



THE JEVONIAN REVOLUTION IN INTERNATIONAL TRADE THEORY

BY
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I. INTRODUCTION

There was no Jevonian revolution in international trade theory. The new ideas of marginal analysis entering British economics in the late nineteenth century seem to have left the field untouched. According to Schumpeter (1954, p. 609), Marshall “did not do more than polish and develop Mill’s meaning ... Edgeworth’s famous restatement added many interesting details but also did not go beyond Mill in fundamentals.”

Why was there no progress in “fundamentals” until much later—until the 1930s? Progress in fundamentals would have involved the application of marginal analysis to international trade and the integration of the new analysis with what was valid in the old. Both these developments took place between 1870 and 1900. However, they had little impact because they were not parts of a single cumulative movement but essentially separate developments.

W. S. Jevons (1835–82) was responsible for the first development. Trade was so important in English political economy that the presence of trade theory in the *Theory of Political Economy* is hardly remarkable. It is remarkable and requiring explanation that trade writers hardly noticed it and historians do not mention it.¹ Jevons not only discussed trade for the sake of completeness, he held strong convictions on trade policy and used the theory of exchange to support them. As in the aggregative neoclassical analysis of the 1930s, international trade was conceived as exchange between countries, each with its own preferences and production possibilities. Jevons developed marginal conditions for consumption and production and extended the theory of comparative advantage in a way that did not become established in the literature until the 1930s.²

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¹ Viner (1937) and Chipman (1965) mention some minor contributions from the *Theory*; Caves (1960) refers only to the *Coal Question*. The tradition is maintained in Gomes’s (1990) recent history. Peart’s (1996) book on Jevons covers the trade theory material without relating it to the trade literature.

² Maneschi and Thweatt (1987) describe Barone’s use in 1908 of community indifference curves in conjunction with the production possibility curve. The Barone construction is quite Jevonian in that production is by labor alone and a country is composed of workers with identical tastes.

F. Y. Edgeworth (1845–1926) was responsible for the second development.³ His higher-level theorizing to which Schumpeter referred was based on methods devised by Mill and Marshall. Even so, his development of their methods, such as the use of indifference curves, relied on the new utility ideas. Edgeworth (1887, p. 356) found the classical theory incomplete, complaining that it was “as if an astronomer should content himself with the proposition, ‘Planets move in ellipses,’ without ascending to the first principles of dynamics.”

The paper describes the “revolutionary” work of Jevons and Edgeworth and tries to explain why there was no revolution. Section II examines Jevons’s analysis of exchange in relation to international trade and Section III the united analysis of production and exchange. Section IV treats Edgeworth’s “ascent” to first principles, i.e., to Jevons’s theory of exchange. Section V contrasts Edgeworth’s approach to commercial policy with Jevons’s. Section VI considers how they treated the relationship of the theories of international and domestic values. Finally, there is some speculation about why all this did not add up to a Jevonian revolution.

II. JEVONS ON EXCHANGE

The two chapters of the *Theory* dealing with exchange and with labor will be treated in this section and the next. The first gives the marginal conditions for a pure exchange economy while the second gives conditions for a production economy with one factor—labor. I will describe only enough of Jevons’s basic theory to support the applications to foreign trade; there is a fuller treatment of the theory of exchange in Creedy (1992, chapter 9).

The transactors in Jevons’s theory are “trading bodies” who (or which) are both buyers and sellers—in the theory of labor they are producers too. These transactors are not like those of Mill’s theory of domestic values where the sellers are producers and the demanders consumers, but they resemble the countries of his theory of international values. Indeed, Jevons had first used “trading bodies” in the *Coal Question* to refer to countries or groups of countries. A passage from the *Theory* explains the extended meaning and argues for its naturalness:

By a trading body I mean, in the most general manner, any body either of buyers and sellers. The trading body may be a single individual in one case; it may be the whole inhabitants of a continent in another I use the expression with this very wide meaning, because the principles of exchange, are the same in nature, however wide or narrow may be the market concerned. Every trading body is either an individual or an aggregate of individuals, and the law in the case of the aggregate, must depend upon the fulfilment of law in the individuals (1871/1970, p. 88/135).⁴

Trading bodies figure in both the positive and normative analysis. They possess

³ His trade theory is treated in the standard works referred to in Note 1. There is also a brief account in Creedy’s (1986) study of Edgeworth.

⁴ The first page number refers to the first (1871) edition of the *Theory* and the second to Black’s 1970 version of the second (1879) edition. The wording follows the first edition.

utility functions though Jevons did not explain how the trading body's utility function is generated from the utility functions of the persons making up the trading body—indeed he (*ibid.*, p. 21/85) argued that interpersonal comparison of utilities is impossible!⁵ Contemporaries criticized both the notion of a trading body and the assumption that—whatever its character—it could always be treated as a *price-taker*. The criticism of the notion in Marshall's *Principles* (1890, p. 534) was particularly effective, and the notion disappeared from domestic value theory although in international theory it has played a role in such forms as community indifference curves. The assumption of price taking was criticized by Fleeming Jenkin and it took some special pleading from Edgeworth—see Section IV below—to save Jevons's view that the principles of exchange, are the “same in nature,” whatever the character of the trading bodies concerned.

In laying out Jevons's arguments I have kept to his formulations and notation but have made some additions. Jevons just writes down marginal conditions; for the sake of clarity I have given the implicit maximization problem. Naturally Jevons had no symbols for total utility and disutility: he uses lower case letters for marginal (final) quantities and I will use the upper case letter for the corresponding total quantity.

