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ABSTRACT

In the 1870 s and 1880 s, the scientist, logician, and pragmatist philosopher Charles S. Peirce possessed an advanced knowledge of mathematical economics, having mastered and criticised Cournot as early as 1871. In 1884 he engaged in a multi-round debate with the editors of *The Nation* over the economics of trade liberalisation in the case of a proposed trade treaty with Spain concerning import tariffs on Cuban and Puerto Rican sugar. While the mathematical underpinings of Peirce's intervention in the debate are not explicit, they are evident in light of Peirce's unpublished writing on Cournot. The debate is reconstructed and related carefully both to Peirce's understanding of mathematical economics and to his philosophy of science. Peirce's intervention is one of the earliest intricate applications of mathematical economics to public policy.

In the opening decades of the new millennium, trade policy has stood in the forefront of American politics; in the late nineteenth century, trade policy was just as fiercely debated – *plus ça change* … Even the much deplored habits of partisanship and lack of intellectual engagement with those with whom we disagree were as much in evidence then as now.[1] In his famous essay, "The Fixation of Belief," Charles Sanders Peirce (1839–1914) offers a story to illustrate the *method of tenacity*, which he would contrast with the *scientific method*, for fixing belief:

> I remember once being entreated not to read a certain newspaper lest it might change my opinion on free-trade. 'Lest I might be entrapped by its fallacies and misstatements,' was the form of expression. 'You are not,' my friend said, 'a special student of political economy. You might, therefore, easily be deceived by fallacious arguments upon the subject. You might if you read this paper, be led to believe in protection. But you admit that free-trade is the true doctrine; and you do not wish to believe what is not true.' [WP 3.249; also CP 5.377][2]

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[2] Following standard conventions among Peirce scholars, references to Peirce's *Collected Papers* (1931–1958) are generally indicated as "CP volume number.paragraph number" (e.g., "CP 6.289" = *Collected Papers* volume 6, paragraph 289). Some references are to larger divisions (e.g., chapters) and these are indicated explicitly (e.g., "CP 1, ch. 4.") Similarly, some references to the *Collected Papers* are to material from editorial apparatus that is not divided into numbered paragraphs, and these are indicated by volume and page number (e.g., "CP 8, p. 283"). References to the *Writings of Peirce* (1982–2010) are given as "WP volume number.page number (e.g., "WP 5.26" = *Writings* volume 5, page 26).

Peirce is most famous as the founder of the American school of philosophy known as *Pragmatism*. He was also a polymath – an important mathematician, logician, empirical psychologist, scientist, and semiotician, as well as, philosopher. And, as it turns out – though it is one of his least appreciated sides – Peirce *was* a special student of political economy; and in 1884 he applied his knowledge of economics in a public debate over a trade treaty between the United States and Spain.[3] His intervention in the debate over the Spanish Treaty illustrates Peirce's mastery of the most advanced economics of his era, showcasing its utility in clarifying questions of practical policy, and it provides a surprising economic case study of Peirce's "model-based" philosophy of science.

1. The first American mathematical economist

1.1 . A mathematician meets economics

In 1871, Peirce was almost certainly the first mathematical economist in the United States. The most advanced mathematical economist in the world was the French mathematician, astronomer, and historian of science Antoine Augustin Cournot (1801–1877), who published his *Recherches sur les Principes Mathematiques de la Théorie des Richesses* in 1838. Over the next three decades very few people read Cournot's masterwork. The first reviews appeared in 1857 and 1864 (Cherriman 1857 (see also Dimand 1995; de Fontenay 1864). And William Stanley Jevons and Leon Walras, the marginalist economists whose later regard for Cournot rescued his *Recherches* from obscurity, had yet to read the book. Peirce, in contrast, had not only read Cournot, he had mastered his analysis.[4]

Unlike Jevons and Walras, who, though central figures in the mathematization of economics, were not up to Cournot's mathematical standard, Peirce was levels above Cournot. As we showed in an earlier article, Peirce not only mastered the *Recherches*, but gave a superior interpretation of Cournot's analysis of market structure to the ones common in the literature and anticipated Bertrand's (1883) criticism of Cournot's analysis of duopoly by more than a decade.

Peirce's intellectual projects were highly varied, and economics was never his central focus; yet economics contributed important ideas to Peirce's thinking on pragmatism, logic, and the philosophy of science. Nevertheless, the trade was not one way. Peirce made two exemplary contributions to economic analysis: the first was his paper, "The Economy of Research" (1879; also WP vol. 7, ch. 2; WP 4.73–78), which was the most advanced application of mathematical economics to any applied problem up to that time; the second was an intervention in the public policy debate over a trade treaty with Spain in 1884 and 1885[5]. This intervention is our focus. Although the debate in

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[3] Ketner and Putnam (1992) provide a capsule summary of some of the key facts of Peirce's life; and Brent (1998) offers a full-scale biography.

[4] Wible and Hoover (2015) offers a detailed account of Peirce's engagement with Cournot.

[5] A comparison of the roughly contemporaneous works represented in Darnell's (1991) six edited volumes of early mathematical economics provides good evidence of the cutting-edge quality of Peirce's "Economy of Research." We are currently writing a book on Peirce's engagement with economics. One chapter of that book will consider Peirce's paper on the economy of research in detail, while a companion paper to this one addresses his analysis of Ricardian inference (Hoover and Wible 2017).

the pages of *The Nation* was conducted in plain English – not in mathematics – we show that Peirce's trenchant and precise analysis was grounded implicitly in his mastery of the economics of Ricardo and Cournot. It was mathematical in substance, if not in form.

1.2 Ricardo and models

Mathematics for Peirce was the most fundamental science, but its essence was its form of reasoning that was, at once, self-contained, working out the implications of arbitrary hypotheses according to rules supplied by mathematics itself, and also observational, formulating those hypotheses diagrammatically and investigating them in much the same manner as an empirical scientist would investigate objects in the world. Peirce interpreted "diagram" broadly to embrace all kinds of mathematical representation – applying equally to geometric and algebraic representations (CP 4.233, Peirce 1898[1992], Lecture 3; also see Ketner and Putnam 1992, 2–3, 68–71, 74–75; Peirce 1976, 219, fn. 1). The essence of mathematics for Peirce is not its formalism but its method of reasoning. For Peirce, David Ricardo – even more than Cournot – represented the mathematical approach to economics, despite Ricardo's unfamiliarity with the mathematician's technical tools. Peirce went so far as to name what he regarded as a fundamental form of mathematical reasoning the *Ricardian inference*.

