Rent and Interest", interested him, but it was quite painful to follow an article in "ordinaire" language, especially when the problem addressed would be much simpler, clearer and easier to solve through a mathematical approach. For him, the reading experience could be compared to that of a hypothetical mathematical researcher forced to listen a discussion among *littérateurs* about the motion of the planets. At the time, he alluded to the fact that it took fifty years before Laplace could be understood by his community. Therefore Walras wrote that he resigned himself to belong to the group that sowed without being certain that he would reap the rewards of the work of the harvest (Jaffé, 1965, p. 247).

Moore replied, days later, that he did not agreed that Walras was one of those who "sowed without seeing the harvest": "I wish you could have seen the enthusiasm with which a small class of my students at Columbia studied your "theory of exchange", during the past winter" (Jaffé, 1965, p. 249). Moore reported that there were not really many willing to undergo such hard work as the quantitative approach, but that in the next ten years, those students would be the leaders of American research in Economics. The American also said that he would start a series of courses in Mathematical Statistics and Mathematical Economics, and that he also intended to extend this last course to a duration of three semesters, dealing, in the first semester, with elementary concepts of statistics and *"pure economics"*, in the second one, with applications of probability theory in statistics, and in the third one, covering topics in advanced Mathematical Economics (Jaffé, 1965, p. 249-50).

[9]Moore, in his doctoral dissertation, for example, analyzed von Thünen's ideas about natural wages.

[10]In a correspondence with Gide, Walras reported that he met Moore and described him as a *"homme parfait, aimable et don j'ai été enchanté"* (Jaffé, 1965, p. 232).

[11]One of Walras' French disciples, Albert Aupetit, failed the test to be a Professor at the Law School, allegedly for his defense of the mathematization of Economics.

In December 1904 Walras informed Moore that he had completed the autobiographical work, but that the American should publish it only after his death. They also exchanged correspondences about an article that Moore would write, by Walras' suggestion, about Cournot, in a special edition of *the Revue de métaphysique et de morale*[12] (Jaffé, 1965, p. 256, 260, and 275).

Knowing that Walras had completed the autobiographical draft, Moore stressed that one of the strongest means to serve the scientific cause would be a series of biographical studies, showing that the best economists were those who believed, "heart and soul", in the supreme value of abstract theory. The American professor further marked out that he was truly grateful that Walras entrusted him with publishing his work after his death, and that he would honor this desire (Jaffé, 1965, p. 278).

In a later correspondence, replying to the question of the biographical works, Walras pointed out to Moore that five economists were the founders of pure economics - for which, therefore, there was a justification for such a work as a biographical one – his father, A. Walras, Cournot, Gossen, Jevons and himself. The works concerning his father, Gossen and Walras', then, were missing. Making a first comment about the translation of his own work, Walras stated that such a translation would be a task too massive to accomplish at that moment, but a good start would be an English version of the teaching material he had prepared for his French disciple, Albert Aupetit[13]. According to Walras, he prepared this teaching material for high schools, so translating it would be a very productive way to begin the propagation of his work in the United States (Jaffé, 1965, p. 279). Walras would send the work to Moore when the American signalled that he could begin the translation. It is worth noting an additional episode. Writing about such correspondences to Gustave Maugin, Walras pointed out that he agreed with Moore on the publication of his work in English since Columbia University would paid the translation of his *Abrégé* and published the work in the United States (Jaffé, 1965, p. 282).

Moore, in a letter of November 1905, pointed out that he would like to see the outline of the *cours élémentaire d'économie politique pure*, since he likewise adopted in his courses in Columbia the original version of the *Éléments* (along with additional materials on economic principles), and a work done by Walras especially devised for teaching would thus be very helpful. However, according to him, about the translation, the French underestimated the difficulty inherent in the content of his work:

> As to whether it would be wise to translate and publish it, I could, of course offer an opinion only after going through the work. You, I am sure, underestimate the

[12]When Moore mentioned this work in a later correspondence, he pointed out that "I am glad if you find any good in the article on Cournot. The editor Mr. X. Leon published the article without waiting for the corrected proof to arrive from New York" (Jaffé, 1965, p. 276).

[13]It is important to emphasize this point: so far, there is no written record of any conversation between Moore and Walras about the possibility of the first translating Walras' books into English. They may have talked in person, but this is the first time the subject has appeared in correspondence.

> difficulty of your method and theories. On the other hand several attempts have recently been made to present the elements of the mathematical method. In English there are Wicksteed's "Alphabet of Economics", and Cunynghame's "The Geometrical Political Economy", 1904. In French, Laurent's *"Petit Trait d'Economie politique mathématique"*, 1902, which opens with the following: *"Dans ce petit traité, l'économie politique sera exposée of a make-up to the nouvelle and accordingly to the preconceptions to Lausanne by M. Walras, puis by M. Pareto".* In Italian, there is Vergilii [*sic*!] Garibaldi's "Introduzione alla economia matematica", 1899 (Jaffé, 1965, p. 281).

On the difficulty of the course, Walras responded to Moore that he had given the program to law students and had used only the knowledge of algebra and two-dimensional analytic geometry. Walras concluded that in special schools of trade and industry the enterprise would be consequently even less problematic (Jaffé, 1965, p. 284).

Despite the content of the previous letter, Walras anyway sent his *Abrégé* to Moore. The American replied that the professor's letter suggested a hope that he would translate the work, and continued: "but if you recall my letter, you will notice that I was quite careful to say that I was sure you underestimated the difficulties of your work, and that I doubted the wisdom of a translation" (Jaffé, 1965, p. 295). Moore concluded that by reading the material, he confirmed his doubts. Apart from the difficulty, he explained that for reasons of health and the workload of the University, he could not make the translation (Jaffé, 1965, p. 295).

Walras replied in early 1906 he had expressed himself badly about hoping for a translation from Moore: what he intended to say was that without the translation, the publication of his biography made no sense[14]. Walras surprisingly ended the letter positively, citing that a magazine, the *Revue du Mois*, would soon publish an article called *La méthode mathématique et les sciences sociales.* He concluded that was approaching the time when the public would be further attentive in the ideas endorsed by them (Jaffé, 1965, p. 298).

Apart from the correspondence exchanged between the two professors, there are also letters in which Walras cited Moore with other correspondents. For example, in a letter addressed to Poincare, Walras reported that Moore told him that he had met Poincare, and the latter agreed, at first, to the use of the mathematical method in political economy. This understanding had satisfied Walras (Jaffé, 1965, p. 315). Further, there are several correspondences in which Walras cited Moore as his American disciple. In a particular letter addressed to Gustave Maugin, he pointed out that Moore was very diligent and kind, but complain about the slowness with which the American was performing one assigned task – the translation of his work (Jaffé, 1965, p. 325).

[14] In the original: *"Si j'ai exprimé l'espoir* (hope) *d'une traduction de mes Éléments ou de mon Abrégé, soit par vous, soit par quelque autre, l'expression a dépassé mes intentions. J'ai voulu seulement exprimer ma conviction que, sans une telle traduction, la publication de ma biographie n'a pas de raison d'être"*(Jaffé, 1965, p. 298).

