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## DRAFT

International Trade: Evolution in the Thought and Analysis of Wassily Leontief

by

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Summary. Leontief's 1933 article on the use of indifference curves in the analysis of foreign trade is widely cited as a fundamental contribution to neoclassical theory. Twenty years later, he collected the data for a simple input-output computation. The results exhibited the famous trade "paradox" that placed the modern theory of factor proportions seriously in doubt, laying the groundwork for today's more heterodox "new trade theory." After the passage of yet another 20 years, Leontief published his Nobel Memorial lecture, which described in embryonic form the input-output model of international exchange he was to construct several years later. A total of only eight publications about international trade exemplify the dramatic evolution in Leontief's thought and analysis about economic structure and interdependence over a period of several decades. The early work, both theoretical and empirical, garnered widespread attention within the profession. By contrast, the post-1973 work with its emphasis on structure and scenario analysis has had more influence on issue-oriented research, notably in the area of the environment, and holds great promise as the framework of choice for a new generation of interdisciplinary scholars.

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Between 1933 and 1977, Wassily Leontief published 4 articles, 2 reviews of the work of other economists, his Nobel Memorial Lecture, and a book on the subject of international trade. Despite the short length of this list, the subject was central to his concern with economic interdependence. By 1973, Leontief was speaking of the "structure of the world economy," a focus that situated all countries' resource endowments, production and choice of technology, consumption, and trade within a unified framework. International trade, of crucial importance for describing and understanding the structure of the world economy, was the mechanism that assured the *closure of the input-output model for all geographic regions*. Leontief's treatment of trade departed from standard treatments – including his own earlier work – in dramatic ways. For these reasons, the centrality of trade in

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Leontief's legacy of input-output economics is not fully recognized. In this paper I will review the 8 publications and offer some observations about the evolution and significance of this body of work.

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1933. "The Use of Indifference Curves in the Analysis of Foreign Trade," Quarterly Journal of Economics.

In this article Leontief developed the geometric representation of the production and consumption of two goods in two countries and the trade that would take place between them. This widely cited piece of work, which the author explicitly situates in the tradition of Marshall, Edgeworth, and Pareto, was credited with extending the notion of economic equilibrium by revealing the relations between national and international phenomena. It earned him a reputation along with these predecessors as well as Haberler, Lerner, and Meade as a major contributor (while still in his twenties) to neoclassical theory. All assumptions and conventions are those that were current at the time: he graphed production possibility frontiers and social indifference curves. The innovation was to do this for 2 countries simultaneously on a single graph. In the article he claimed as the significance of this achievement the ability to assess the implications for trade of changes in one or more variables in either country, an advantage over the standard demonstration by numerical example because of the greater ease in handling all cases of theoretical interest. Nonetheless, Leontief makes the following remark, which is reflected in his later work:

Without trying to make a point against the spirit of the theory of comparative costs, it may be interesting to observe that two countries with costs of production that are equal not only comparatively but even absolutely, will start an exchange of their products if their systems of indifference lines, i.e., their relative demands, are different.... The case is not as artificial as it may appear at first sight. It may partly explain the highly developed interchange of commodities between countries with similar industrial structure (p. 501).

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1953. "Domestic Production and Foreign Trade: the American Capital Position Re-examined," Proceedings of the American Philosophical Society.

1956. "Factor Proportions and the Structure of American Trade," Review of Economics and Statistics.

In 1953 Leontief published (in the Proceedings of the American Philosophical Society) the numerical results that established what became known as the Leontief Paradox, notably that the United States in 1947 is revealed by the factor contents of its trade to have abundant supplies of labor but scarce capital. The article was followed a few years later by a second one (this time in a prominent economics journal), in which he reported that the

initial results still held after substantial refinement of data and method. The work was presented as an empirical test of the contemporary interpretation of the Heckscher-Ohlin theory of comparative advantage, a test that was made possible by an unprecedented program of data collection on Leontief's part. A clever construction of variables – what Leontief called the “factor content” of an export or import bill of goods -- made it possible to derive conclusive results from these data on the basis of a simple matrix multiplication and data for one country only. In these articles he stresses that these simple computations are as far as one can go in an operational understanding of the structure of international trade so long as comparable data have not been collected for at least one other major trading country. These influential articles were successful in demonstrating the power of input-output economics. Later Leontief would oversee a massive data collection effort covering all parts of the world economy.