While we have carefully investigated Peirce's Ricardian inference elsewhere (Hoover and Wible 2017), it may be helpful to provide a brief sketch and to frame its relevance to the kind of economic analysis that Peirce offers of the Spanish Treaty. Exactly, how to interpret Peirce's Ricardian inference is open to debate. One interpretation of Ricardian Inference identifies it with an analogue to mathematical induction. Mathematical induction involves infinite sequences of countable numbers; whereas Ricardian inference on this interpretation involves real (or uncountable numbers) and is, therefore, applicable to the continuous functions, typically addressed in the differential calculus.[6] It is surprising that Peirce should single out Ricardo as the eponym for what he regarded as a deeply fundamental piece of mathematics. Apparently, he saw in Ricardo's use of marginal arguments in his theory of differential rent and income distribution a particularly clear illustration of the reasoning, despite the lack of mathematical formalism. A second interpretation identifies Ricardian inference with what Peirce calls the *Analytical Method*. We believe that Peirce saw these two interpretations as deeply related to the point that, for him, they may ultimately be the same. Nonetheless, it is the aspect of Ricardian inference as the Analytical Method that most readily applies to his analysis of the Spanish Treaty.[7]

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[6] Peirce was familiar with the term "mathematical induction," but rejected it as involving a confusion, since it is a form of deductive, and not inductive, reasoning. He most often calls it *Fermatian inference*, in honor of the French mathematician Pierre de Fermat, whom he credits with inventing it. He typically refers to the analogue for uncountably infinite numbers as the *primipostnumeral syllogism*. Peirce was familiar with Gregor Cantor's proof of the existence of transfinite cardinal numbers, and the adjective "primipostnumeral" is his own coinage for the first such uncountably infinite number. He gives strong hints that he regards Ricardian inference as a synonym. See Hoover and Wible (2017) for a detailed discussion.

[7] Parts of the remainder of this section are drawn verbatim from Hoover and Wible (2017, section 4).

The Analytical Method for Peirce is

> to substitute for those problems others much simpler, much more abstract, of which there is a good prospect of finding probable solutions. Then, the reasonably certain solutions of these last problems will throw a light more or less clear upon more concrete problems which are in certain respects more interesting.
>
> This method of procedure is that Analytic Method to which modern physics owes all its triumphs. It has been applied with great success in psychical sciences also. (Thus, the classical political economists, especially Ricardo, pursued this method.)[8] [CP 1.63–64]

Analogy is the core of the Analytical Method. Peirce divided inference into deduction, induction, and abduction. Deduction constitutes necessary reasoning. Abduction and induction are related to hypothetical reasoning – abduction introducing hypotheses and induction testing or precisifying them. The form of abduction is:

> The surprising fact, C, is observed
>
> But if A were true, C would be a matter of course,
>
> Hence, here is reason to suspect that A is true. [CP 5.188]

Induction amounts either to the gathering of facts that refute an abductive hypothesis or to making measurements – especially statistical estimations – that help to pin down free parameters or otherwise lend greater precision to a hypothesis. Peirce's view is similar in some respects to Popper's (1963) logic of science as one of conjectures and refutations. There is, however, a key difference: where Popper denies that the origin of conjectures is a scientific matter at all, Peirce maintains that abduction has its own distinct logic.

Abduction and induction are cooperative forms of inference, with abduction setting the framework for inductions and inductions evaluating abductions. Peirce goes further and suggests that there is actually a fourth, hybrid form of inference, which he terms "analogy" that combines the character of abduction and induction (CP 1.65). It is analogy that forms the basis of the Analytical Method to which Peirce attributes so much scientific success in economics, as well as in the physical sciences. Peirce defines *analogy* as "the inference that a not very large collection of objects which agree in various respects may very likely agree in another respect" (CP 1.69).

What Peirce appears to have in mind is something closely akin to the way in which modern economists, as well as scientists in many other disciplines, employ models as inferential tools.[9] Self-consciousness about modelling in any science is largely a post-World War II phenomenon. Earlier, the word "model" in the sciences almost always referred to physical representations such as an orrery or a patent model. Yet there is good reason to think that, although the word "model" may be an anachronism, it is not anachronistic to see the *concept* of modelling in Peirce's understanding of analogy

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[8] Weighing into contemporary debates among political economists over *Historismus* versus *a priori* methods (and anticipating debates between Institutionalists and neoclassical economists), Peirce goes on: the Analytical Method "is reprobated by the whole Hegelian army, who think it ought to be replaced by the 'Historic Method,' which studies complex problems in all their complexity, but which cannot boast any distinguished successes" (CP 1.64; cf. Keynes 1917, 314–327; Robbins 1935, 79–83, 1998, Lectures 25 and 26; Schumpeter 1954, ch. 4, part 2).

[9] Morgan (2012, ch. 2, esp. sections 1–4) offer an interpretation of Ricardo as a modeler *avant la lettre*.

as a distinct form of inference.[10] Peirce takes *analogy* to be an English translation of Aristotle's παράδειγμα, which is the etymological source of *paradigm* (CP 1.65). "Paradigm," in the wake of Kuhn's *Structure of Scientific Revolutions* (1962), is widely used, but in Peirce's day it was an obscure, largely grammatical term, and Peirce would not have invested it with Kuhnian resonances. According to the *Oxford English Dictionary*, the root word" δειγμα (*deigma*) designates a "sample [or] pattern," while the prefix παρά- (*para-*) conveys the idea of "analogous or parallel to, but separate from or going beyond" that pattern. The word itself aptly conveys the strategy of analogical reasoning that Peirce attributed both to physics and to classical political economy and maps very nicely onto modern practices in which stripped down or idealised root models are elaborated successively to come closer to empirical observations while maintaining their underlying basic character and tractability.[11]

Peirce clarifies analogy as a mixed type of inference with an extended analysis of Kepler's discovery of his laws of planetary motion: "the greatest piece of Retroductive reasoning ever performed" (CP 1.72–74, especially CP 1.74; WP 5.352).[12] Kepler began with Copernicus's hypothesis of the planets in circular orbits around the sun and Tycho Brahe's and his own observations. The analogy was, if we can use the terminology anachronistically, between Kepler's mathematical model, with its precise orbits, and the actual observations. The analogy was not, at first a good one: the Copernican model fit the data rather badly. Out of keeping with Popper's later methodological pronouncements, Kepler did not simply scrap Copernicus's model. His procedure was not haphazard, but systematic and conservative, in the sense that at each new abductive step, he tried to preserve his quantitative success hitherto – that is, to stay within the bounds of error already achieved – and to use the specific ways in which the hypothesis fell short to suggest the next abductive step. Peirce notes that Kepler's reasoning is diagrammatic and that Kepler used his partially successful early diagrammatic model, which he referred to as his "vicarious theory," because it permitted him to conduct experiments without having to revert to additional direct observations and, thereby served as a tool of failure analysis and as guide to further abductive elaboration (WP 8.290–291).[13] Kepler's own abductive contribution was to consider the dynamical implications of the sun, which he knew to be vastly larger than any of the planets and which he conjectured exercised some vaguely-defined causal power over them. Alternating abductions to introduce modifications and inductions to characterise the

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[10] Peirce does use the term "model" in the sense of a physical representation and, importantly connects models to diagrams, which he regards as central to mathematical reasoning: "The word diagram is used here in the peculiar sense of a concrete, but possibly changing mental image of such a thing as it represents. A drawing or *model* may be employed to aid the imagination; but the essential thing to be performed is the act of imagining" [Peirce 1976, 219, fn. 1; emphasis added].