After more than a year since Moore's refusal to translate Walras's work, the latter sent comments on the young man's recent book, *The Differential Law of Wages*. Walras began by pointing out that he was truly interested in any empirical work on supply and demand curves, as they were the "base of *notre économique*". Walras also said that probably a Sorbonne professor, Emile Borel, would contact Moore about his father's biography, which the *Revue du Mois* would publish in an article (Jaffé, 1965, p. 351). In addition, he wrote to Moore about a work that two of his disciples, Aupetit and Barriol, would publish, in an encyclopedia. They – all the defenders of mathematical economics — were, according to Walras, officially researchers of *Mathématiques Appliquées*. Walras highlighted that the academic community would probably discriminate Moore, as one defender of the *Mathématiques Appliquées*. Nevertheless, the young man's adherence to his work was a delight to Walras (Jaffé, 1965, p. 351).

Given the failed attempt to get a translation from Moore, in March 1908, Walras wrote to Henry Walcott Farnam of Yale University, reporting that his American disciple, for a variety of reasons, could not support him with the task, and Walras recognized someone else would have to make the translation. According to the Frenchman, he expected at least Moore's help to find someone who could do the job but since the latter also could not help him in this task, he thought it best to take it for himself, the reason he was writing to Farnam (Jaffé, 1965, p. 354). The American answered him just two days later (Jaffé, 1965, p. 355), saying that in response to Walras's request, he wrote to Fisher to find out if the latter had any information about the whereabouts of the manuscript that the Frenchman gave to Moore - which in reality was not exactly what Walras asked him.

Walras wrote to Moore about the episode, as he "did not know what Fisher could do other than write to the young man", and add that he also did not want any misunderstanding between them – everything he was wishing was to add some contributors to the difficult task of getting his *Abrégé* translated (Jaffé, 1965, p. 355). Moore said that no disciple would like to see more the professor's work in English than him, but that, given his present conditions, he would hand over the copy to whom Walras trusted. The American also commented that he was eager to read the book *Économique et Mécanique*, which Walras alluded to in the previous letter. According to Moore, Jevons was the first one to observe the parallelism between the two sciences, economics and mechanics, but no one, to the extent he knew it, apart from Walras, had in fact showed such similarity (Jaffé, 1965, p. 356 and 357).

Still in the same letter, Moore asked Walras' opinion on the attempts to empirically test some conclusions of pure economic theory. He said that one reason the science did not attract young students, was the absence of inductive demonstrations, adding that "I have, therefore, assumed that the present generation of scholars could render most effective service by attacking inductively the problems which you and others have treated so brilliantly on a deductive manner" (Jaffé, 1965, p. 357). That was the reason, according to him, why he wrote the *Differential Law of Wages* (Jaffé, 1965, p. 357). There is no record of Walras' answer to Moore's question[15]. A few days later Moore then sent the *Abregé* manuscript back to Walras (Jaffé, 1965, p. 361). Still in the same month of this letter, July 1908, Moore paid a visit to Walras, and in his message of acknowledge for the professor's attention at the time, pointed out that "I also hope that you now understand very clearly why I returned your volume" (Jaffé, 1965, p. 365).

On Walras' seventy-year anniversary, the University of Lausanne organized a tribute ceremony for the professor, who invited Moore to the event. The American, then, in the reply, recalled that the first time he visited Walras, they talked about how maybe it would take approximately 50 years for a revolution to happen in Economics, but "it is scarcely fifty months since that first visit, and now you writings are about to receive a unique recognition of merit on the part of you Lausanne colleagues!" (Jaffé, 1965, p. 369).

Less than a year before his death in March 1909, Walras sent his father's biography, published in the *Revue du Mois*, to the American, and pointed out that he could publish the translation if it interested him. Walras further stated that it surprised him when he discovered that someone had published his autobiography in Italian, albeit briefly, in the announcement of his jubilee. However, when he "thought better", he recalled that a few years earlier he had given Pantaleoni a previous version of the story of his life[16].

Finally, in May 1909, Walras received a letter from Farnam talking about the translation of his work into English. The American had met with Seligman and discussed the possibility of the publication of the work in the *Columbia University Studies*, but he said it would be impossible to publish in the series, given the high cost and the expected low return. He then sent again the material to Walras' residence, with an additional apology for not being able to collaborate with the task (Jaffé, 1965, p. 416). The English translation, in fact, would only be done in 1954 by William Jaffé. However, the dissemination of Walrasian theory in the United States would begin earlier: Moore would develop his own approach to the theory, from the main equations of the Walrasian model, as we will see in the next section.

[15]Mirowski (1990, p. 595) pointed out that Moore had "never received an answer, perhaps because Walras was never that enamored of statistics" or "perhaps because the self-pity of those convinced of their unjustly neglected genius rarely has room for sympathy for another, different species of neglected genius".

[16]Shortly before his death, Walras faced some noticeable mental health difficulties. Schumpeter, for example, told Jaffé that on his visit to the Frenchman, the professor had praised the book that the young man sent him, but had so far believed it was in fact the work of Schumpeter's father. The latter corrected the misunderstanding, but on saying goodbye, Walras congratulated the author's father again for the "excellent book" (Jaffé, 1965, p. 385).

3. Moore and the development of his empirical approach to the general equilibrium theory

The first child of fifteen brothers, Moore was born in Maryland, United States, in 1869 and received his PhD from Johns Hopkins University at the age of 27 in 1896. However, even though he obtained his degree in the United States, as pointed out by Mirowski (1990, p. 589), "Moore was a member of that generation of fledging American scholars who travelled to Europe to round out their education, aspiring to a level of sophistication which was absent in the American academic scene of that period"[17]. Before obtaining his degree, Moore attended lectures at the University of Vienna, and participated in Karl Pearson's courses on mathematical statistics at the University of London (Mirowski, 1990, p. 589). As noted before, in his early career, Moore devoted himself to the history of economic theory, although he taught, for example, in 1896, a course named "mathematical economics" at Johns Hopkins.

At the same time, Columbia University's engagement with the statistical approach had been noticeable since about the 1880s, when Richmond Mayo-Smith, the first economist of Columbia's School of Political Science, incorporated Statistics in the field of Political Economy (Camic & Xie, 1994, p. 794). When Mayo-Smith died in 1901, Columbia University, unable to find a suitable senior replacement, hired two assistant professors to replace Mayo-Smith: Henry Seager and Henry Moore[18].

One point, therefore, is worth underlining: until entering Columbia, Moore had not yet produced any work involving the statistical method. Bernert (1983, p. 238) specified that "Columbia University served as a portal for the English statistics". Apart from Moore in Economics, three were other researchers at the University in different fields using statistics, with a dual purpose. These were Franklin H. Giddings in Sociology, James McKeen Cattell in Psychology and Franz Boas in Anthropology (Camic & Xie, 1994, p. 773). The dual purpose was 1) to present their conformance with acceptable scientific model data and; 2) to establish a special form of analysis to differentiate their disciplines from separate

[17]Still on Moore's education, as Christ (1985, p.42) pointed out, at the time of Moore as a student at John Hopkins University, there were merely two courses listed as "Economics" that had any mathematical content: "10 lectures on Economics as an Exact Science" by Simon Newcomb and "25 lectures on Statistics" by Elgin Gould. The course records of Moore are filed in the University of Chicago Archives. This document of Johns Hopkins shows that his formal education was fairly substantial in the historical approach: the American attended, for example, courses like Historical Seminary, Germanic History, Church History, English Constitutional Law and History, Ethnological History of the Indo-European Peoples, Methods of Historical Research, Prussian History, Elements and History Political Economy, Economic and Social History of Europe, History of the Nineteenth Century and History of Economic Theories.