The basic exchange situation envisages two trading bodies, A and B, exchanging corn and beef. A starts with a units of corn and B with b units of beef. After exchange, A has $a - x$ units of corn and y of beef while B has x of corn and $b - y$ of beef.

The first trading body chooses x and y to maximize the additive utility function

$$\Phi_1(a - x) + \Psi_1(y),$$

subject to $y = mx$ where m is fixed.

The second trading body has a similar problem. According to Jevons, the “law of indifference,” stating that all units of corn and beef exchange at the same rate, together with utility maximization entail that the quantities exchanged satisfy the equations

$$\frac{\phi_1(a - x)}{\psi_1(y)} = \frac{y}{x} = \frac{\phi_2(x)}{\psi_2(b - y)}, \quad (1)$$

where ϕ_1 is the marginal utility of corn for the first body, ψ_1 is the marginal utility of beef for the second body, etc. (1871/1920, p. 100/142).

Jevons was a lifelong Free Trader. As a twenty-one year old he wrote to the *Sydney Empire* on the “exploded subject” of Protection and criticized the “sophistry” of its supporters (Black 1973, p. 281).⁶ In 1866 he told an audience of primary school teachers that the introduction of Protection would be the “one great disaster almost the greatest that I can figure to myself” (Black 1981, p. 43). Cairnes remarked in 1870 (see Hutchison 1978, p. 95) that political economy

⁵ See the discussion in Black's introduction to Jevons's *Theory* (1970, pp. 20–24).

⁶ Goodwin (1966) surveys the Australian Protectionist debate of the 1850s. White (1982) reviews Jevons's Australian writings and the features of his mature outlook to be found in these works.

was “very generally regarded as a sort of scientific rendering” of the *laissez faire* maxim. Jevons’s *Theory* comes close to being such a “scientific rendering.” Perfect freedom of exchange is “to the advantage of all” because “no one is ever required to give what he more desires for what he less desires” (1871/1920, p. 134/171). It is true that this conclusion is qualified by the condition that “so far as is consistent with the inequality of wealth” but the qualification is not emphasized. In a passage on methodology added to the second edition of the *Theory* (1879, p. 88), he wrote that “the beneficent results of Free Trade are great and unquestionable” and are to be believed “because deductive reasoning from premises of almost certain truth leads us confidently to expect such results, and there is nothing in experience which in the least conflicts with our expectations.”

Jevons was determined that protectionist sophistry got no aid from the writings of economists. In *The Coal Question* (1865, p. 432), he noted that the infant industry argument was being abused by colonial manufacturers: “Mr. Mill can hardly know the evil which his words are working, misapplied and distorted in meaning, as they are for interested purposes.” In the *Theory* he criticized Mill himself. In his catalogue of the “supposed conclusions of the science” (1871/1970, p. vii/44) one was of a “less harmless” character—Mill’s analysis of the gain from exchange. Jevons thought there was a fundamental flaw in Mill’s analysis of the possible advantage in manipulating the terms of trade. He objected that Mill confuses “two distinct things—the price of a commodity and its total utility ... in estimating the benefit which a consumer derives from a commodity, it is the total utility which must be taken as the measure, not the final degree of utility on which the terms of exchange depend” (*ibid.*, p. 136/172).

Jevons estimates the gain to Australia from exporting so much wool in exchange for European manufactures by the difference between the utility loss to Australia on the wool and its utility gain on the manufactures. However, he was “inclined” to reverse Mill’s view and argue instead that “the greatness of the price ... measures the greatness of the benefit.” As Viner (1937, p. 558) observes, the plausibility of this proposition “derives from the very defect of analysis which he had charged against Mill, namely, disregard of the total utility aspects of the problem.”

Jevons argued that Mill’s error vitiated the whole of his analysis of the possible advantage of manipulating the terms of trade:

The fact that we can most imperfectly estimate the total utility of any one commodity should prevent our attempting to measure the benefit of any trade. Accordingly, when Mr. Mill proceeds from his theory of international trade to that of taxation, and arrives at the conclusion that one nation may, by means of taxes on commodities imported, “appropriate to itself at the expense of foreigners, a larger share than would otherwise belong to it of the increase in the general productiveness of the labour and capital of the world,” I venture to entirely question the truth of his results. I conceive that his arguments involve a confusion between the ratio of exchange and the total utility of a commodity, and a far more accurate knowledge of commercial laws than any one yet possesses would be required to estimate the true effect of any tax (1871/1970, p. 139/173).

Jevons (*ibid.*, p. 139/174) considered that the “time is past when any economist should give the slightest countenance to [the employment of customs duties] for manipulating trade, or interfering with the natural tendency of exchange to increase utility.”

Jevons’s criticism of Mill’s analysis of the gain from exchange was noticed, but his discussion of trade in the context of the exchange model went beyond this one point. He systematically applied his marginal conditions to international trade. First we consider the analysis of “a very small country trading with a very much larger one.” The country is large in the sense that it holds large quantities of both the traded goods. In this case the exchange ratio is imposed upon the smaller partner.

The first country, the large one, holds stocks a and b of x and y respectively. The equation of exchange is given by:

$$\frac{\phi_1(a-x)}{\psi_1(b+y)} = \frac{y}{x} = \frac{\phi_2(x)}{\psi_2(c-y)}. \quad (2)$$

Since $a-x$ and $b+y$ are approximately the same as a and b , the ratio of exchange m is determined by the conditions of the large country. The equations can be rewritten (*ibid.*, p. 111/151):

$$\frac{\phi_1(a)}{\psi_1(b)} = m = \frac{\phi_2(x)}{\psi_2(c-mx)}. \quad (3)$$

In the section on “impediments to exchange,” Jevons adapts the basic exchange argument to the case of transport costs, customs duties, etc.: “In whatever mode the charges are payable, they may be conceived as paid by the surrender on importation of a certain fraction of the commodity received; for the amount of the charges will almost always be proportional to the quantity of goods, and if expressed in money, can be considered as turned into commodity” (p. *ibid.*, 104/147). This procedure lives on as Samuelson’s “iceberg” assumption.