[11] On the history of models in economics, see Morgan (2012).

[12] Peirce uses "retroduction," "hypothesis," and sometimes "presumption" as synonyms for "abduction." Later Peirce (WP 8, ch. 49, esp. 290–291) provides a more extensive biographical account that explains Kepler's reasoning process in greater detail.

[13] Kent (1987, p. 3) compares Peirce's ability to reason with diagrams to Einstein's thought experiments: "Einstein began using his thought experiments (*Gedankenexperimente*) at sixteen, and Peirce began training himself to think in diagrams when a young man, finding it a great advance over algebraic thinking….Both men traced their own creative initiatives to systematized diagrammatic thought."

nature and degree of the deviations between conjecture and data, Kepler refined the model:

> never modifying his theory capriciously, but always with a sound and rational motive for just the modification he makes, it follows that when he finally reaches a modification – of most striking simplicity and rationality – which exactly satisfies the observations, it stands upon a totally different logical footing from what it would if it had been struck out at random, or the reader knows not how, and had been found to satisfy the observation. [CP 1.74]

The Analytical Method for Peirce is largely the method of refining and precisifying analogies or, as a modern economist might put, a method of modelling. Later Peirce wrote:

> Keppler [*sic*] was forever trying experiments with his figures. No bad luck, not dozens of negative results, which other men reckon failures, could discourage him from trying again. Yet it would be a great mistake to suppose that he was addicted to wasting time on wild-cat theories, or what Darwin used to call nonsense-experiments. Each step was made deliberately, and for sound reasons; and few of Keppler's "failures" failed to throw some light on the problems he hand in hand. [WP 8.290–291][14]

1.3 "This is all in Cournot"

In December 1871, the Scientific Club of Cambridge, Massachusetts, a group of scientists and scholars centred on Benjamin Peirce, Harvard professor and Charles Peirce's father, was scheduled to discuss Cournot's *Recherches*. Peirce senior was the foremost American mathematician of his day, a professor at Harvard and the Director of the Harvard Observatory. In his capacity as the Superintendent of the United States Coast Survey – at the time the premier scientific organisation within the U.S. government – he was also his son's employer, having given him a position as a scientific assistant at the Coast Survey's headquarters in Washington. Benjamin Peirce commissioned Charles to prepare diagrams for the meeting of the Scientific Club. While we cannot say exactly when Charles first read the *Recherches*, we know from correspondence at this time with his father and with Simon Newcomb, who was Benjamin's protégé and also an astronomer, mathematician, and sometime economist, that he had read the *Recherches* before December 1871. The letters, along with later letters, and manuscript fragments offer considerable insight into Charles Peirce's mastery of Cournot's book.[15]

By his own account, Cournot (1838, 4–5) aims not to radically revise the substance of economics, but to formalise existing ideas in mathematical terms. He does not address questions that would not be illuminated by formalisation. In Cournot's view, Adam Smith and Jean-Baptiste Say, approached economics with a fundamentally literary method. In contrast, while David Ricardo displayed no familiarity with mathematical technique, his method of reasoning was fundamentally mathematical; and, in Ricardo's numerical examples, Cournot saw algebra struggling to escape the bonds of

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[14] Peirce's apparently idiosyncratic spelling follows the German, rather than the Latin, spelling of Kepler's name, as it appears in his own in German letters. Kepler was apparently indifferent to the spelling variation in his contemporary published works (WP 8, p. 452).

[15] Wible and Hoover (2015) provide a detailed exposition of the content of these letters and manuscripts; it would be beyond our purpose to repeat them here.

an awkward literary style. Cournot saw his own achievement as formulating key economic ideas in terms of mathematical functions that could be analysed qualitatively without implicit or explicit quantification. Demand was no longer just a quantity that consumers were willing to purchase at a price, but was the entire schedule of quantities and prices or, graphically, a curve[16]. His own original contribution is largely to his analysis of market structure, which makes use of the demand curve, to distinguish among monopoly, duopoly (and other forms of oligopoly), and "unlimited competition" – the limiting case of oligopoly as the number of competitors becomes large, commonly known today as *perfect competition*.

Peirce's scattered writings on Cournot address mainly these central issues of market structure. In one letter – evidently in reply to an earlier one from Newcomb – Peirce aims to convince Newcomb that the supply curve can be defined only in perfect competition, in which conceptually the firm's optimisation problem is separable, in the sense that, unlike in the case of monopoly or duopoly, to determine its preferred supply it need only minimise its cost of production without reference to the demand curve. In doing so, Peirce offers an interpretation of Cournot's treatment of different market structures that renders Cournot's method of analysis as logically correct and more consistent than most later commentators have regarded it to be (Wible and Hoover 2015, 527–531).

Peirce's letter to Newcomb ends with a hint of exasperation: "This is all in Cournot." If Newcomb would but study Cournot, as Peirce himself had done, all would be clear. Peirce was himself above all a mathematician, who immediately appreciated the advantages of Cournot's mathematical treatment of economics. Cournot certainly had more mathematical technique than Ricardo; and, while Peirce agreed with Cournot that Ricardo's *Principles* were chock full of implicit mathematics, he did not see Cournot as either a more profound economist nor a better logician than Ricardo; and, when seeking examples of economic reasoning, he more often refers to Ricardo than to Cournot. But in his analysis of the Spanish Treaty, Peirce certainly draws on both sources.

2. Tariffs and reciprocity

Peirce's intervention in the debate over the tariff provisions of the Spanish Treaty provide us with one of the few illustrations of his actually engaging in economic analysis rather than discussing its scope and method. Although our interest is not primarily in the actual historical debate – and particularly not in the later history of tariffs and tariff reform – but in the nature and significance of the Peirce's intervention as an illustration of his economic method, it will be helpful to set the historical stage in which the debate occurred.