[18]Ginzberg (1990) marked out that in the late 1920s, there was another big change in the Economics Department of Columbia. In 1928 Moore retired and disappeared from the academic scene, R.A. Seligman, the department chairman, had a mild heart attack and Henry Seager passed away, the same summer, on a visit to the Eastern Europe. The three were replaced by Harold Hotelling of Stanford, Carter Goodrich of the University of Michigan, and Leon Wolman of the National Bureau of Economic Research (Ginzberg, 1990, p. 14).

areas (Camic & Xie, 1994, p. 773)[19]. Camic and Xie (1994), therefore, pointed out that Columbia, determined to preserve a given institutional advantage, provided a supportive environment for the multidisciplinary process of incorporating the statistical methods into the social sciences.

After some activities on the history of ideas – analyzing, for example, von Thünen's and Cournot's ideas – Moore published his first work directed at statistically testing a statement of pure economic theory in 1907. His first goal was analyzing the differential law of wages. The differential law of wages determines the distribution among different workers of the products of the labor. According to Moore statistics and pure economic theory, were so distant at the time that researchers had to establish a series of hypotheses so they could use statistical data and statistical methods to make pure economics theories effective. Given the failure, to empirically analyze the theory of differential wages, accordingly to Moore, this later should be "regarded as without significance so far as scientific uses are concerned" (Moore, 1907a, p. 639).

This issue of hypotheses is a query that Moore considered notably relevant: in the absence of accurate data, researchers should take special care to preserve "a befitting sobriety in the use of hypotheses". The assumptions he employed for the test of the theory were 1) premises about the distribution of workers' efficiency and 2) allowance for particular time and place. Moore assumed that the distribution of workers' sagacity and energy followed a Gaussian law (Moore, 1907a, p. 642). In his work in 1908, he re-asserts a related point: it is necessary to give priority to formulations with higher affinity with the normal curve: "in cases where the normal law is evidenced both by a priori reasoning and observed fitness, there can be no hesitation about preferring that law" (Moore, 1908, p. 6)[20]. He quotes Pearson and Lee (1903) to support his idea that the normal can describe, within the limits of random sampling, the distribution of men's main physical characteristics. This assumption that general sagacity follows a normal law appears in several of Moore's works on wages, such as one of his major books, the *Law of Wages*, in 1911 – although he also analyzed cases whose distribution was asymmetric. We might still stress one point about hypothesis: at the beginning of his attempts at empirical verification of theories, Moore believed it was very important to consider differences in space and time analyzed - thus being maybe problematic to consider a theory like the general equilibrium.

However, the query of the universality of theoretical laws presents itself intricately in Moore's approach. In his 1911 work, he reasoned that there were two kinds of laws: those

[19]The authors pointed out that this dual task, showing conformity with established scientific methods and, at the same time, differentiating their emerging disciplines from others, can be characterized as a "dilemma" whose one solution found was the use of statistics. At least for some contemporaries, statistical tools were both demonstrably scientific and capable of diversification.

[20]Moore, later in his work, made no assumption about the distribution of variables. One possible explanation is the criticism received. Edgeworth (1912), for example, condemned the use of the hypothesis in its review of the *Law of Wages: An Essay in Statistical Economics*.

determining mass phenomena and those relating particular cases, depending on the time and place. Global laws did not require explaining all particular phenomena. However, how much, for example, the price oscillates with the supply depends on the location: "The statistical law of the variations of price with the supply of a commodity has one form in a highly competitive center and quite a different form in an agricultural community" (Moore, 1911, p. 21). In his 1914 book, addressing some difficulties of establishing a law of demand, Moore suggested that agricultural goods were a special case in relation to other economic goods. One of the main difficulties was because of changes that occurred in the market, at the time researchers got the data. But at least for staple commodities, they could overcome this difficulty using the method that Moore presented:

> This usually means that, during the interval surveyed in the statistical series, important changes occur in the condition of the market. **But in case of staple commodities**, such as the agricultural products with which we shall have to deal, the effects of those changes in the condition of the market that obscure the relation between prices and amounts of commodity may be largely eliminated (Moore, 1914, p. 68)[21].

Before addressing the method that Moore presented, some other points are worth examining. Much of Moore's work, in addition to addressing wages and the labor market, aimed at analyzing crop yields for specific commodities such as corn, hay, oats, potatoes (Moore, 1914), cotton (Moore, 1917), and specific markets such as the US, (Moore, 1919), France, the United Kingdom (Moore, 1920a), and the Dakotas (Moore, 1920b). In reporting the history of probability and statistics, Tabak (2014) pointed out that many researchers, since late nineteenth century, also dedicated their works to measure crop yield - chemists, botanists, and other. These scientists generated a multitude of informations, but frequently, they did not place such data in a specific theoretical framework (Tabak, 2014, p. 142). In its turn, Moore analyzed crop yields while addressing economic cycles, which was related in some degree with the empirical verification of the general equilibrium theory.

The first work fully concerned with statistical analysis of economic theory is the 1908 paper, *The Statistical Complement of Pure Economics*, an article published in The Quarterly Journal. Previously, empirical verification appeared in his works, but secondarily. In this 33-page essay, Moore pointed out that his three goals were three: 1) to show that the major contributors to economic development – Cournot, Jevons, Edgeworth, and Pareto for example – had in mind an inductive statistical complementary science; 2) describe

[21]Walras also, in his Studies in Applied Economics, pointed to the peculiarity of some agricultural goods: "Among ordinary commodities, there are those, like certain agrarian products, which tend to increase regularly in rareté and value, independently of weekly, monthly or annual fluctuations" (Walras, 2008, p. 95). Therefore, for Walras, there were some commodities that showed no trend. Moore, in his model, as we shall see ahead, later adopted the idea that all types of goods had a trend in their prices.

the fundamental statistical processes that should be employed in inductive analysis and; 3) show how economic theory and the statistical field were being used together in the development of Statistical Complement of Pure Economics (Moore, 1908, p. 2).

Moore quoted Jevons to argue that the only insurmountable obstacle in the way of economics being an exact science was that they had not yet developed a "perfect system of statistics" (Moore, 1908, p. 5). Deductive Economics, according to Jevons and Moore, should be verified and made useful by the purely empirical science: "Theory must be invested with the reality and life of fact" (Moore, 1908, p. 5).

Moore argued that during the nineteenth century there was a detached development in Statistics and Pure Economics. However, there was also attempts to use both together, and he aimed to present some of these works in Scientific Realism (Moore, 1908, p. 23). The most promising field of exact research seemed to be the investigation of demand and supply curves (Moore, 1908, p.23). Jevons' work on the corn demand curve promised an immediate connection between economic theory and statistics. However, according to Moore, the best known empirical law of economics was still Pareto's law of income distribution, although this law was a purely empirical one, whose origin Pareto had not yet offered an explanation. Pareto's method, according to Moore, was similar to that of physicists such as Boyle, Gay-Lussac, and Avograd, who first established their cases from purely empirical results (Moore, 1908, p. 28).

Discussing these evolutions in neoclassical theory and Probability and Statistics, Mirowski (1989, p. 223) argued that one of the most curious aspects of the development of the neoclassical theory is that many of the marginalists were also instrumental in the development of probability theory and statistics, such as Jevons, Edgeworth, Bowley, Keynes, Slutsky and Wald. However, between the 1870-1925 period none of these theorists actually made explicit links between stochastic theory and the neoclassical approach.

This first 1908 work on the development of economic statistics ended with Moore marking that "it is not unreasonable to say that at the point which economics has now reached further fecunt scientific ideas and abiding practical results are to be found in the development of the *Statistical Complement of Pure Economics*" (Moore, 1908, p. 33). Given the numerous references to other authors who devoted themselves, albeit remotely, to statistics and empirical laws, we may conjecture that in this first paper, Moore used the authority argument to legitimize all the remaining work in statistical verification that he will develop in the following years.