If A gives x , this is not the quantity received by B who receives only a part, mx —not the same m as in (2.3). For B the optimal exchange becomes:

$$\frac{y}{mx} = \frac{\phi_2(mx)}{\psi_2(b-y)}. \quad (4)$$

Similarly A receives only ny so that the equations of exchange become:

$$\frac{\phi_1(a-x)}{\psi_1(ny)} = \frac{ny}{x}. \quad (5)$$

So the new equations of exchange are (*ibid.*, p. 105/148):

$$\frac{\phi_1(a-x)}{n\psi_1(ny)} = \frac{y}{x} = \frac{m\phi_2(mx)}{\psi_2(b-y)}. \quad (6)$$

Jevons comments on equations (2.4) and (2.5): “The result is that there is not one ratio of exchange, but two ratios; and the more these differ, the less advantage, there will be in exchange. It is obvious that A has either to remain satisfied with less of the second commodity than before, or has to give more of his own in purchasing it” (*ibid.*, p. 105/148).

His equations did not enable him to see that a large country could manipulate the terms of trade in its favor. His “obvious” point fitted his views that exchange was to the advantage of all and that Mill’s argument confused total and final utility.

These are the international adventures of Jevons’s pure exchange theory. The pure exchange model never played more than a limited role in international trade theory: Pigou’s (1932) essay on the transfer problem was perhaps its finest hour. In Jevons’s work it is the only model used for analyzing commercial policy, for the production model is confined to treating the pattern and terms of trade.

III. JEVONS ON LABOR AND EXCHANGE

Jevons’s analysis of exchange became well known—or at least its basic point did. The same is not true of his “Theory of Labour.” His argument goes from the “balance between need and labour,” through the “distribution of labour” between the production of different goods to the “uniting” of the theories of exchange and production. The “balance” analysis was transmitted through Marshall’s *Principles* (1890, Appendix Note 10) as an analysis of labor supply, but Marshall used the “distribution” analysis only in an unpublished piece, the “Abstract Theory of a General Uniform Tax” (Whitaker 1975, vol. 2, pp. 289–302), written soon after the *Theory* appeared. Marshall never used or mentioned the “uniting” work; on the contrary, he persuaded readers of the *Principles* (1890, p. 535) that Jevons had been concerned with only one blade of the demand and supply scissors.

Jevons’s (1870/1970, p. 178/199) producers are as abstractly characterized as his trading bodies: “I give formulae as they would apply to an individual, only because they are identical in form with those which apply to a whole nation.” In fact he does not expect his labor (or consumption) equations to ever apply exactly to individuals. Workers specialize in occupations and do not divide their time between different jobs, and consumers do not smoothly vary their consumption with every small change in price. Averaging produces the smoothness needed for the application of calculus.

As Black (1970, p. 25) points out, the prevailing assumption is that workers are self-employed—not that Jevons hesitates to apply his results to the case of employed labor. Jevons’s procedure, which was so peculiar for domestic values, fits more naturally into trade theory. The essence of Ricardo’s argument for treating domestic trade differently from international was that there was a domestic market for factors of production but no international market. In Jevons’s united treatment of exchange and labor there is no market for factors at all. Or rather this was so in the first edition; in the second edition he interpolated a section on “Relations of Economic Quantities” which treated wages and costs without changing any of the trade discussion. Abstraction from capital was also standard in trade theory and, when Jevons combined production and exchange, goods were made by labor alone, or implicitly by labor with the cooperation of land.

In his analysis of the balance between need and labor Jevons again assumes an additive utility function. The worker maximizes utility $u(x) - l(t)$ subject to

the production function constraint $x = x(t)$. Here t is the time spent working, l is the “amount of labour”—i.e. the disutility of working— x is output and u is the utility derived from it (1871/1970, p. 173/194).

The first result is the best-known of the chapter: the laborer “will cease to labour just at that point when the pain exactly equals for a moment the corresponding pleasure acquired; and we thus have t defined by the equation”

$$\frac{dl}{dt} = \frac{dx}{dt} \frac{du}{dx}. \quad (3.1)$$

The argument continues on what has become a familiar course, but with one confusing difference. The derivative dx/dl , the “ratio of production,” replaces dx/dt as the focus of attention. The ratio of production is not the marginal product of labour but the marginal product of pain. The transformation, Ω , from pain, l , to output, x , depends on both the production function ($x(t)$) and on the disutility of labor function ($l(t)$). In some of his analysis (in particular, of comparative advantage and of rent) Jevons uses dx/dl where dx/dt would have been more appropriate.

Jevons proceeds to analyze the optimal allocation of labor effort between the production of different goods. There are goods x and y (or 1 and 2). The problem is to choose x and y , l_1 and l_2 to maximize the utility function

$$\Phi(x) + \Psi(y) - (l_1 + l_2),$$

subject to the constraints $x = \Omega_1(l_1)$ and $y = \Omega_2(l_2)$

Jevons writes down the marginal condition. “When the labour is finally distributed, we ought to have the increments of utility from each employment equal and at the limit we have the equations”:

$$\phi(x) \cdot \omega_1 = \psi(y) \cdot \omega_2, \quad (3.2)$$

where $\omega_1 (= dx/dl)$ and $\omega_2 (= dy/dl)$ are the marginal product of labor (pain) applied in the production of x and y respectively (ibid., p. 180/199). He recognized that this single condition is insufficient to determine the two unknowns l_1 and l_2 and that the condition, $\phi(x) \cdot \omega_1 = 1$, is also needed.