Tariffs, as every economist knows, both raise revenues for government and alter relative prices against imported goods, making them a tool for the protection of domestic industry from foreign competition. In the United States before the American

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[16] Cournot is generally credited with being the first to draw supply and demand curves, although not to name them (Cournot 1838, 47 and 91; see also Blaug 1997, 189, 283, 301–306; and Wible and Hoover 2015). Humphrey (1992, 2010) provides a rich history of the development of supply and demand analysis.

Civil War (1861–1865), tariffs were the largest source of revenue to the relatively small Federal government. They were also a constant source of sectional frictions (see Irwin 2017, chs. 3–5 for a general account of U.S. trade policy in the periods immediately surrounding the Civil War.) Roughly speaking, the Democratic Party was the party of free trade; while the Whig Party and its successor, the Republican Party, were the parties of trade protection. While national in scope, the Democrats were dominated by the slave states of the South. As the source of America's most valuable export, cotton, and with relatively little industrial production to protect, the slave states found low tariffs to be advantageous and were generally happy to keep Federal revenues low and the Federal government small. In contrast, the Republican Party, which had formed after the collapse of the Whig Party in sectional disputes among its southern and northern members, was founded as an explicitly anti-slavery party and was committed to protection and to northern industrial interests.

The defeat of the southern Confederate States in 1865 temporarily left the Republicans and northern industrial interests with the upper hand. With the re-entry of southern states into the union and with the end of the period of Reconstruction, during which the South was significantly governed from Washington, the Democratic Party regained political clout and American politics were once again competitive (Irwin 2017, 236–249). The inclinations of the two parties, Democrats towards free trade and Republicans towards protection, remained; but each party's positions became more nuanced. Democrats picked up support in areas with industrial interests. To finance the war, revenues had been raised through higher tariffs and the introduction of the first American income tax. As the size of the Federal government, no longer swelled by a massive army, returned to near pre-Civil War levels, the Federal government enjoyed a massive budget surplus. Pressure mounted for tax and tariff reduction (Irwin 2017, 254ff). Republicans both wished to address popular demands for a realignment of revenues with expenditures and to retain the advantages of trade protection. And they faced the complexity of needing to garner some support from Democrats to secure their goals. Tariff policy again stood in the centre of the political stage.

Reciprocity treaties in which countries agreed to specific exchanges of tariff reduction provided the more nuanced instrument that Republicans hoped would satisfy demands for lower tariffs, while still protecting key industries. They were focussed on countries dominated by tropical agriculture, particularly on the Caribbean islands, which provided raw materials for industry, as well as goods such as "coffee, tea and other articles of universal use not produced" in the United States (President Ulysses S. Grant in 1870, quoted in Irwin 2017, 230). While the first reciprocity treaty was negotiated in 1876 with Hawaii – then an independent nation – the effort to promote such treaties gained steam, starting in the early 1880s. While moving in the direction of freer trade, reciprocity treaties also provided an opportunity to squeeze out Europe, and especially Great Britain, as the main supplier to manufactures to the tropical countries. They were, in the eyes of their advocates, "the safeguard of protection" (Irwin 2017, 303).

Starting in 1882, the U.S. government opened negotiations with Mexico, Santo Domingo, and Spain to establish commercial treaties with reciprocal trade agreements. Until the Treaty of Paris, which ended the Spanish-American War in 1898, Cuba and

Puerto Rico were Spanish colonies and the principal suppliers of sugar to the United States. The Republican president Chester Arthur observed in his fourth state-of-the-union address that "[t]he countries of the American continent and the adjacent islands are, for the United States, the natural mart of supply and demand" (quoted in Foster 1885, 55) A preliminary agreement, applying not to Spain itself, but only to Cuba and Puerto Rico, was signed in Madrid in January 1884, and negotiations were begun on a permanent treaty.[17] The commercial convention was agreed in November 1884 and transmitted to the Senate for ratification on 1 December 1884. It is a this point that Peirce's engagement begins.

3. Peirce and *The Nation*

The debate was a reaction to an editorial in *The Nation*, a periodical founded in 1865 and still published today, to which Peirce was a frequent contributor of book reviews. Although Peirce, who was committed to free trade, clearly favours the treaty, it is his positive, not normative, analysis that interests us. That analysis provides an example of Ricardian inference in practice. It is Ricardian inference under either interpretation of that term; for underlying Peirce's analysis is an application of Cournot's mathematical economics, with its reliance on the differential calculus, which is, Peirce tell us under-girded by the real-number analogue to mathematical induction; and it takes Cournot's supply-and-demand model as its paradigm and successively modifies it to address the issues raised by *The Nation's* editors in the rounds of the debate.

  The Nation, of course, was not an economics journal, and both its editors and Peirce frame the discussion in ordinary language, not in the formal apparatus of Ricardo's or Cournot's economics. Indeed, few readers would have been able to discern the economic framework that lay behind Peirce's intervention. We argue that, once one is aware of the analytical resources that Peirce brought to the policy question, then a rational reconstruction of Peirce's analysis apparatus drawn explicitly from Ricardo and Cournot fully captures the details of his argument. A reconstruction is necessary, precisely because the argument was conducted in a purely verbal form and in a public and not scientific discourse. Peirce's argument, as we will show was consistent with the scientific economics of the day, but was enthymematic – the details have to be filled in and it is not a simple transformation from the language of Ricardo and Cournot into a public discourse, but involved the *application* of Ricardo's and Cournot's tools to a specific political question. Moreover, the rational reconstruction of Peirce's analysis will clearly display a pattern of analogical reasoning, less momentous than, but following the same pattern as, the one that Peirce attributed to Kepler. The reconstruction does not in any material way distort history; for, once it is on the table, the connection of Peirce's reasoning to Ricardo's and Cournot's is transparent to the most casual observer, and the underlying invocation of calculus and the doctrine of infinitesimals is remarked on explicitly by his interlocutor at *The Nation.*

  The Nation in the 1880s, just as in the twenty-first century, was an organ of "liberal" opinion, although the nature of liberalism has changed radically over a century and a

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[17] See Willis (1903) and United States Tariff Commission (1919) for further discussion of the treaty in its wider context.

quarter.[18] Liberals of the 1880s were acolytes of free trade. On this point – as a general proposition – Peirce and the editors of *The Nation* were in complete agreement. Yet, President Arthur's commercial treaties, including the Spanish Treaty, were "very widely objected to as being hopelessly objectionable in their details, even by those who consider the principle of them sound" (Foster 1885, 55). The New York Free Trade Club published a report entitled "The Spanish Treaty Opposed to Tariff Reform" (Foster 1885, 55). On 11 December 1884, *The Nation* weighed in against:

> If we are unable to approve of the treaty in its present shape, or in any shape in which it is likely to be presented, we are moved by no prejudice against reciprocity in general, or against the author [Minister John W. Foster] of the important negotiation now before the Senate. [*The Nation* 1884a, 491][19]

The bare facts of the trade, according to *The Nation* (1884a), were these: Cuba and Puerto Rico together supplied something more than half of the 2300 million pounds of sugar imported into the United States with a value of $91 million dollars.[20] The import duties on the sugar from the two islands raised between $20 and $25 million for the U.S. Treasury. The treaty sought to remove the tariff (about 2¢ per pound) on Cuban and Puerto Rican sugar in exchange for duty-free status for some American agricultural and manufacturing exports – many others remaining subject to substantial Spanish duties.