We mentioned earlier that Moore, in many of his works, developed an analysis of the law of demand in specific markets such as corn, hay, oats and potatoes. The first mathematical model incorporating the idea of general equilibrium is found in his 1917 book, *Forecasting the yield and the price of cotton.* This is the first time the price of a commodity formally appears to be dependent not only on its own demand, but also on other factors:

$$x_0 = \phi(x_1, x_2, x_3, ..., x_n) \quad (1)$$

Where x_0 is the percentage change in the price of the commodity 0, x_1 is the percentage change in the quantity demanded of this product and $x_2, x_3, ..., x_n$ are "percentage change in other factors" (Moore, 1917, p. 152). According to Moore three were the problems innate to formulations of the law of demand in general: 1) The form of ϕ is unknown; 2) the influences of the factors $x_2, x_3, ..., x_n$ are usually ignored and; 3) the interactions between $x_2, x_3, ...x_n$ had not yet been determined. Moore assumed that the ϕ function was linear, so that $\phi(x_1, x_2, x_3, ..., x_n) = \mu = a_0 + a_1x_1 + a_2x_2 + ... + a_nx_n$ and that the relationship between $x_1, x_2, x_3, ...x_n$ was also linear; for example, $x_1 = b_1 + b_2x_2$ (Moore, 1917, p. 153). The value of $a_0, a_1, a_2, ..., a_n$ should be chosen such that the correlation, R, between x_0 and μ was maximum. Meanwhile, $S = \sigma_0\sqrt{1 - R^2}$, which measures the root-mean-square value of forecasts should be minimal. It is pertinent to point out that, at the time, Pearson had already developed a version of the χ^2 test to obtain the probabilistic measure of the accuracy of the estimated curves (Tabak, 2014). The development of significance tests was also of concern, for example, for Fisher (Tabak, 2014). Another concern to some extent missing from Moore's discussions was the stability of statistical ratios, one of the main themes of continental econometrician's staticians (Aldrich, 2010).

This method of calculating the multiple coefficients can, according to Moore, solve the three limitations simultaneously (Moore, 1917, p. 152). The approach, according to the American, was in direct contrast to Marshall's *coeteris paribus* method of assuming all other factors constant. In his 1914 book, *Economic Cycles: Their Law and Cause*, Moore also condemned Marshall's approach[22]: "the "other things" that are supposed to remain equal are seldom mentioned and are never completely enumerated" (Moore, 1914, p. 66). Later, he continued:

> The fruitfulness of the statistical theory of correlation stands in significant contrast to the vast barrenness of the method that has just been described, and the two methods follow opposed courses in dealing with a problem of multiple effects. Take, for example, the question of the effects of weather upon crops. What a useless bit of speculation it would be to try to solve, in a hypothetical way, the question as to the effect of rainfall upon the crops, other enumerated elements of weather remaining remaining constant? The question as to the effect of temperature, *coeteris paribus*? How finally, would a synthesis be made of the several individual effects? The statistical method of multiple correlation formulates no such vain questions. It inquires, directly, what is the relation between crop and rainfall, not *coeteris paribus*, but other things changing according to their natural

[22]Interestingly, Moore taught a course in Columbia, Quantitative Economics II: Mathematical Economics, whose content included Marshall's mathematical methods. The program also included the approaches of Walras and Pareto.

> order; what is the relation between crop and temperature, other things conforming to the observed changes in temperature (Moore, 1914, p. 67).

On this point of Moore's theory, G. J. Stigler (1954, p. 110) argued that while criticizing theorists for assuming that other things remain equal, the very method that Moore adopted, the link relative method - to be presented ahead in this paper – does the exact same thing. The approach, according to G. J. Stigler (1954), eliminates the factors that did not remain constant in the data. Moreover, although he criticized the *coeteris paribus* hypothesis in his 1914 and 1917 books, Moore ended the latter, surprisingly, commenting that despite the high correlation between x_0 and x_2, there was little advantage in forecasting accuracy when considering x_0 as a function of the two variables x_1 and x_2 instead of the simple linear relationship between x_0 and x_1. Moore concluded the book by pointing out that "The seal of the true science is the confirmation of the forecasts. Economists theoretical and practical have grown impatient with any form of speculation that is not of immediate use" (Moore, 1917, p. 163).

In many parts of his work Moore pointed the need for a theory to be useful. For example, in Moore (1911, p. 1) he argued that the usefulness of the theory must be measured by its ability to work on three different issues: 1) definition and analysis of concepts; 2) the discovery of appropriate methods for dealing with mutually dependent social phenomena and; 3) the ability to provide a general representation of the economy. However, while defending the importance of the theory's usefulness to the business man, Moore does not write to these businessmen: his works were clearly meant to be read by his academic peers. In its turn, we can see some incredulity of these peers regarding the predictability of the theory. Burns (1931, p. 95), for example, reviewing Moore's book, Synthetic Economics, pointed out that "one reason why economic forecasting can never have the quality of perfection of the Nautical Almanac, is that the number of variables in the economic system is itself a variable".

Later in his works, the importance of forecasting appeared even more prominently. For example, in Moore (1920b, p. 205) the author asserted that the role of economic science was to be able to evidence, by looking at data, the elements that were routine, to determine their interrelationships, and to use this knowledge to forecast. It is worth recalling that the issue of forecast had been present since the very development of Statistics itself: one of the earliest record and process of data, for example, was meant to *predict* Halley's comet reappearance (Tabak, 2014, p. 39). The discussion about the usefulness of the theory has also been present since the original Walrasian program. Walras in his book "Elements of Pure Economics or the Theory of Social Wealth" pointed out that the theorist has the right to develop science for its own sake. However, the truths of pure economics generate solutions to important problems of applied economics (Walras, 2013, p. 71).

Discussing not the difference between Moore's work and the original Walrasian theory, but the former in relation to subsequent generations, there may yet be a point to make regarding the role of theoretical constructions. The post-Moore generation of macroeconomists were much more concerned with introducing structural changes than merely producing forecasts (Epstein, 2014, p. 7). In this next generation there was a central belief that economic policy should somehow change the fundamental economic structure of society (Epstein, 2014, p. 7). Alternately, for Walras, the role of science was to formulate the ideas of justice and advantageousness, and to indicate the means for this realization - the rest was specifically political work (Walras, 2010, p. 245).

Regarding the theory of general equilibrium in Moore's works, we addressed until now mainly his works of 1908 and 1917. Another important paper of Moore in the area is a 1925 article, *A Moving Equilibrium of Demand and Supply*, published in the Quartely Journal of Economics. One of his main points is that "the concrete determination of the laws of supply and demand leads to the conception of a moving equilibrium of demand and supply" (Moore, 1925, p. 358). Here is one of the central features of the development of Moore's empirical basis of the general equilibrium theory: the explicit association between empirically analyzing the theory and making it dynamic. In fact, even in his 1917 paper, this association between dynamics and empirical verification was already evident: "our law of demand is a dynamic law, it is a summary description of routine in concrete affairs" (Moore, 1917, p. 147). Moore then uses, shortly, "dynamic" and "empirical" as essentially synonymous. This becomes even more explicit when Moore describes the development of the history of general equilibrium theory:

> There are three stages in the development of the theory of general equilibrium. In the first stage, the whole economic system is seen as a complex of interdependent parts, the interrelations of which must be apprehended before the working of any single part can be adequately understood. Cournot was the first to see clearly this characteristic of social science and to suggest the method appropriate to its treatment. In the second stage, the device of the static state is introduced, and the interrelations of the parts of the economic system are enumerated and expressed symbolically in the form of general equations. Walras and Pareto worked out this part of the general problem. In the third stage, the transition is made from statics to dynamics, and the equations expressing the relations between the parts of the economic system receive the definite, numerical form in which theory admits of empirical testing. The object of the present paper is to treat this phase of the subject (Moore, 1926b, p. 28).