Next, producers are given the opportunity to trade:

Let it be observed that, in uniting the theories of exchange and production, a complicated double adjustment takes place in the quantities of commodity involved. Each party adjusts not only its consumption in accordance with the their ratio of exchange, but it also adjusts its production of them. The ratio of exchange governs the production as much as the production governs the ratio of exchange (ibid., p. 183/202).

Jevons writes down the appropriate first order conditions. When this agent is able to trade, he gives up, say, y_1 for x_1 in accordance with

$$\frac{\phi(x + x_1)}{\psi(y - y_1)} = \frac{y_1}{x_1}. \quad (3.3)$$

The “equation of production” (3.2) is modified to

$$\phi(x + x_1) \cdot \omega_1 = \psi(y - y_1) \cdot \omega_2 \quad (3.4)$$

(*ibid.*, p. 182/201). Jevons's notation is infelicitous in that the subscript on x and y indicates first trading body and those on w different goods.

In his discussion of labor and exchange Jevons's main objectives were to develop a theory of wages and to demonstrate the proposition that commodities exchange in the ratio of their costs of production. The equations (3.3) and (3.4) together imply the "all-important equation" (*ibid.*, p. 182/201) which expresses the equality of the price ratio to the ratio of marginal products:

$$\frac{\omega_2}{\omega_1} = \frac{y_1}{x_1}. \quad (3.5)$$

Jevons did not write down the corresponding equations for the second trading body and so his analysis of the labor and exchange case is formally incomplete. However the missing equations just mirror those he wrote down.

The analysis is applied to international trade in the section, "Various Cases of the Theory," which treats the theory of comparative advantage. Jevons draws the conclusion from equations (3.3) to (3.5) that "the absolute facility of producing commodities will not determine the character and amount of trade" (*ibid.*, p. 185/205). This "point of great importance ... was correctly conceived by Ricardo and fully explained by J. S. Mill" (*ibid.*, p. 185/206). However, Jevons made the further point that, should there be a doubling of the powers of production, the ratio of exchange would change because of differences in the rate at which marginal utility falls. Jevons's formulae actually apply to marginal products of labor pain while the "powers of production" are most plausibly interpreted in terms of the transformation of labor time into output.

An established doctrine going back to James Mill (1821), which needed correction, held that countries with identical production possibilities have no incentive to trade:

But I do not think that the statement will hold true if the conditions of consumption are very different in two countries. There might be two countries exactly similar in regard to their powers of producing beef and corn, and if their habits of consumption were also exactly similar, there would be no trade in these articles. But suppose that the first country consumed proportionately more beef and the second more corn; then, if there were no trade, the powers of the soil would be differently taxed, and different ratios of exchange would prevail. Freedom of trade would cause an interchange of corn for beef. Thus I would conclude, that it is only where the habits of consumption, as well as the habits of production, are alike, that trade brings no advantage (1871/1970, p. 187/207).

This result only became fixed in the literature when it was rediscovered by Lerner (1932) and Leontief (1933), who had developed geometry for preferences and production opportunities.

In both the chapters on exchange and on labor Jevons noticed cases in which the marginal conditions are not satisfied, and he tried to explain them. In the case of exchange, these are situations where no trade takes place or situations in which indivisibilities are important. In the case of international trade, the breakdown of the marginal conditions is associated with specialization:

As in the theory of exchange, so in the theory of production, any of the equations may fail, and the meaning is capable of interpretation. Thus if the equation

$$\frac{\omega_2}{\omega_1} = \frac{y_1}{x_1}$$

cannot be established, it is impossible that the production of both commodities y and x , can go on. One of them will be produced at an expenditure of labour out of proportion to that at which it may be had by exchange. If we could not, for instance import oranges from abroad, part of the labour of the country would probably be diverted from its present employment to raise them, but the cost of production would always be above that of getting them indirectly by exchange, so that free trade necessarily destroys such a wasteful branch of industry (ibid., p. 188/207).

Jevons was fairly successful in writing down the required marginal conditions and interpreting them—including the interpretation of corner solutions. But he had no reliable technique for going beyond this stage for comparative static analysis. For the pure exchange case—the Jevonian tradition, if one can call it such, never took up the production model—the development of technique was very slow. Wicksteed (1888) tried to show how an increase in the endowment of one of the trading bodies would influence the quantities traded. When Pigou (1932, 1947) switched from Marshall's methods to Jevons's for treating the transfer problem and import taxes, he developed a technique based on linearization. The widespread use of these models only followed the development of diagrammatic techniques for handling them.⁷

Jevons explained the pattern of trade, like Leontief and Viner in the 1930s, who used indifference curves and the transformation curve. His model is close to that of the “specific factors” model of the 1970s. However, the specific factors, different kinds of land, are only implicit; he assumes the same diminishing returns technology in the chapter on labor—where trade is discussed—and in that on rent. Jevons (1871/1970, p. 198/217) argues: “The general correctness of [my views on utility, exchange and labour] derives great probability from their close resemblance to the Theory of Rent.” Findlay (1974, p. 10) refers to the “curious fact” that Ricardo used different models for comparative advantage and the repeal of Corn Laws, the policy objective “most closely associated with his name.” The model that Jevons devised could have encompassed the themes of both Ricardo's “Essay on Profits” (1815) and his *Principles* (1817); Jevons used the effects of the Corn Laws to illustrate his “complicated double adjustment.”⁸

This completes the survey of Jevons's analysis of international trade. International trade was important to him, and his methods were tailored to its problems—perhaps better than to domestic trade. His models and methods were not further refined until well into the twentieth century when they were

⁷ Caves (1960) and Chipman (1965) review these later developments associated with Haberler, Leontief, and Lerner.