Leontief *believed* the results and provided an interpretation for why the United States was indeed richly endowed with labor and not capital. Other subsequent authors did not believe the United States to be rich in labor and in their articles attempted to explain the paradox by pointing out phenomena Leontief had failed to take into account, like other factors of production or non-competitive imports. While the theoretical implications still remain unsettled (see below), Leontief must have been gratified that his example stimulated many empirical studies that examined the factor contents of imports and exports for different countries and time periods. Those for the United States continued to confirm the paradox (see Duchin, 1990, and the review of the empirical literature in Helpman, 1999).

A new line of refutation was introduced in 1980, when Leamer (1980) claimed that Leontief had made a methodological mistake by comparing the factor contents of an equal dollar value of imports and exports and that, once the error is corrected, there is no paradox. He showed that using what he considered the right variables (the factor contents of net exports compared to that of domestic consumption), the United States would be revealed (using Leontief's data) as capital-rich in 1947. The article was influential, although questionable on several grounds. All the standard equilibrium assumptions are made, notably full utilization of factors and common technologies and tastes in all countries. On the basis of these assumptions, he concluded that factor proportions in domestic consumption (presumably for any country) are the same as the factor proportions in world endowments. Furthermore, Leamer acknowledged in a footnote that the paradox *did* hold for years other than 1947, a fact that would seem to undermine the main point of his paper.

Over the past 20 years, the still substantial literature stemming from the Leontief Paradox has followed two paths. One line of inquiry has been whether or not there really is a paradox and if so how to explain it. The 1980's featured articles with titles like “The Leontief Paradox, Continued” (Brecher and Choudhri, 1982) and “The Leontief Paradox: Continued or Resolved?” (Casas and Choi, 1985). In 1993 Trefler published an article called “International Factor Price Differences: Leontief Was Right!” The other line of inquiry involves the use of the factor-content variables for other purposes, such as to sort out the impact of technological change from that of trade on changes in domestic income

distribution. A special issue of the Journal of International Economics (2000, 50(1)) is devoted to evaluating the usefulness of factor proportions in methods that serve as a shortcut to a general equilibrium analysis. See especially the divergent views of Krugman (2000) and Leamer (2000).

In 1961 Linder had remarked: “Not even Leontief, who has made extensive empirical research and reached results conflicting with factor proportions hypotheses, dared to conclude that the factor proportions approach was unsatisfactory.... There are, however, alternative ways of explaining differences in relative price structures” (1961, p. 16). By the time of his Nobel Memorial Lecture (1974), Leontief did dare to take an entirely new approach to trade. Three short articles (2 of them reviews) written between 1964 and 1973 paved the way by establishing a few critical convictions.

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1964. Review of “An International Comparison of Factor Costs and Factor Use” by B.S. Minhas, American Economic Review.

In the monograph under review Minhas poses the question: Can a meaningful distinction be made between capital-intensive and labor-intensive sectors? He concludes that it cannot because “cross-overs” (in the capital vs. labor intensity of different sectors) are common in response to changes in factor prices. Leontief finds these empirical results implausible and ends by drawing different conclusions using Minhas’s data and methodology (by correcting an error, or oversight, of Minhas). Having established his empirical point that relatively few industries experience cross-overs even using Minhas’s methods, Leontief subsequently also rejects the methodology, dismissing not only Cobb-Douglas but also the CES production functions featured in the monograph (and still in today’s literature) as not useful for empirical analysis. Instead, he claims that if a sector can legitimately be called capital-intensive, because any substitution among factors in a given country due to changes in factor prices occurs only within a narrow range, then “fixed” coefficients are a good approximation of factor requirements. He clearly had in mind the technical coefficients of an input-output model.

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1970. Comments on John Chipman’s “Induced Technical Change and Patterns of International Trade,” in R. Vernon, ed., The Technology Factor in International Trade.

Chipman claims in this paper that the deteriorating terms of trade of resource-rich poor countries cannot be due to technological change in the rich countries, a result reached on the basis of an aggregative growth model with endogenous technological change. Leontief finds this result implausible and attributes it to the assumptions about elasticities of substitution among inputs that he calls empirically unjustifiable, even if conventional. In particular, technological change in Chipman’s model cannot eliminate any input that was

formerly used, except in the unrealistic case of an *infinite* improvement in its efficiency of use. Thus Leontief concludes that a declining share of expenditures in the rich countries on raw materials may well be due essentially to technological change brought on by investment in research and development. This conclusion calls attention to the importance of technology and technological change in determining comparative advantage, and it lays the groundwork for insisting on representing different technologies in different countries and on the use of technical input-output coefficients rather than given elasticities of substitution.