4. The debate

4.1. Round one

The Nation judged that the exchange of tariff relief was not symmetrical or fair: "What the treaty amounts to is a scheme to purchase a small market in the West Indies at a present cost of $20,000,000 per annum and at a growing cost hereafter … ," which was too high a price to be regarded as wise policy. The central rationale behind *The Nation*'s objection to the treaty was their conclusion that, with respect to sugar itself, American consumers would reap no benefit whatsoever and that the benefits to increased exports of other goods were too small to offset the direct losses of sugar duties: "If so large a sacrifice of revenue is to be made by the Treasury, surely the consumers of sugar ought to reap a share of the benefit." The key to their analysis is the following positive claim:

> Sugar cannot be cheaper to American consumers so long as any portion of our supply comes from countries paying the tax. The Cuban planters will simply pocket the duty

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[18] Politically, "liberal" in nineteenth century America referred to adherents to the line of thought that can be identified with advocates of both personal liberty, going back, for example, to John Locke in seventeenth century England and with *laissez faire* political economy, going back to Adam Smith. "Liberal" in today's American politics more typically refers to the social democratic and "progressive" views that focus on minority rights and distributive equity. As the meaning of "liberal" changed, so did the political orientations of both the Democratic Party and *The Nation*, so that they are can be consistently labeled as liberal, despite the change in the nature of liberalism.

[19] *The Writings of Charles S. Peirce* (WP 5.144–148) reprint Peirce's exchange with the editors of *The Nation*, beginning with his first reply, but they do not reprint the original article that prompted the first reply.

[20] Converted to 2019 dollars using the consumer price index (CPI), this is the equivalent of $2.45 billion. Sugar was a relatively more important part of consumption bundles in 1884. An equivalent share of per capita GDP would amount $27.8 billion.

which would otherwise go into the Treasury of the United States. If an appropriation of $20,000,000 per annum were made by law as a bonus to the Cuban planters, the effect would be the same.

It is this analysis that Peirce would challenge in a letter to the editor the next week (Peirce 1884; WP 5.144).

Peirce's objected to *The Nation's* claim that the consumers would not reap any benefit from the cut in tariffs on Cuban and Puerto Rican sugar so long as sugar was also imported from other countries that paid the full tariff. He poses three questions for the editors:

- First, given the profit advantage that they claim would accrue to the "Spanish ports" (i.e., the ports of Cuba and Puerto Rico), he asks would they not immediately increase their exports to the United States, even to the point of importing sugar from other countries for re-export?
- Second, would these additional exports of sugar not inevitably either a) reduce the price of sugar in the United States or b) displace sugar imported from countries without a tariff advantage?
- Third, if sugar exports were reduced from non-Spanish ports would not the land removed from sugar production be the "worst fitted" for sugar production leaving the "worst of the land then producing sugar for us … better than the worst of the land now doing so?" And would not, then, competition force the price to fall as a result?

4.2. Peirce's first model

Peirce's interrogatory analysis is readily reconstructed in using Ricardo's analysis of differential rent and Cournot's supply-and-demand paradigm.[21] The textbook analysis that follows is commonplace in the twenty-first century, but would have been cutting-edge in 1884. Peirce conceptualises the situation with as simple an analytical framework as will address the questions. Let us assume that there are two sugar suppliers, call them Cuba, standing for itself and Puerto Rico, and Manila, the capital of the Philippines. (The Philippines was another Spanish sugar-exporting colony, but one not subject to the reciprocity treaty.) Furthermore, suppose that there are no domestic American sugar producers. (In fact, as becomes noted in the exchange, Louisiana is at this time a minor sugar producer.) And suppose that Cuba and Manila produce only for export and export exclusively to the United States.

The left-hand panel of Figure 1 plots production exported through Manila as a function of the gross price (inclusive of the tariff) of sugar in the United States. The supply

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[21] A referee queried the lack of any attention to general-equilibrium effects of a tariff reduction. In fact, the issues were not framed in either the exchange between Peirce and the editor of *The Nation* in a way that even implicitly raised questions of general-equilibrium effects. In the wider discussion at the time, the focus was almost exclusively on questions of government revenue, the price of sugar to consumers, and, to a smaller degree than most tariff issues, to protection of American producers. Cournot (1838, chs. XI and XII) does address the issue of "social income," which he defines essentially in the way that modern national accounting defines gross national income, as the sum of all wages, profits, and rents (p. 128). But he also notes that taking "the entire economic system into consideration . . . would surpass the powers of mathematical analysis and of our practical methods of calculation . . ." (p. 127).
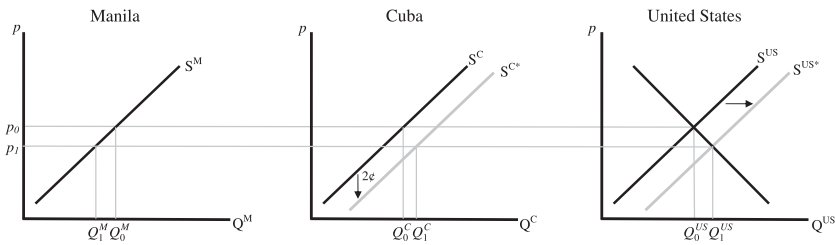
Figure 1. Peirce's First Model of Tariff Reduction.

curve (S^M) is upward sloping to reflect Peirce's fundamentally Ricardian assumption that land comes in qualities ranked from best to worst, in which the output of the best land will cover wages and profits at the lowest price, while each less productive unit of land can be brought into production only at a higher price adequate to cover the higher per unit costs of production.[22] The black supply curve (S^C) in the centre panel reflects the same situation in Cuba. Manila and Cuba are shown to have about the same supply curves, so that they divide the American market nearly equally, reflecting the *status quo ante* as reported by *The Nation*. The right-hand panel reflects both supply and demand in the American market. The black supply curve (S^{US}) is the horizontal sum of the black supply curves for Manila and Cuba ($S^M + S^C$).