⁸ Aldrich (1997) discusses Ricardo's various models and the development of the principle of comparative advantage.

re-invented. Keynes (1924, p. 23) missed the mark when he wrote that “Jevons saw the kettle boil and cried out with the delighted voice of the child; Marshall too had seen the kettle boil and sat down silently to build an engine.” There is an “engine” in the *Theory*, a different kind of engine from the one in the *Principles*.

IV. FROM THE LAWS OF SENTIENCE TO MARKET PHENOMENA⁹

The second phase of the Jevonian non-revolution began in 1881 with Edgeworth’s *Mathematical Psychics*. Edgeworth went beyond Jevons’s (1871/1970, p. 135/171) appraisal of Mill’s theory of international values as “always ingenious and nearly always, as it seems to me, true,” for he showed how Mill’s theory could be deduced from Jevons’s theory of exchange. To the “subordination of the more complicated phenomena of the market to the simple laws of sentience” Edgeworth brought rigorous standards and a massive mathematical technique. The change was not all gain; his uniting of production and exchange was less skillful than Jevons’s.

In *Mathematical Psychics*, Edgeworth refined the notion of a trading body, distinguishing between the cases in which the trading body is divisible or indivisible. Jevons had stated that “the principles of exchange, are the same in nature, however wide or narrow may be the market concerned.” Edgeworth (1881, p. 109) pointed out that the “law of indifference” only applied when there was competition, i.e., when the trading bodies were divisible, and that Jevons’s equations of exchange should be read as referring to a “typical couple” with competitors in the background. Edgeworth did not present this analysis as correcting a mistake, but as bringing out something that Jevons had not emphasized. However, when Bastable compared trade between nations to exchange between isolated individuals, Edgeworth (1887, p. 356) criticized him. Though Edgeworth did not adopt the term “trading body,” he treated countries as trading bodies whose components were subject to the law of indifference—see the “Theory of International Values” (1894, p. 440).

Edgeworth did not go directly from Mill to Jevons, or rather from Jevons to Mill; he went via Marshall—in particular, the privately circulated “Pure Theory of Foreign Trade” (1879), part of a book Marshall never finished. Marshall later recalled, “As to international trade curves—mine were set to a definite tune, that called by Mill” (Pigou 1925, p. 451). Jevons’s utility ideas slowly penetrated Marshall’s demand theory but not his trade theory, for he stopped working on that at the end of the 1870s.¹⁰ None of Marshall’s embellishments of Mill—the graphical apparatus, stability, multiple equilibria, etc—connected readily with Jevonian analysis.¹¹

⁹ This paper does not try to cover all of Edgeworth’s trade work. He made other important contributions—e.g., the analysis of “immiserizing growth” discussed by Bhagwati and Johnson (1960).

¹⁰ Aldrich (1996) considers Marshall’s debts to Jevons in the field of demand. Groenewegen (1995, chapter 6) discusses the fate of the trade book.

¹¹ Creedy (1990) reviews Marshall’s work on international trade.

Mathematical Psychics reduced Marshall's pure theory of foreign trade to Jevons's theory of exchange. Edgeworth derived offer curves (or "demand curves," as he calls them) in the pure exchange case from assumptions of utility maximization. Perhaps this analysis was the fulfillment of Jevons's promise to demonstrate how the "laws of supply and demand" follow from the principle of final utility. Later Edgeworth (1889, p. 682) called the offer curve form the diagrammatic representation which "most closely corresponds to Jevons's formulae."

More significantly for trade theory, Edgeworth discussed the offer curve for a production economy. *Mathematical Psychics* (1881, pp. 104–08) has a derivation of the properties of an offer curve when there is production with decreasing costs. This arcane discussion introduces the model that was basic to Edgeworth's work on the foundations of trade theory. The set-up is the simplest extension of Jevons's corn/beef analysis—see Section II above—to incorporate production. Edgeworth assumes a single factor of production, labour, and that the countries are completely specialized. Jevons did not consider this simple case for he only integrated production and exchange after he had considered the choice of output mix. Edgeworth (*ibid.*, p. 104) mentions how Jevons had "glanced" at the "complicated double adjustment," but his own analysis does not treat the problem of output mix and so cannot explain the pattern of trade. In all other respects his analysis makes Jevons's look rather feeble.

In the "Pure Theory," Marshall considered different kinds of offer curve and gave the name of "exceptional Class II" to the case in which "an increase in the amount of wares which a country produces for exportation effects a very great diminution in the expenses at which she can produce them; so that the consequent fall in their value diminishes the imports that she receives for them" (Whitaker 1975, vol. 2, p. 134). Marshall discusses demand and technology as explaining the characteristics of offer curves but only in an imprecise way. Edgeworth did much more.

Edgeworth (1881, p. 105) considers an individual—presumably the typical individual in the country. The individual consumes two different commodities but produces only one. The utility function P has two components: F , the utility derived from consumption of the two goods, and ϕ , the disutility associated with producing the exportable:

$$P = F[f(e) - x, y] - \phi(e),$$

where e is the "objective measure of labour," f is the production function, x is the level of exports, y is the level of imports, and $\phi(e)$ is the "subjective measure of labour." The utility specification is more sophisticated than Jevons's, for it does not assume additive utilities in the consumption goods.