Moore presented the complete Walrasian model in his 1925 and 1926 articles. But the American author gave its definite form in the last book — and work in general – that he wrote, the Synthetic Economics, in 1929. Moore began the work by pointing out the advantages he had over, for example, Cournot, since his generation had new tools and materials to deal with theoretical issues (Moore, 1929, p. 4). Moore reasons that the title of the book, *Synthetic Economics*, "is intended to indicate a concrete, positive description of moving equilibria, oscillations, and secular change, by a method which presents all of the interrelated economic quantities in a synthesis of simultaneous real equations" (Moore, 1929, p. 5). According to him, as far as he was aware, neither Walras nor Pareto used the term before[23]. For Moore, to find the solution of the general equilibrium, it is not enough just to prove that there were many equations as the number of variables, but also to show that the equations could be empirically derived: the problem should admit a *real* solution (Moore, 1929, p. 6).

There are three advantages, according to the author, of the Synthetic Economics approach. First, it deals with the issue of remuneration of the production factors (Moore, 1929, p. 6). Second, it allows to identify when a solution to an economic problem has actually been reached (Moore, 1929, p. 7). The third is that "it gives ground for the hope of introducing into economic life rational forecasting and enlightened control" (Moore, 1929, p. 8).

Moore, in this book, returned to the question of assumptions adopted by models. One hypothesis that he claimed to abandoned is that of absolute competition. He called the free competition premise a "spurious superfoetation". For him the fundamental hypothesis should be "competition" only in the real sense that each economic factor seeks maximum net gain. Thus, his theory, accordingly to him, was not based on any "unrealistic premise" (Moore, 1929, p. 107). However, according to Burns (1931, p. 95) the premise of perfect competition is implicitly introduced when Moore assumed that in equilibrium costs are equal to prices and that an industry's total product is the sum of the marginal product of the factors of production multiplied by the units of each factor.

The theoretical model developed by Moore is quite extensive: it has 164 equations. Importantly, the theory he had as his starting point was not only the general equilibrium theory, but the Walrasian general equilibrium theory: "it is desirable, in the interest both of science and of personal loyalty, to adhere as far as possible not only to Walras' terms but also to his symbols" (Moore, 1929, p. 17).

One of the most important concepts Moore employed developing his equations is the elasticity of demand and supply. Already in his 1914 book, "Economic Cycles: Their Law and Cause", Moore pointed out that by using relative change in demand, $\Delta D \backslash D$, rather than the absolute change in demand, eliminated the effect of the rising population on the variable, while using the relative price $\Delta p \backslash p$ partially eliminated errors due to general price fluctuation (Moore, 1914, p. 69). The elasticity of demand, in infinitesimal terms as usual, is given by $dD \backslash dp \cdot p \backslash D$ and is denoted by η. In turn, the so-called coefficient of flexibility of prices is given by $dp \backslash dD \cdot D \backslash p$ and is denoted by ϕ.

[23]Walras employed the term "synthetic socialism" or "synthesism" to refer to his theory. For the French, synthetic socialism opposed both individualism and communism, and proposed a synthesis of the rights and duties of the state and the individual (Walras, 2013, p. 158).

Moore started with the simple demand of just one product depending on its own price. If the quantity placed on the market is the independent variable, the demand functions can be built from the elasticity of demand:

$$\eta = \begin{cases} \beta, \text{ or} \\ \beta + \beta' p, \text{ or} \\ \beta + \beta' p + \beta'' p^2 \end{cases} \quad (2)$$

That is, the elasticity of demand can be a constant, or to depend linearly on the price, or be a quadratic function of this price. Each of these assumptions about the elasticity generated a different typical demand function:

$$\mathrm{D} = \begin{cases} Bp^{\beta}, \text{ or} \\ Bp^{\beta} e^{\beta' p}, \text{ or} \\ Bp^{\beta} e^{\beta' p + \frac{1}{2}\beta'' p^2} \end{cases}$$

(3)

Where B is the integration constant to be determined by the observations. The issue is to derive from the data the parameter values of these functions. The problem, however, is that both price and quantity are constantly changing secularly. Although, according to Moore, there are many methods to deal with the question, he chose the trend-ratios method[24]. By the trend ratios method prices are expressed as a ratio to their trends (Moore, 1929, p. 42). The law of demand for the method are then:

$$\frac{D}{\overline{D}} = F\left(\frac{p}{\overline{p}}\right) \tag{4}$$

Moore gave a numerical example of the estimate for the potato market (Moore, 1929, p. 43). He determined the trend for the period from 1881 to 1913 for both production and price. The correlation coefficient gives the quality of the fit of the estimate between production-ratios and price-ratios. Finding, $r = -0.84$, Moore pointed out that it was sufficient evidence of a high relationship between the two series. Next he started from the

[24]Moore references Schultz (1925) for an inquiry into other methods. Akhabbar (2010, p. 51) indeed included Schultz as one of the three leading proponents of the neoclassical research program on empirical studies of the law of supply and demand. The two other were Moore and Harold Hotelling. However, Akhabbar (2010) pointed out that the three programs were abandoned roughly because of a “curse”: Moore suffered from psychological problems after his 1929 book, Schultz died in a car accident in 1938 and Hotelling abandoned the project after Schultz’s death. The author also added two other important research programs on the empirical studies of supply and demand, then, with a total of five programs: 4) Leontief’s, which brought him a controversy with Frisch, and that Leontief later abandoned; 5) Milton Friedman’s, who when confronted with the analytical difficulties abandoned not the approach, but the positivist epistemology that accompanied it. Friedman opted for an instrumentalist epistemology that freed the theory from its constraints on realism.

function:

$$\frac{p}{\overline{p}} = A\left(\frac{D}{\overline{D}}\right)^{\alpha} e^{\alpha'(D\setminus\overline{D})} \tag{5}$$

He applied the logarithm to both sides of the equation and estimated the following expression, by the least squares method: (Moore, 1929, p. 46)

$$log\left(\frac{p}{\overline{p}}\right) = \alpha log\left(\frac{D}{\overline{D}}\right) + \alpha'\left(\frac{D}{\overline{D}} - 1\right) loge \tag{6}$$

The author estimated the demand equation taking its price as an independent variable, instead of the quantity, using the same method[25]. Thereafter, he dealt with the more difficult problem of estimating the demand equation of a commodity as a function of the price of all other commodities. Since the price of $(m-1)$ commodities is expressed in terms of the monetary standard, commodity A, the Walrasian demand functions are:

$$\begin{aligned}
&\mathrm{D}_b = F_b(p_t, p_p, p_k, ..., p_b, p_c, p_d, ...),\\
&\mathrm{D}_c = F_c(p_t, p_p, p_k, ..., p_b, p_c, p_d, ...),\\
&\mathrm{D}_d = F_d(p_t, p_p, p_k, ..., p_b, p_c, p_d, ...), ...
\end{aligned} \tag{7}$$