The American market is completed by moving past Ricardo to introduce Cournot's downward-sloping demand curve (D^{US}). Equilibrium in the American market occurs at the point (Q_0^{US}, p_0). At price p_0, the market is divided between Manila, producing Q_0^M, and Cuba, Q_0^C. Of course $Q_0^{US} = Q_0^M + Q_0^C$.

Peirce's three questions are answered by considering the effect of a reduction in the tariff on Cuban sugar. After the reduction, the producer will make the same revenue net of the tariff at each level of production at a 2¢ lower price, which corresponds to a downward parallel shift of the Cuban supply curve to the grey curve (S^{C*}). This results in an additional willingness to supply sugar to the United States at each gross price, resulting in a rightward shift of the U.S. supply curve to the grey curve (S^{US*}) and a movement of the equilibrium down and to the right to point (Q_1^{US}, p_1). Each of the implied answers to Peirce's rhetorical questions are affirmed;

- First, at the new price p_1, Cuban exports increase. (The model in this form does not address the question of re-export.)
- Second, the new price is indeed lower, so demand in the United States increases; and, at the lower price, supply from Manila decreases, so that sugar from Cuba has, in fact, displaced sugar from Manila.
- Third, since the supply curve rank-orders the productivity of the land from best at the bottom left to worst at the top right, the reduced supply from Manila implies

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[22] Following Ricardo, Peirce recognizes two distinct, but logically similar margins. Here, he refers to what modern economists refer to as the *extensive margin* – that is, to the increasingly smaller output that arises from bringing intrinsically and increasingly worse land into production. Elsewhere, he also refers to the *intensive margin* – that is, to the increasingly smaller additions to output that result from the increasing use of inputs (labor, fertilizer, etc.). (See CP 4.115; Ricardo 1821[1951], pp. 70–72).

that the worst land in production for export from Manila after the tariff cut is bet-
ter than the worst land in production before the tariff cut.

4.3. Round two

Given Peirce's understanding of the Analytical Method, we are justified in employing
an anachronistic terminology and referring to his initial analysis of the tariff as his
First Model. It serves a similar function to Kepler's "vicarious theory," as a simple case
that captures the main phenomenon in question and that can serve as a stepping-stone
to additional refinements, should they be necessary. And necessary it proved to be:
hard on the heels of Peirce's intervention in the same number of the magazine, the the
editor of *The Nation* delivered a reply (*The Nation* 1884b; WP 5.144–146).

The editor argued, first, that sugar must have the same price in the New York mar-
ket, no matter its conditions of production. Second, that the planter in Manila and
Cuba would both, therefore, receive the same revenue per pound, but the planter in
Manila would have to cover the tariff out of that revenue while the planter in Cuba
would not; but, in any case, the revenue would have to be high enough to cover the
costs of the planter in Manila or else he simply would not ship sugar to New York at
all. Third, if Cuba could supply all of the U.S. market and something more besides (i.e.,
if the Manila planters were shut out of the market by the price advantage of Cuban
planters), then competition among Cuban planters would drive the price of sugar
down in the New York market. But in the case in which Cuba were unable to supply
the whole market, then the balance of the imports must come from Manila (or other
markets), and the price must be high enough to cover the tariff (or the sugar would
not come at all). In that circumstance, the Cuban planters would feel no pressure to
lower their prices and would pocket the full value of the tariff cut.

The editor then considers the actual situation in the U.S. markets. Some have sug-
gested that Cuba and Puerto Rico together could supply the whole U.S. market. But, he
argues, even if that were possible in 1884, the demand for sugar in the U.S. was grow-
ing rapidly and the available land in Cuba and Puerto Rico was finite, so that it would
be unlikely that Cuba and Puerto Rico could monopolise the U.S. market, even in the
near future. And in that circumstance, some sugar paying the tariff would be imported
from Manila and other producers, "which would, by virtue of the economic law already
stated, be the sign and evidence that American consumers were deriving no benefit
from the treaty."[23]

The editor answers Peirce's third question by claiming that the considerations that it
raises presume that the U.S. is the only export market for producers other than Cuba
and Puerto Rico, so that lost demand translates into the idling of some land of inferior
productivity and, therefore, raising the quality of the land at the margin of profitability,
which is tantamount to lowering the costs of production at the margin. But, say the
editors, in reality sugar is exported to other countries; Manila and other producers shut

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[23] The editor also answers Peirce's re-export argument by pointing out that tariff relief applies only to sugar
actually grown in Puerto Rico or Cuba. He acknowledges that Cubans could export the full amount of their
own domestic consumption, replacing it by imported sugar for their own use; but, since their domestic mar-
ket is small, that would add little to their duty-free export capacity. He also acknowledges, but minimizes, the
possibility of cheating on re-export.

out of American markets would simply increase their exports to England and other markets, so that no increase of productivity and no reduction in costs would occur.

A fortnight later, *The Nation* published Peirce's rejoinder to the editor's reply (Peirce 1885). The editor's argument, he noted, required that the tariff reduction result in an increase in exports from Cuba and Puerto Rico to the U.S. and a corresponding decrease from other countries completely offset by increased exports from those countries to other sugar importers, such as England. "But now I object," says Peirce, "that a great volume of trade will not spontaneously divert itself from one market to another without any motive." The relative price of sugar must change among importing countries if sugar is to be diverted from one market to another. If, as the editor had argued, the price will not fall in the United States, then it must rise in England; and, if it rises in England, then demand must fall in England, so that the amount of sugar exported from the countries other than Cuba and Puerto Rico would have to fall to some degree. Production would be diminished accordingly, and "somebody [would be] forced out of the sugar-growing business." That could not happen if no prices in any market had fallen.

Peirce poses a dilemma. The first horn: if sugar is diverted from the U.S. market to England, owing to relative price changes, then either prices received by producers, must either be higher in England or lower in the U.S. A non-U.S. producer receiving a lower price would reduce sales to the U.S. and, therefore, reduce production. The same producer could secure higher prices in England only by reducing production somewhat. Either way, the selective tariff reduction a reduction in their supply as inferior land is taken out of production; so, contrary to the editor's assumption, the full volume of their previous exports of sugar to the U.S. is not simply redirected to England. Second horn: if no prices change, then no sugar is diverted, as non-U.S. producers do not face any change in demand, and Peirce's original argument applies. Peirce asks, "How can you escape this dilemma?"