Making reasonable assumptions about the properties of the utility function, Edgeworth shows that there will be a reduction in the quantity of imports when there is an increase in the quantity of exports if, and only if, the second derivative of the production function is positive. Edgeworth never published a derivation of the utility and technology analysis underlying less pathological types of offer curve—presumably he thought it unnecessary and uninteresting.

The model was elaborated in the part of "The Theory of Inter-

national Values” devoted to the mathematical theory. After analyzing the two-country, two-good case geometrically, Edgeworth expounds a more general model algebraically. There is a sense of half-heartedness about the analysis, and it is framed by Marshall’s observation “that it seems doubtful whether any one spends his time well in reading lengthy translations of economic doctrines into mathematics, that have not been made by himself,” and Mill’s suggestion that “the further adaptation of the theory ... may be left with great advantage to the intelligent reader.”

There are two countries, three goods, one factor, and constant costs. The maximand for a country is its “advantage,” which depends on its level of consumption of the goods it imports and of the exportable goods it retains for home consumption. The advantage of the first country and the advantage of the second country are, respectively,

$$\Phi(X, Y, z) \text{ and } \Psi(x, y, Z),$$

where upper-case letters denote consumption of home-produce and lower-case, consumption of imports. The first country produces quantities $x + X$ and $y + Y$, and the second country produces quantity $z + Z$. The first country has an output mix problem, but neither country can produce what the other produces.

The first country has A “units of work” available and the second country B units of work; there is no labor choice problem. These units are allocated between production of the goods in the following way:

$$\begin{aligned} a_1(a + X) + a_2(y + Y) &= A \\ b_1(z + Z) &= B \end{aligned}$$

and an additional condition

$$a_1x + a_2y = vb_1z,$$

where v is the “rate of exchange between the product of work” in the first country and the product in the second. Of course labor is not traded, but because commodities are produced under constant costs, the exchange rate between goods determines an implicit rate of exchange between labor.

Each country maximizes its advantage subject to its technical constraint and its trading possibility condition. Edgeworth obtains nine equations (in nine unknowns, including two Lagrange multipliers) that can be reduced to the following three equations, analogous to the two offer curves in the case of two goods.

$$\begin{aligned} \Phi_1(x, y, z) &= 0 \\ \Psi_1(x, y, z) &= 0 \\ \Psi_2(x, y, z) &= 0. \end{aligned}$$

The first pair of equations describes the amount of exports the first country is prepared to supply for a given level of imports and the third equation the amount of its good that the second country is prepared to supply for given levels of exports from the first country.

Edgeworth indicates, without analyzing, possible generalizations—to non-constant costs and variable factor supply. He thought that such elaboration would add little, and of course he had treated both complications in the simpler model of *Mathematical Psychics*. From the 1920s onward a different limitation became the focus of criticism—the assumption of a single input, what writers like Mason (1926) or Ohlin (1933, p. vii) called adherence to the “labour theory of value.”¹² Edgeworth (1894, p. 441) has a footnote glossing “units of work” as “more exactly ‘effort and sacrifice;’ involving at least two dimensions of disutility, labour and waiting.” But this is all he says about the subject; he never analyzed the two categories of subjective cost.

Other Jevonian analysis was subject to the same limitation. Wicksteed (1888, p. 109) wrote of “efforts and sacrifices” without saying how they were to be disentangled. Jevons himself never discussed “sacrifices” in relation to exchange. More recently, the assumption of a single mobile factor has become acceptable—especially for short-run analysis. The Ricardo-Viner or specific factors model of Samuelson and Jones of 1971 is a rediscovery of the Jevons model of 1871. But to the generation of Ohlin, going beyond Mill “in fundamentals” meant escaping from the single factor assumption as much as applying marginal analysis.

In the “Theory of International Values,” as in *Mathematical Psychics*, the mathematical analysis does not determine which of the goods will be imported and which exported. Edgeworth did not develop the incomplete specialization analysis sketched by Jevons. Yet he grasped the principles involved and their bearing on the principle of comparative costs. He did not expound them in any of his set-piece statements of the principle of comparative costs but in a review of Bastable’s *International Trade*.¹³ He (1900, p. 392) argued that “So in the production of goods for foreign use, there would be no more motive for trade unless there was initially a difference, there would be no limit to the trade unless there was finally an equality, between comparative costs.” He added that “mathematically the condition that comparative costs should finally be equal is represented by Jevons’s Equation of Exchange ... the functions being understood to involve the disutility of labour as well as the utility of consumption.” However, Edgeworth did not develop this line of analysis. His applied theory was based on offer curves, not on marginal conditions.

V. STUDYING POISON

“The Theory of International Values” is a primarily a work of applied theory focusing on the arguments that “attribute advantage or detriment ... to changes in the supply of or demand for articles of trade,” especially in the context of commercial policy. Jevons’s views were described in Section II above, and

¹² Haberler interpreted the transformation curve in terms of “opportunity cost.” If there is only one factor of production that is variable and subject to disutility, then the “real cost” analysis—basically Jevons’s—produces the same condition. See Vanek (1959).

¹³ For Edgeworth’s “generalised statements” of the “Principle of Comparative Cost,” see his “Theory of International Values” (1894, p. 36) and “On the Use of the Differential Calculus ...” (1910, p. 375).

although Edgeworth held similar views about the importance of adhering to free trade, he disagreed completely about the soundness of existing analysis of the effects of commercial policy.