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1973. "Explanatory Power of the Comparative Cost Theory of International Trade and Its Limits," in Economic Structure and Development: Essays in Honor of Jan Tinbergen.

In this short and little-known paper, Leontief points out that the literature explaining bilateral trade makes the implicit assumption that comparative cost theory can explain these flows. He observes that the theorists know better but are silent about the limitations of theory, much to the disadvantage of those engaging in empirical research or policy analysis. His somewhat surprising claim about the non-uniqueness of bilateral trade is of course not relevant in the textbook case of only 2 countries.

In general, Leontief argues, bilateral flows are indeterminate in a comparative cost framework: the most that can be deduced (and this only in principle, because an adequate database is not yet available) is each trade partner's outflow and inflow of goods and services. Only if the transfer costs are large and truly differential among trade partners can a determinate bilateral solution based on comparative costs be found. Leontief presents data for the United States in 1963 according to which the differential portion of the transfer costs amount to only a small percentage of the value of the goods.

Toward the end of the article, Leontief makes the following statement:

In the discussion of the factor price equalization theorem it is however not often enough emphasized that under the (obviously quite unrealistic) set of conditions described above, not only one, but many alternative distributions of industrial activities between different countries could yield the same combination of aggregate world outputs of all goods while satisfying at the same time the requirement of full utilization of all primary resources that happen to be available in each country. This means that under such conditions and in the absence of international costs not only the network of country-to-country commodity flow, but even the level and the composition of each country's total exports and imports,...could not be uniquely determined (p.157).

Leontief demonstrates his first claim (about non-unique bilateral flows) through a mind experiment; unfortunately, no proof is offered for the second, stronger claim (about the level and composition of a country's trade). By this time he is clearly convinced of the

inadequacy of the standard assumptions for explaining the structure of international trade. His rethinking of appropriate fundamental assumptions will become evident when he creates “trade pools” in his important model of the world economy.

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1974. “Structure of the World Economy: Outline of a Simple Input-Output Formulation,” Nobel Memorial Lecture.

1977. Leontief, W., A.P. Carter and P. Petri. The Future of the World Economy.

Wassily Leontief’s Nobel Memorial Lecture describes a few blocks of linear equations that, for the first time, extend a static, one-country, input-output model to many regions. The motivation for the model is to analyze scenarios – not to prove theorems or test hypotheses. He quotes from a United Nations document: “By thus indicating alternative future paths which the world economy might follow, the study would help the world community to make decisions regarding future development and environmental policies in as rational a manner as possible” (1974).

No mention whatever is made of factor proportions – or even of comparative costs! Instead he speaks about an input-output perspective as a “framework for assembling and organizing the mass of factual data needed to describe and understand the world economy” in terms of 28 groups of countries, about 45 sectors producing goods and services, 40 minerals and fuels, and 30 pollutants. Leontief took advantage of the incomparable prestige of the Nobel Prize to publish a very unconventional formulation. Funding to construct the model and database had already been obtained through the United Nations with the objective of exploring future prospects for the developing economies.

A slim volume with the fruits of this effort was published in 1977 (Leontief, Carter and Petri). The model and database, which are used to explore the implications of several alternative scenarios, include several regions, several goods, and several factors (15, around 50, and 3, respectively, in this version). The data describing production technologies and consumption preferences are specific to each region, and there is no restraint regarding common factor prices. Factor endowments need not be fully utilized, and the framework naturally captures intermediate production. The resulting model is one of the general interdependency of production, consumption, and trade but does not include all the feedback mechanisms, and parameters, required for a model of Walrasian competitive equilibrium. Thus Leontief’s framework is innovative in two ways: it does not provide a unique, optimal solution, and this is so because not all phenomena of interest are endogenous. He has been able to drop many of the clearly unrealistic assumptions characteristic of the neoclassical and modern trade theories. He achieves this increased realism by requiring a massive base of factual information and detailed scenarios that themselves require a major effort for the projection of parameter values. And he forgoes the elegance of optimal solutions and the convenience and conceptual power, which he would claim is illusory, of treating many phenomena, such as technological change, as endogenous.

International trade is represented in Leontief's World Model through a *trade pool* for each traded item. For each good and each region, there are two sets of parameters, import coefficients and export shares. Export shares specify the portion of the total amount of world exports of the item provided by each region to the pool, and import coefficients specify the volume of competitive imports as a fraction of domestic production of the same good.