Where p_t, p_p and p_k are respectively the price of land, people and capital services and p_b, p_c and p_d are the prices of commodities B, C, D and all others (Moore, 1929, p. 52-3). Regarding the fact all commodities are subject to forces that give each a secular trend, the new demand equation for commodity C, for example, is given by:

$$\frac{D_c}{\overline{D_c}} = F_c\left(\frac{p_t}{\overline{p_t}}, \frac{p_p}{\overline{p_p}}, \frac{p_k}{\overline{p_k}}, ..., \frac{p_b}{\overline{p_b}}, \frac{p_c}{\overline{p_c}}, \frac{p_d}{\overline{p_d}}, ...\right) \tag{8}$$

Presenting this formula, Moore argued that "While this hypothesis is simple it is the means of making the transition from a purely rational construction to a real situation" (Moore, 1929, p. 54). He also assumed a new elasticity of demand for one variable relative to all others – the partial elasticity. For example:

$$\eta_{cp_t \cdot p_p p_k \cdots p_b p_c p_d} = \frac{p_t}{D_c} \cdot \frac{\partial D_c}{\partial p_t} \tag{9}$$

Using the idea that demand elasticity could be equal to a constant, a linear or a quadratic function, Moore developed the new equations. For example, assuming that

[25] Judge (1968, p. 1707) pointed out that this practice of estimating two different equations, one with quantity and the other with price as the dependent variable, was common. Schultz summed up the situation humorously: "If, however, we are asked to determine the effect of a change in conditions of supply-say the imposition of a tariff-on prices, imports and consumption, we need to know among other things the elasticity of demand of the commodity in question, and we cannot conveniently say to the legislator "your tariff will have one effect if the elasticity of demand is computed from the regression of price on quantity and quite a different effect if it is derived from the regression of quantity on prices"

partial elasticity-price was equal to $\beta_{ct} + \beta'_{ct} p_t$ the demand function for commodity C was:

$$\frac{D_c}{\overline{D_c}} = Constant \left(\frac{p_t}{\overline{p_t}}\right)^{\beta_{ct}} \left(\frac{p_p}{\overline{p_p}}\right)^{\beta_{cp}} (...) \times \left(\frac{p_b}{\overline{p_b}}\right)^{\beta_{cb}} \left(\frac{p_c}{\overline{p_c}}\right)^{\beta_{cp}} (...)\, e^{\beta'_{ct}\left(\frac{p_t}{\overline{p_t}}\right) + \beta'_{cp}\left(\frac{p_p}{\overline{p_p}}\right)} + ... \quad (10)$$

The author argued that for most practical problems, to calculate the two demand functions derived from the two simplest price elasticities was already sufficient. Moore also addresses in his works the issue of "simplicity" of theories. In Moore (1908, p. 16) he pointed out that one criterion for choosing fitting curves it was simplicity, priori validity, and fecundity. However, "the impossibility of rigidly defining what is simple and what is complex has not escaped statisticians". A formula may be simple because it has few constants, but involves the use of highly tortuous processes to be determined (Moore, 1911, p. 16). Moore also argued in his 1929 book that starting from the simplest solutions is a valid aproach to solve particularly the problem of the general equilibrium theory:

> The chief difficulty in the way of extending the realistic treatment and of making the transition from particular equilibria to general equilibria is the necessity in case of the more complex inquiry, of working with functions of many variables. Is it not probable that help toward overcoming this difficulty may be obtained by extending the theories which facilitated the solutions of the simpler problem of particular equilibria? (Moore, 1926a, p. 393)

Moore's attention to the simplicity of theories might be understood from the criticism received by him in his past works. As we have seen, one of the most important critics of his works was Edgeworth. Edgeworth (1912, p. 70) addressing his statistical approach to the law of wages pointed out that "not only has he employed a steam-engine to crack a nut; but the nut is blind". Edgeworth (1912, p. 70) still added that "we cannot acquit our author of the charge – often brought too justly against mathematical economists and statisticians – of having overlaid a simple matter with useless and cumbrous technicalities". Moore replied that Professor Edgeworth was the first economist to regard the question as "simple" (Moore & Edgeworth, 1912, p. 315). Edgeworth, in his rejoinder, pointed out that he did not affirm that the relationship between workers' habilities and wages was a simple matter. What he meant was that the method of dealing with the relationship was considered simple when "divested of disguise" (Moore & Edgeworth, 1912, p. 318)

Treating the trend series was a central point of Moore's approach, as can be seen. This discussion about the trend data had also been present since his first works. For example, in his 1907 paper, Moore (1907b, p. 63) criticized official government statistics for not strictly trending the data. In Moore (1917, p. 121), the author marked out that data variations had three distinct sources: 1) secular change; 2) cyclical changes and; 3) random changes. Therefore, by Moore's own standards there was still two problems left that the trend could not solve - cyclic changes and random changes[26]. The idea of the multiple causes of price changes likewise appeared in his 1921 work: "No one familiar with the theory of prices and with their *multitudinous* causes of changes would expect the record of general wholesale prices to show an exact mathematical precision in the working of any one cause" (Moore, 1921, p. 515).

Still discussing trends, in the original Walrasian theory, concerns with price comparison at different time periods were already present. Walras pointed out that researchers should exercise caution when comparing separate prices over a longer period of time, given that "one would run the risk of comparing non-comparable things. Ideally, high-tide prices should be compared with high-tide prices, or low-tide prices" (Walras, 2008, p. 25). Indeed, economic series were compiled and presented with their trends for a long time, but until the turn of the twentieth century they did not use them to indicate any kind of causal relationship (Epstein, 2014, p. 12). However, a discussion of the original Walrasian theory was absent from Moore's theory about trends: While admitting it, Moore did not discuss whether the trend would be negative or positive.

The criticism Moore's work received also addressed the method of the trend ratios. Allen (1930, p. 112) for example, pointed out that "the method of trend ratios is made to bear a greater burden than it can really support". Burns (1931, p. 93) also pointed out that Moore used the concept of "secular change" just to support the adoption of trend-ratios, but that the Professor did not consider that the very existence of secular trends was an object of curiosity by itself. Ezekiel (1930, p. 678) also pointed out that the trend-ratios method was perhaps not the most appropriate to deal with data problems: "Simply fitting empirical trends to series of data, and expressing them in percentages of trend, is not an adequate treatment of the dynamic element in economic activity. In such a statistical process, the influences of *all* factors which change progressively in time are eliminated, and this may include economic factors just as well as others". Ezekiel (1930, p. 678) pointed out that new methods were being developed to deal with price fluctuations. Such approaches attempted to understand the changes that occurred over time, rather than placing them all under the same category of "secular change".

Some remarks about the estimation method, the least squares, are also worth noticing. Moore did not specifically justify the choice of method in his 1929 work. In Moore (1907a), he used, for example, alternatively, the method of moments. In Moore (1908) he compared Cauchy's method, used by Pareto, against the least squares method. His conclusion was that the least squares, although more difficult to calculate, has a higher degree of accuracy. In Moore (1911), the Professor further used the method developed by Pearson for the derivation of the coefficient of mean square contingency (Moore, 1911, p. 112). Moore

[26] In his book *Economic Cycles: Their Law and Cause*, Moore used Fourier's theorem to analyze periodic phenomena and the periodogram to separate natural-cause fluctuations from spurious-cause fluctuations (Moore, 1914, p. 10-4)

(1917) used two different approaches for estimation: the method of progressive averages and the method of percentage changes. The latter used the hypothesis that there was a close relationship between the percentage change in price from one year to another and the percentage change in production from one year to the next. Alternatively, in Moore (1925) the author employed the trend ratios method, and the method of link ratios, to estimate the supply curves.