Edgeworth never discussed Jevons's views on trade, but his own career as a trade theorist was one long engagement with the presumption of harmony found in Jevons's writings. He (1894, p. 608) reversed Jevons's judgement on Mill: "Mill is, I think, the first—indeed almost the only—economist who has stated the proposition [that the facilitation of trade may be prejudicial to one party]." Yet he accepted Jevons's criticism of the use of price to measure the gain from trade: "To measure the variations in the advantage accruing from trade by the variations of price ... is a confusion which could hardly have occurred to the mathematical economist" (1889, p. 683). However, he denied that the application of this false principle had led to misleading results. Mill's definition was "adequate to the purposes for which it is used" (1894, p. 609). Edgeworth (1908, p. 555) remarked of Bickerdike's theory of "incipient taxes": "the direct use of the theory is likely to be small. But it is to be feared that its abuse will be considerable ... Let us admire the skill of the analyst, but label the subject of his investigation POISON."

Edgeworth's welfare analysis of international trade was utilitarian, but much more clear-headedly utilitarian than Jevons's. He ascribed indifference curves (i.e., level curves of the utility function) to countries—as well as to individuals. He did this for the first time in his 1889 address on "Mathematics and Political Economy." He (p. 685) stated that the postulate of "incommensurability of pleasures appertaining to different persons" must be abandoned when dealing with countries or combinations. After drawing an indifference curve for an individual, he wrote: "Now add properly the Utility-curves [indifference curves] for all the individuals of a community, and we may obtain what may be called a Collective Utility-curve" (p. 684).

The principal innovation in Edgeworth's welfare analysis was the use of a system of indifference curves for registering a country's advantage. He used them in two ways, to measure the size of the gain from trade and to consider whether a change constituted an improvement for a country or the reverse. Edgeworth's welfare analysis built on the work of Auspitz and Lieben (1888). In the "Theory" (p. 636), he wrote how they had "enriched" the subject with "important propositions" and "embellished" it with "splendid illustrations." Their technique was based on offer curve analysis, which they developed independently of Marshall. They analyzed the gain from trade and the welfare effects of the imposition of a tariff. In their analysis the export good is exchanged for money which has constant marginal utility. Edgeworth relaxed this assumption, and he used the indifference curve technique from *Mathematical Psychics*. In the "Theory" he covered more cases than Auspitz and Lieben because, as he points out, their assumption of the constant marginal utility of money prevented the offer curve from bending backwards.

To measure the gain from trade, Edgeworth (1889) plotted the country's offer curve and its "utility-curve," which traced out the bargains indifferent to the no-trade point. The intersection of the offer curves of the two countries describes the level of exports required to pay for a particular level of imports. The gain

from trade is measured by the difference between the amount of exports the country would be prepared to pay for the imports it buys and the amount it does pay—i.e., the difference between the utility-curve and the offer curve at the point of exchange. The measure is the same as that given by Hicks (1939, p. 40) in his account of consumers' surplus, though, of course, Hicks's indifference curves are not the contours of a country's utility function.¹⁴ The analysis of the "Theory" (1894) was based on indifference curve analysis with the emphasis on whether a change put a country on a higher indifference curve rather than on the size of the gain. This is the well-known analysis described by Viner (1937, p. 576) as the "most elaborate" in the literature.

VI. THE DISTINCTNESS OF INTERNATIONAL TRADE THEORY¹⁵

Reform in international trade theory has often taken the form of adopting the latest advances in the theory of value. Jevons's *Theory* did this in perhaps too spectacular a way, for it violated the reader's expectations by mixing up international and domestic trade, using the same methods and laws. Ricardo (1817, pp. 134–35) argued that the law of domestic values—that goods exchange in proportion to the quantity of labor devoted to their production—does not apply to international values because the mobility of capital, which polices the law, does not obtain between countries; his follower, J. S. Mill (1844, p. 237), argued that it is necessary to "revert" from the cost of production to the "anterior" principle of demand and supply.¹⁶

Marshall followed Mill in keeping domestic and international values in separate boxes, or at least requiring different techniques—the demand curve for one and the offer curve for the other. In his review of *Mathematical Psychics* he argued against using the barter model in domestic trade:

[Edgeworth] takes barter as his typical bargain, and lets x and y represent ... quantities of the two things bartered. No doubt this is the right way of treating some problems of international trade ... but there are many reasons for thinking that the greater part of economic theory can be dealt with most easily by letting x represent the amount of the commodity dealt in, and y the price of the unit of that commodity expressed in the terms of money, which is supposed provisionally to have a uniform purchasing power (Whitaker 1975, vol. 2, p. 265).

Marshall's main argument for supposing that domestic trade was best handled by demand and supply curves was "realism." He was never so explicit about his reasons for handling international trade using barter. Analytical tractability rather than "realism" seemed to be the reason.

Edgeworth (1894, p. 36) followed Jevons in recognizing that "the fundamental principle of international trade is that general theory which Jevons called the

¹⁴ Viner (1937, pp. 576–82) discusses Edgeworth's analysis of the gain from trade. Bhagwati and Johnson (1960, p. 87) discuss the 1889 argument.

¹⁵ The classic reference on this issue is Viner's (1937, pp. 594–601) note on the "scope and method of the theory of international trade."

¹⁶ Their views are expressed in Aldrich (1997).

Theory of Exchange.” But, while there is no reflection in Jevons, in Edgeworth there is an explanation of what differentiates the two special theories—in the domestic case there is a “tendency to equal remuneration of efforts and sacrifices.” He elegantly rewrote Ricardo and Mill to accommodate Jevons’s theory of exchange and the mathematical method:

The general conditions which determine equilibrium are the same for both species of trade; the only difference is that in the case of the home trade there are one or two more equations (*ibid.*, p. 35).

VII. CONCLUSION

Jevons developed a theory of exchange and production and applied it to international trade. In some respects the analysis has more in common with twentieth century trade theorizing than with the theorizing of its own time: it works directly with marginal conditions, and the model unites production and consumption. All that was noticed out of this was the general theory of exchange, which was more or less accepted, and the criticism of Mill, which was noted and put aside. Why was the rest of the material lost?