In principle, one should be able to replicate past and present quantities and prices of factors, goods and services, in all economies using any framework that is "calibrated" to the historical data. The greater challenge is for the choice of parameters and key relationships in a model to sufficiently well capture the most critical attributes of the real situation as to perform well in hypothetical scenarios about the future or of what might have been in the past (also called counterfactuals, but-for's, or what-if's). It is abundantly clear, however, that for phenomena as complex as an economy not to mention the world economy, even the performance of a calibrated model in replicating the past is highly imperfect because formal equations cannot capture the complexity of the actual relationships. Leontief's claim is that the input-output interpretation of general interdependency is a fully operational simplification of general equilibrium that is theoretically grounded and empirically far more useful. The reliance on what may appear to economic theorists as a massive quantity of data about the present and past permits an empirical content not otherwise available for economic analysis and not massive by contemporary standards in, say, the natural sciences.

Economists have for the most part ignored not only the World Model but also the one-country models that share its features because the departures from standard practice are too great, in particular the rejection of elasticities of substitution as the fundamental parameters and of competitive equilibrium as the solution concept. But within new fields like Ecological Economics and Industrial Ecology, input-output economics is a natural counterpart to such data-based models as those of physical stocks and flows of materials (used in material balances or material flow analysis). Researchers whose work involves phenomena in the natural world have become suspicious of equilibrium concepts for representing the behavior of what are clearly *complex systems*.

Within the economics profession, it was the profoundly unsettling effect of the Leontief Paradox and the evident absence, in the real world, of factor price equalization that opened the way for the unprecedented questioning of received wisdom about international trade by the so-called new trade theorists. There is a curious and to some extent tactically motivated tension in the work of these theorists between the embrace and the rejection of some of the most deeply-engrained concepts. A good example is a recent article by Krugman, where he provides a great deal of insight into what has gone wrong, but I believe that he contradicts his own logic in stopping short of the right conclusions (2000, pp. 63-70). His argument is worth recounting.

Krugman states that we need to think carefully about what questions we are trying to answer, making the case (in a different rhetoric) for the formulation of relevant scenarios

and not just the testing of the mechanics of a given model. He goes on to ask of economists making a substantive claim, “(C)an they produce a general equilibrium model...that is consistent both with their assertions and with the... actual volume of trade? If they cannot, they have not made their case” (pp.65-6). Nonetheless, he reports his own “quick and dirty version of this exercise” (p. 65), pointing out that “many economists studying the impact of trade on wages have been reluctant to commit themselves to a specific CGE model” (p. 66). Why, we must ask? He answers that there are so many parameters that “it would be hard to do any systematic sensitivity analysis” (p. 68). But this is not a logical criterion for spurning a model. He comes closer to the truth when he says, “In the end, of course, one must return to the data.... The assessment of the causes of changes in factor prices is ultimately an empirical matter” (p. 69). I can only agree. But Krugman’s conclusion is baffling, especially for one of the main architects of the new trade theory: “Why then has the subject [the use of factor contents to explain the relation between trade and factor prices] become a matter of intense, sometimes bitter dispute? Not because of arguments about the appropriate model: *all players in the controversy agree that the relationships among trade, technology, and factor prices are indeed very well suited for analysis using the standard competitive trade model.* The dispute is, instead, philosophical: it hinges on the question of what thought experiments to perform....” (p. 70, emphasis added).

Economists certainly agree that various kinds of differences among countries drive trade, and trade acts to diminish some of these differences. Abundant factors tend to be cheaper and thus are used more intensively, and trade tends to lower the price of scarce factors and raise that of abundant ones. Relative cost structures are of critical importance for understanding the structure of the world economy and anticipating changes in it. However, the conventional formalization of the standard assumptions in a mathematical model is far too rigid to replicate the empirical reality at the level of detail of many sectors and many factors even for the past, or be useful for counterfactual scenarios or scenarios about the future. This is true of a model of even a single economy, let alone the world economy.

Leontief wanted to identify strategies countries might adopt for economic development and investigate how their implementation could be expected to affect production quantities, relative prices, standards of living, and their insertion in the world economy. He claimed that the simplifications of input-output economics make it possible and practical to use a framework of general interdependence to explore responses to such systemwide challenges. These are challenges that can yield to empirical analysis, but they will require concerted effort and an intellectual division of labor on the part of a new generation of scholars to make substantial headway. The obstacles are building the necessary database, accepting the replacement of elasticities and equilibrium by other concepts, and incorporating a comparison of cost structures into the closure of the input-output model for many regions. As long as I knew him, Wassily Leontief was convinced that it was only a matter of time until this was achieved.



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