In the second paragraph of his letter to the editor, Peirce elaborates on the analytical foundation of his argument. He notes that sugar from countries other than Puerto Rico and Cuba are produced under a variety of conditions – some barely paying the cost of production, some highly profitable; some more profitable if sent to the United States than to England, some equally profitable to whichever market it is sent. If the proposed tariff reduction were to decrease the amount of sugar from these countries sent to the United States, the particular producers who would cease to ship to the United States would be those who are at the margin of profitability (i.e., those producers of sugar "which there is now scarce any inducement to ship here"). On *The Nation*'s own analysis, the diversion of this higher priced sugar would remove the rationale for keeping U.S. prices high. Peirce's point is that *The Nation* maintains that, if any non-tariff-advantaged producer is willing to ship to the United States, the price in the United States must cover all the costs, including the cost of the tariff. To which he says, yes, but that is true for the marginal unit shipped, for the unit for which the producer is indifferent whether he sends it or not. All the other producers – the ones with higher productivity whether in Cuba, Puerto Rico, or Manila – collect a Ricardian rent but do not affect the price, which is determined only by this point of indifference. Peirce writes:

> If now the treaty should cause less of this non-Spanish sugar [i.e., non-Cuban, non-Puerto Rican sugar] to be sent to this country, that which would be diverted would clearly be that which there is scare any inducement to send here. [Peirce 1885]

In Ricardian terms, the diverted sugar is that produced on land that is less productive than the land that pays no rent.

4.3. Peirce's second model

What is interesting for our purposes is Peirce's dialectical strategy. His first letter offered an excellent example of his Analytical Method: a complex issue in international trade was reduced to a problem "much simpler, much more abstract," for which a clear cut solution was possible, and Peirce suggested that it threw all the necessary light on the issue raised by *The Nation*. Our diagrammatic reconstruction was completely true to Peirce's verbal account and used no formal resources beyond those that he had mastered in his study of Ricardo and Cournot. Then *The Nation* raised the stakes, claiming that additional real-world complexities vitiated the salience of Peirce's implicit analogical model. The complications pointed out were not abstruse data, but were genuine empirical features of the world – particularly, the facts that the United States was not the only market for sugar in the world. We want to suggest that Peirce's response to the editor's new challenge was very much of the same nature as Kepler's successive abductions leading to his planetary laws. Just as Kepler invoked the prepotency of the sun to enrich the dynamics of the planetary system, Peirce proposes to exploit geographic comparative advantage – the idea that each producer may be especially well situated relative to different producers. We can reconstruct Peirce's analysis in a Second Model.[24]

Again, consider two producers – Cuba, standing for Puerto Rico as well as itself, and Manila, standing for producers not favoured under the proposed treaty. The editor implies that, while Cuba and Manila, supply the United States, Manila is especially well suited to supply England exclusively. Tariffs in this respect include not only literal duties, but also any cost associated with bringing the sugar from a producer to a market.[25] The problem of the optimal allocation of production from multiple producers to multiple consumers in markets in which each producer faces different costs of marketing with respect to each consumer is a relatively complex one, involving two interrelated but distinct decisions: First, for any producer A, should it sell only to consumer α or only to consumer β or to both? Second, conditional on producer A selling to a consumer, how much should it sell? It is a constrained optimisation problem with possible corner solutions. Fortunately, for a diagrammatic analysis, we can follow Peirce's hint to focus on the situation in which a producer is at the point of indifference as to whether it ships to a market or not.

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[24] Cournot's (1838), Chapter X. Of the Communication of Markets, is not referred to directly in Peirce's extant writings on Cournot, but would be relevant to his Second Model.

[25] Elsewhere, Peirce gives an analysis of the effect of a change of import duties on the price of consumer goods: "we must understand by the *duty*, not merely what goes to the government, but what has to be paid in consequence to brokers, bankers, and increased expenses of all kinds caused by the change in the law" (CP 4.115); cf. Cournot (1838), 117.
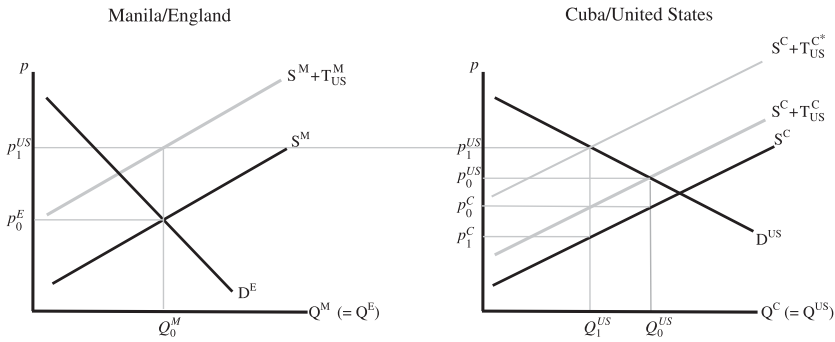
Figure 2. Peirce's Second Model of Tariff Reduction.

In general, each producer will ship to the market to which it is most favourably situated, and will ship to the second market only if the price in that market rises enough to overcome the differential costs of the tariff. Consider, first, the situation shown in Figure 2 in which Manila ships exclusively to England. Let us assume for simplicity (and without loss of generality) that the English impose no tariff on sugar from Manila. We can, then, put the supply curve for sugar from Manila (the black curve S^M) in the same left-hand panel as the demand curve for England (D^E). Similarly, assume that Cuba ships exclusively to the United States, but that Cuba faces a tariff. The supply curve for Cuba is the black curve in the right-hand panel (S^C) and the grey curve ($S^C + T_{US}^C$) plots the supply price to the consumer in the United States equal to the producer's supply price plus the tariff. The gap between the two parallel curves corresponds to the size of the tariff. Initially, the two markets are disjoint with the equilibrium between Manila and England at point (Q_0^M, p_0^E) and equilibrium between Cuba and the United States at point (Q_0^{US}, p_0^{US}). The after-tariff price received by Cuban producers is p_0^C.

When will Manila wish to ship sugar to the United States, which corresponds the actual situation in 1884? It is less advantageously placed than Cuba, which is reflected by the grey curve in the left-hand panel ($S^M + T_{US}^M$), in which the gap between it and the parallel supply curve (S^M) indicates the U.S. tariff on sugar from Manila. It will want to enter the U.S. market only if the price that it receives for its sugar in the U.S. covers its cost of production plus the tariff. The point (Q_0^M, p_1^{US}) is the point of indifference at which an infinitesimal quantity of sugar could be equally well shipped from Manila to the U.S. or to England. At any price below p_1^{US}, Manila would not earn enough to overcome the disincentive of the tariff. At any point above p_1^{US}, it would want to divide its production between the two countries (a problem that would require a new set of diagrams to represent adequately). At the initial equilibrium, with the price in the U.S. market $p_0^{US} < p_1^{US}$, the markets are disjoint. If the tariff on Cuba is raised so that the grey curve ($S^C + T_{US}^C$) shifts vertically to become the thin grey curve ($S^C + T_{US}^{C*}$), the price rises to p_1^{US}, and the two markets are at equilibrium at exactly the point at which Manila is indifferent to joining the U.S. market. Any tariff higher than this corresponds to the situation at the time at which the Spanish Treaty was negotiated.