The fifteen or so pages of the *Theory* treating international trade are not consolidated into a separate chapter, into a statement about international trade, and were perhaps passed over as mechanical exercises. When the book appeared, Cairnes (1875) and especially Marshall were taking trade theory in other directions, and they were not sympathetic to Jevons’s work. For practical problems Marshall’s technique was much better than Jevons’s eyeballing of marginal conditions.

In the long run, Marshall’s *Principles* made Jevons’s entire book seem a matter of historical interest only, but there were a few economists on whom Jevons had an important influence. Of these Wicksteed, Wicksell, and Fisher did not write on international trade, only Edgeworth did. None of them used Jevons’s united analysis in their work.

Edgeworth’s neglect of his friend’s efforts is puzzling. Jevons did not work on trade when he and Edgeworth were acquainted, and so they may never have discussed trade theory. Edgeworth may have thought that the analyses discussed in Section II were best overlooked. He made a glancing reference to the united analysis, but it seems his grasp of the analysis was not very firm. When he reviewed Marshall’s *Principles*, he (1890, p. 165) accepted its depiction of the “one-sidedness” of Jevons on value. Later, however, when Smart (1892) claimed Jevons for an Austrian, Edgeworth (1892, p. 337) objected, insisting that “It is to be remembered that Jevons, in his chapter of labour, in effect makes value depend ... also on the disutility of labour.” However, this remark does not necessarily show that he understood Jevons’s analysis.

Marshall was the source of Edgeworth’s workaday theory, to which he added “interesting details.” Edgeworth (1894, p. 443) stressed his own unoriginality in an extravagance of self-effacement:

What is written on the subject after a perusal of [Marshall’s] privately circulated papers, and pending the publication of the second volume [of the

Principles], can make no claim to originality or permanence—like the light of the planet which preceded the rising of the sun, borrowed from and destined to be effaced by the prime orb.

That sun never rose, but it was never part of Marshall's project to include the utility foundations of international trade—to efface Edgeworth's work.

Edgeworth's work on welfare analysis and on the utility and technology foundations of the Mill-Marshall analysis transcended that tradition: Edgeworth brought "the 'province' of trade theory under the suzerainty of *Mathematical Psychics*," as Creedy (1986, p. 118) puts it. The work was not perfect even in its own terms—the integration of the offer curve and indifference curves with technology was particularly weak—yet the program itself was a major new departure and it was not further advanced until the 1930s.¹⁷

Edgeworth's foundational analysis had no direct impact on trade theory, though it had an indirect influence through works on general theory, notably Bowley's *Mathematical Groundwork* (1924). Four reasons may explain its lack of impact. The primary focus of Edgeworth's trade theorizing was on problems of applied theory, the consideration of advantage and detriment. Some of the most important results were not in trade publications but hidden elsewhere, especially in *Mathematical Psychics*. The foundational results were not spectacular—they only confirmed the basic correctness of the Mill-Marshall analysis. Perhaps most importantly, Edgeworth made little fuss about them.

The Theory of Political Economy had made a fuss about a theory and a method. *Mathematical Psychics* aggressively promoted the method, challenging those who are "ignorant of geometry." When he reviewed the book, Marshall (Whitaker 1975, vol. 2, p. 265) warned the author about letting the mathematics run away with him and "carrying him out of sight of the actual facts of economics." In the "Theory" Edgeworth is self-deprecating about the method and gives only one case where the "Ricardian and mathematical methods lead to somewhat different results" and a conclusion is reached "which can be most peculiarly and exclusively attributed to the mathematical method."¹⁸

In reaction perhaps to Jevons's "regrettable polemic" against Mill—as he (1886, p. 355) judged it—Edgeworth stressed continuity, writing (1894, p. 607) that "Mill's exposition of the general theory is still unsurpassed." Edgeworth protested only mildly about trade works that found no place for the new value theory. Bastable's *Theory of International Trade* (1887) became the standard textbook. Bastable restated Mill, holding that while the "whole body of economic science stands in need of a thorough revision and, in some of its parts, an entire reconstruction," the theory of international trade is "one of the products of the older political economy which is well worth preserving." While Edgeworth (1887) admitted, "It is refreshing in these days to find an economist who has a good word for the classical English school," he found "the treatment of the

¹⁷ Caves (1960, p. 36, n. 90) identifies Edgeworth's construction with Meade's trade indifference curve, adding that Edgeworth used it incorrectly. This is another aspect of Edgeworth's failure to integrate his analysis of the pattern of trade with the determination of international values.

¹⁸ This was his demonstration (1894, pp. 435, 624) of the "want of symmetry" between the effects of import and export taxes. Ironically this result turned out to be incorrect. See Lerner (1936).

abstract theory of value does not evince a firm grasp of first principles.” He welcomed successive editions and continued to find fundamental errors. Yet this book, incorporating none of the innovations that mattered so much to Edgeworth, remained “the best manual on the most difficult part of Economics” (1897, p. 397). Edgeworth seems to have been satisfied with the practical soundness of Bastable’s work.

Metzler (1948, p. 233) wrote of the repercussions on trade theory of the 1930s’ revision of value theory: “Despite these modifications, however, many of the conclusions which the economists had reached with more antiquated equipment remained essentially unchanged.” Edgeworth evidently thought much the same of the repercussions of the 1870s’ revision of value theory, but he was so quiet about the modifications that it might seem as though there had been none. The “more antiquated equipment” replaced in the 1930s and 1940s was not the work of Jevons and Edgeworth but of Mill and Marshall.

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