A peculiar point about Moore's method is the query of outliers. The author seemed to consider removing the discrepant observations as scientifically disloyal. For example, in trying to predict cotton production from climate reports, the author pointed out that "it would have been possible, on several occasions, to increase the coefficients by omitting one or two rainfall-ratios which, in consequence of torrential storms, presented unduly large values; but no such liberty has been taken with the crude material" (Moore, 1917, p. 117). In analyzing the history of statistics before 1900, S. M. Stigler (1986) marked out that this practice of informally discarding extremely discordant observations was actually common among astronomers, for example.

So far we have presented the demand functions developed by Moore. In chapter IV of *Synthetic Economics*, the author reasoned that "the fundamental symmetry with which demand and supply co-operate in the determination of price suggests the possibility, and indicates the desirability that the typical functions descriptive of supply may be of the same general forms as those which have been found useful when dealing with demand" (Moore, 1929, p. 65). Like the elasticity of demand, the elasticity of supply could have different patterns:

$$\mathrm{S}\eta_{tp_c \cdot p_t p_p p_k \cdots p_b p_d \cdots} = \frac{p_c}{S_t} \cdot \frac{\partial S_t}{\partial p_c} = \begin{cases} \gamma_c, \text{ or} \\ \gamma_c + \gamma_c{}' p, \text{ or} \\ \gamma_c + \gamma_c{}' p + \gamma'' p_c{}^2 \end{cases} \tag{11}$$

Therefore, supply equations could be obtained analogously to demand equations. However, the data that Moore employed to obtain the law of supply was the price of the previous year. That is, the output was built as a function of the price of the preceding period. Commenting on this approach, (Wright, 1930, p. 332) pointed out that except in agricultural goods, there was no apparent reason why the lag should be one year. As Wright reasoned, "it is fairly obvious" that in drafting the law of demand, if the author finds a high negative correlation between price and quantity, using the value with lag one will find a high but positive correlation. Wright (1930, p. 333) argued also that "it raises the question whether the curves so derived can with propriety be called demand and supply curves". Demand may be inelastic, while supply need not necessarily be inelastic as well (Wright, 1930, p. 333). Schultz, commenting Wright's review, pointed out that the lag method was not essential to Moore's main thesis. Wright (1930, p. 333) responded to Schultz that "I did not mean to imply that Moore might not accept other methods of deriving supply and demand functions. What methods he might accept but did not use I do not know". One final criticism by Wright of the supply curve is that it looked nothing like the neoclassical supply curve, since it had no connection to marginal cost. In fact, (Wright, 1930, p. 338) prefers to refer to both curves as "Moore curves" rather than supply and demand.

There are four original equations of the Walrasian model. The first two, demand and supply, have already been presented. The third equation expresses the equality between the quantity of services demanded and the quantity of services offered:

$$= \begin{cases} a_t D_a + b_t D_b + c_t D_c + d_t D_d + ... = S_t \\ a_p D_a + b_p D_b + c_p D_c + d_p D_d + ... = S_p \\ a_k D_a + b_k D_b + c_k D_c + d_k D_d + ... = S_k \end{cases}$$

(12)

Where a_t, for example, is the production coefficient that expresses the amount of factor T (land) used in the production of the commodity (A). The fourth equation indicates that the cost of production of a commodity must be equal to its price. Taking commodity (A) as *numéraire*:

$$= \begin{cases} a_t p_t + a_p p_p + a_k p_k + ... = 1 \\ b_t p_t + b_p p_p + b_k p_k + ... = p_b \\ c_t p_t + c_p p_p + c_k p_k + ... = p_c \end{cases}$$

(13)

To develop the algebraic formations of demand and supply functions, Moore used the theory of partial elasticity of demand and the theory of partial elasticity of supply. To find the two last equations Moore will use the theory of partial relative efficiency of organization. ω was defined as the ratio of the relative change in total production to the relative change in total cost. If we assume that Q_c represents the quantity of the commodity (C) that is produced, and that land, persons, and services of capital services are represented by T_c, P_c, K_c, the function of production is given by: $Q_c = \Psi(T_c, P_c, K_c, ...)$. Therefore, the relative efficiency of organization is:

$$\omega_{ct \cdot pk \cdot \cdot} = \frac{T_c}{Q_c} \cdot \frac{\partial Q_c}{\partial T_c}$$
$$\omega_{cp \cdot tk \cdot \cdot} = \frac{P_c}{Q_c} \cdot \frac{\partial Q_c}{\partial P_c}$$
$$\omega_{ck \cdot tp \cdot \cdot} = \frac{K_c}{Q_c} \cdot \frac{\partial Q_c}{\partial K_c}$$

(14)

Such coefficients, in turn, may be constant, or depend on the cost linearly or quadratically. For example:

$$\omega_{ct\cdot pk\cdot\cdot} = \begin{cases} \epsilon_{ct}, \text{ or} \\ \epsilon_{ct} + \epsilon'_{ct} T_c, \text{ or} \\ \epsilon_{ct} + \epsilon'_{ct} T_c + \epsilon''_{ct} T_c^2 \end{cases} \qquad (15)$$

In Walrasian notation $T_c \backslash Q_c = c_t$, $P_c \backslash Q_c = c_p$ and $K_c \backslash Q_c = c_k$. Moore assumed that the coefficient of relative efficiency of organization was a linear function. Another assumption was that the use of each factor in production was carried to the point where the value of the product imputed to the final increment of the factor was just equal to the price of the increment of the factor (Moore, 1929, p. 120). The author further assumed that the most likely value of p is its trend value, $\overline{p}$. Therefore, the constant production coefficients by which Walras describes equation (14) can be replaced and this equation became:

$$\left[\epsilon_{at} + \epsilon'_{at}\left(\frac{T_a}{\overline{\overline{T_a}}}\right)\right]\frac{\overline{p_a}}{\overline{p_t}}D_a + \left[\epsilon_{bt} + \epsilon'_{bt}\left(\frac{T_b}{\overline{\overline{T_b}}}\right)\right]\frac{\overline{p_b}}{\overline{p_t}}D_b + \epsilon'_{bt}\left(\frac{T_c}{\overline{\overline{T_c}}}\right)\frac{\overline{p_c}}{\overline{p_c}}D_c + ... = S_t \qquad (16)$$

In place of Walras cost and price equations that depended on the assumption of fixed coefficients of production, Moore also replaced this fourth equation. Still assuming that the coefficient of relative efficiency of the organization is a linear function:

$$\left[\epsilon_{ct} + \epsilon'_{ct}\left(\frac{T_c}{\overline{\overline{T_c}}}\right)\right]\frac{\overline{p_c}}{\overline{p_t}}p_t + \left[\epsilon_{cp} + \epsilon'_{cp}\left(\frac{P_c}{\overline{\overline{P_c}}}\right)\right]\frac{\overline{p_c}}{\overline{p_p}}p_p + ... = p_c \qquad (17)$$

Moore concluded that "these four groups of equations (...) like Walras' equations (...) determine a general equilibrium, but the equilibrium with which they are concerned is *real* and not *hypothetic*, is *moving* and not *static*. It is a moving equilibrium about the lines of general trend" (Moore, 1929, p. 126).