Imagine that the tariff on Cuban sugar is initially well above p_1^{US}. Because Manila would be shipping sugar to the United States, we cannot describe the equilibrium completely with these diagrams, which assume disjoint markets. What is clear, however, is that any small cut in the Cuban tariff, will result in it selling more sugar to the United States at a lower price. This was Peirce's conclusion from his simpler model in Figure 1, and it carries over here, because it depends only on the downward-sloping demand curve for the United States, which is unaffected by the disjointness of markets. But once the price reaches p_1^{US}, any further fall results not only in further cuts to price but in a shutdown of the trade in sugar between the Manila and the U.S. The collapse in U.S. demand for sugar from Manila also cannot be shown accurately on Figure 2, but it amounts to a leftward shift of the total demand curve (English plus American demand), and must result in a fall in both output and price as the markets, previously integrated into a world market, disintegrate into the two disjoint markets shown in Figure 2, and the equilibrium moves down the supply curve (S^M) to the equilibrium at point (Q_0^M, p_0^E). Exactly as Peirce claimed, the lower output corresponds, by the construction of the supply curve, to a higher productivity for the marginal producer trading through Manila than does the higher output. And as Peirce also asserted, none of the supply or demand shifts is possible without changes in prices altering the relative "inducements" to ship to one country or another, and some producers in Manila – ones with the relatively less productive land – are forced out of the sugar-growing business.

4.4. Round three

In his rejoinder, Peirce had offered a challenge for the editor of The Nation: "How can you escape this dilemma?" The editor of The Nation (1885) replied, "We 'escape this dilemma' by the use of infinitesimals." He concedes that, yes, Peirce is right that the price would have to fall in the United States in order to justify additional demand for Cuban sugar. But he says, a tiny fall ($1/32^{nd}$ of a cent per pound) "or even less" would be sufficient to secure the entire American market, and this tiny fall would be the outer limit of the price fall that would be observed. The editor pulls the number out of thin air and implies that the demand curve for sugar in the United States turns horizontal (becomes infinitely elastic) at a price ever so slightly below the current price – not impossible, but not grounded in any evidence or argument.

The editor failed to address the major point of the second paragraph of Peirce's intervention, which is to reassert the lesson from the Ricardo's theory of rent, that land will be drawn into production in order of its productivity and that costs of production, including cost such as tariffs and transportation, are related to price only for the marginal land. The editor acknowledges his failure: "Mr. Peirce's second paragraph, he will permit us to say, carries us into the region of differential calculus beyond our depth." "Quite so," Peirce might have, but did not, reply – the correspondence ended with the editor's having the last word and using that last word to resolve the dispute in his own favour with the introduction deus ex machina of an unsupported factual claim.

5. Epilogue

The debate over the Spanish Treaty was one of the vital political issues of the early 1880s – not on as large a scale, though inspiring the same sorts of arguments, as the debate over the North American Free Trade Agreement (NAFTA) in the early 1990s and, again, in the 2016 American presidential campaign and through Donald Trump's administration. The letter to the editor of *The Nation* that immediately proceeded Peirce's first letter foreshadowed Ross Perot's charge during the 1992 U.S. presidential election that the "giant sucking sound" we would hear after ratification of NAFTA would be U.S. jobs flowing to Mexico. The correspondent identified only by the initials T.E.C summarised the net effects of the treaty: "In other words, we are asked to pay the Cubans $30,000,000 for the privilege of making not over $5,000,000" (T.E.C. 1884). The correspondent goes on to question the negotiator's loyalty and his education, as well as his patriotism: "Really, Mr. Editor, is Mr. [John W.] Foster a Yankee? Did he ever learn to *kalkerlate*?" *The Nation* itself was an important player in the debate (see Foster 1885, 55). Peirce had tried to bring scientific political economy to bear on a key problem in public policy, but, in the end, to no avail: Grover Cleveland was elected president in November 1884 – the first Democrat to hold that office since the Civil War – and one of his first acts on his inauguration in March 1885 was to withdraw the Spanish Treaty.

Despite a clear victory in the battle over economic analysis, Peirce had backed the losing side in the immediate political argument. Echoing *The Nation's* editor: In his message to Congress, withdrawing the treaty, Cleveland took the proposed reduction in the duty on sugar as a synecdoche for the reciprocity treaty as a whole:

> Upon sugar alone duties were surrendered to an amount far exceeding all the advantages offering exchange. Even were it intended to relieve consumers, it was evident that, so long as the exemption but partially covered our importation, such relief would be illusory. [Cleveland 1885 quoted in United States Tariff Commission 1919, 141]

Seven years later, the editor's dig at the application of the differential calculus to political economy still rankled Peirce:

> Some newspapers maintain that all doctrines involving [the differential calculus] ought to be struck out of political economy because that science is of no service unless everybody, or the great majority of voters, individually comprehend it and assent to its reasonings. [CP 4.114][26]

Naturally, Peirce found such arguments no more persuasive with respect to economics than he did with respect to mathematics or any other science. "But whether people be wise or foolish," he concluded, "it remains that there is no possible way of establishing the true doctrines of political economy except by the reasonings about *limits*, that is, reasoning essentially the same as that of the differential calculus" (CP4.114).

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[26] Peirce goes on to name the newspaper in mind as the *New York Post.* But the reference is almost certainly to *The Nation*, which the *Post* had purchased in 1881 and which served as the *Post's* weekly literary supplement. He packages his disagreement in fulsome praise of the newspaper in general. It is unclear whether Peirce is sincere, satirical, or venal: he earned essential income from writing for the *Nation*, as well as other periodicals.

Peirce's debate with the editor of *The Nation* remains of interest, partly because it reflects the sophistication of his grasp of the economics of his day, being an exceptionally trenchant example of economic analysis. His audience was a popular one, but the ease with which his argument is reconstructed using the early marginal analysis of Ricardo and the more formal apparatus of Cournot, suggests an integration of abstract economic theory with real-world policy concerns uncommon in the economic science of the nineteenth century. And it provides a compelling case study of analogy (or, as we might say today, modelling) as a scientific mode of inference, displaying Peirce's readiness to see economics as a discipline, different in its scope and precision, but no less scientific and using essentially the same logic as physics, chemistry, and biology.

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