The model presented so far is the simplest version of the book: later Moore will distinguish the price of capital goods from the price of services of these goods. The model will also take into account the supply of credit, the interest rate and the creation of capital goods. Although more mathematically complex, Moore justified that such changes supported for greater similarity with economic facts (Moore, 1929, p. 128). However, apart from this more complete model, Moore also addressed two other important points. The first one is that the American marked out that his approach allowed to statistically test the productivity theory of distribution. Moore reasoned that:

There are three cardinal features of that doctrine which seems to present insuper-

> able obstacles in the way of statistical verification: (a) The productivity theory obtains only when consumption and production have reached a state of equilibrium. But how may one know when the state of equilibrium is reached? (b) The productivity applies to marginal increments. But how may we isolate the marginal increments? (c) The productivity theory asserts that each factor in production receives an income equal to the number of units of the factor multiplied by its marginal product. But can one prove that the sum of all the several incomes determined by this formula is equal to the product of industry? All three of these difficulties may be removed by the preceding analysis (Moore, 1929, p. 143).

As for the first problem, Moore argued that the theory of a moving general equilibrium solves the issue: trend prices and trend products are equilibrium prices and equilibrium products (Moore, 1929, p. 143). The second query, according to the author, is also solved. After we determine the statistical values of the model's constants, the marginal product of any factor can be immediately calculated. To demonstrate the third point, Moore made some algebraic manipulations from the equation that expresses that the price of commodities is equal to the cost of production. The author arrived at the expression:

$$\overline{T}_c \frac{\partial \overline{Q}_c}{\partial \overline{T}_c} + \overline{P}_c \frac{\partial \overline{Q}_c}{\partial \overline{P}_c} + \overline{K}_c \frac{\partial \overline{Q}_c}{\partial \overline{K}_c} + ... = \overline{Q}_c \tag{18}$$

Which, according to the author is proof, in a form that can be statistically tested, that in an equilibrium state the industrial product is partitioned according to the productivity formula (Moore, 1929, p. 145).

The second important point of Moore's theory is that his last chapter of the 1929 book dealt with economic oscillations. For him, the theory of economic equilibrium is a prerequisite for understanding the fluctuations of the economic activity. The oscillations appeared in the model as a result of perturbations of a system under the influence of forces that lead it to a moving general equilibrium. As in the rest of the book, he first analyzed a particular equilibrium and then the general case, building *the synthetic theory of economic oscillations*. On the occasion of Moore's death, Columbia University, in its Memorial Minute, pointed out that "Moore's final work, "Synthetic Economics" provided a significant bridge between the now classic work of Walras and Pareto in the field of mathematical economics and the more recent formulations of Hotelling and Samuelson" (Columbia, 1959).

As pointed out at the beginning of this paper, Moore's main objective was to adapt the Walrasian model so that it could be statistically tested. According to the American author, it was precisely this lack of empirical verification that caused the absence of interest in Walrasian theory at the time (Moore, 1914, p. 82). Persons (1925, p. 194) argues that Mitchell, in his Presidential address before the American Economic Association, raised the question of whether, in fact, the economic theory developed so far could be used as a first approximation to reality, to be tested empirically. In this sense, according to (Persons, 1925, p. 195): "The fact remains, however, that there are two views in regard to this question. Moore's view is that it is possible, while Mitchell's view is that it is impossible, starting with economic theory as it exists today, to develop a statistical complement of pure economics". Persons (1925, p. 195), then continues: "These are the views of two leading investigators in the field of economic statistics, both optimists as to the future contributions of statistics to the science of economics"[27]. However, Persons (1925, p. 195) argues that overall, studies in economic statistics had supported Moore's defense that it is possible to develop the statistical complement to the body of economic theory. Burns (1931, p. 88), in turn, points out that the general opinion at the time, even among the exponents of the mathematical school, was that the empirical derivation of the Walrasian system was practically an unreachable goal. According to the author, the required statistical work "would be extraordinarily, almost superhumanly, laborious" (Burns, 1931, p. 92).

The difficulty of obtaining the data was also a point that appeared in the reviews. Flux (1931, p. 272) argued that Moore did not seem to regard obtaining the information as a very important obstacle to determine the parameters of his model. Still on the amount of data required, Ezekiel (1930, p. 677) made an estimate: if demand for cotton depended on 100 prices, it would be necessary, for example, 150 independent observations to establish the estimate, and with annual data "the determination of the elasticity of demand for cotton would thus have to be based on the entire history of cotton production in this country, even back to well before the cotton gin was invented!". Ezekiel (1930, p. 677) therefore criticized the fact that existed two extreme models, one in which demand for a good depended only on its own price, and the other in which demand depended on *all* other prices.

However, despite this criticism, Ezekiel (1930, p. 679) ended his review pointing out that "It cannot be said that Synthetic Economics will always remain a dream". Curiously, Moore's last book also ended with a section called "economic dreams". According to it, the society needed both forecasting and control. For Moore, Economics should go long beyond a "philosophy of the closet". Marxism, for example, would not yield to refutation, ridicule, and persecution: the only countermeasure of society was to mitigate the grievances of the working class.

4. Concluding remarks

The main purpose of this paper was to present Henry Moore's attempt to make the Walrasian model of general equilibrium statistically operative. The perspective of analysis was twofold, considering both the relationship between Moore and Walras, and the theoretical development, exploring the American's work. The letters exchanged between

[27]Comparing Mitchell and Moore's work on Economic Cycles, Magee (1915) pointed out that Moore's approach was poorer in terms of sense of reality than Mitchell's.

the two professors demonstrated Walras' academic isolation and his attempt to propagate his theory in the United States.

One of the main difficulties in analyzing the dissemination of an idea is the lack of materiality about the object of study. However, the paper allowed us to analyze the dissemination from a very concrete point of view: the translation of Walras' work. Moreover, we have seen that Walras' foreground was the translation of a teaching material: thus, the propagation of his theory in the New World would begin in the classroom. We also conclude that the main analytical tool used by the author was the treatment of data using a secular trend. As this trend is empirically derived, according to Moore, there was a transition from a purely rational construction to a real and dynamic situation. Therefore, in Moore's works, the transition from a static analysis to a dynamic analysis was intrinsically related to the empirical basis of the theory. The author also claimed that the formulation of the general moving equilibrium allows the empirical test of the productivity theory of distribution.

We also observed that the question of the empirical grounding of the general equilibrium theory was something more prominent in Moore's later work. The main effort on Walrasian theory, his 1929 book, was also the last work the American author ever wrote. He retired shortly thereafter and never again engaged in any academic activity. Curiously, in one of his books, Moore mentioned Darwinism as a specific case of theory development and dissemination (Moore, 1905, p. 370). Darwin, according to Moore, succeeded in propagate his theory as a result of several favorable conditions: independent income, leisure time, great ability to work, a subject close to the public's interest, and *"courageous, able, aggressive disciples"*. As, in Walras' words, his chief American disciple, it is undoubtedly that Moore is important in explaining the manner in which the Walrasian theory disseminated in the United States – which also would soon become the world's leading academic center.

Also doubtless, one of the most important works in the history of general equilibrium theory is Ingrao and Israel (2005). The book's title, *The Invisible Hand: Economic Equilibrium in the History of Science*, is fairly suggestive: such theory, in its essence is inseparable from Smith's poetic notion of the forces of society moving without much help toward a state of, in a broad sense, optimal balance. We have seen, however, that for Moore, the empirical grounding of the theory was primarily aimed at forecasting, and forecasting has a very explicit purpose: it is possible to improve the outcome of the economy if we can know what the future holds.

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