TAUTOLOGIES IN ECONOMICS AND THE NATURAL SCIENCES

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THE TOPIC AND A DISCLAIMER

Quibbles over Walras's Law trace, in my experience,[1] to failure to recognize that the Law is tautologically true. To forestall misunderstanding of this and other pieces of economic theory, it is worth recognizing that useful tautologies are fairly numerous.

This paper issues no methodological exhortations or taboos. It does not urge armchair theory over empirical research. Instead, it looks at a feature shared by several specific examples of successful theorizing. Just as scientists try to explain puzzling phenomena by revealing uniformities hidden beneath superficial diversities, so we may better understand the nature and force of argument on a particular topic by recognizing how it resembles (when it does) arguments on even quite different topics. Elucidating one style or strand or component of argument is not the same as insisting on it as the only proper method of research or exposition.

Tautologies are analytic or logically necessary propositions. They are valid thanks to covering all possibilities ("The world is either round or not round") or thanks to interlocking definitions. A negation of a tautology is self-contradictory. (Consider denying "If A implies B, then not-B implies not-A".) Most of the tautologies mentioned below hinge on the formulation and interlocking of terms and concepts, whose meanings and interrelations they illuminate.

Analytic propositions *can* "give us new knowledge" (or aid us in its pursuit). "They call attention to linguistic usage, of which we might otherwise not be conscious, and they reveal unsuspected implications in our assertions and beliefs" [Ayer, 1946/69, 35]. Logic and mathematics, although apodictically certain, can sometimes yield surprising results. Analytic propositions help one check that the factual propositions being brought to bear on some problem are mutually consistent [ibid., 36, 40-41]. Tautologies can be useful in applying the "translation test" (illustrated later) and in exposing error (for nothing contradicting a logically necessary proposition can be correct). Tautologies can be useful in focusing attention and organizing discussion.

The examples reviewed below illustrate John Harsanyi's point [1976, 64] that social scientists encounter not only formal or logical problems and empirical problems but also conceptual- philosophical problems. Larry Laudan [1977, Ch. 2] calls it "an enormous mistake ... to imagine that scientific progress and rationality consist entirely in solving empirical problems." Grappling with conceptual problems "has been *at least as important* in the development of science as empirical problem solving" [ibid., 45]. One of the most important ways science progresses is "the explication of conceptions" [William Whewell, quoted by Laudan, 50].

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A theory runs into conceptual problems when it is internally inconsistent or vague or when it conflicts with another theory or doctrine believed to be well founded [Laudan, 1977, esp. 48-49]. Ptolemy's astronomy managed to avoid most of the empirical anomalies of earlier Greek astronomy, but at the price of *"generating enormous conceptual problems"* with its epicycles, eccentrics, and equants. Its hypothesis that certain planets move around empty points in space, that planets do not always move at constant speed, and the like were in flagrant contradiction with the then accepted physical and cosmological theories [ibid., 51-2]. Methodological norms, in Laudan's view, "have been perhaps the single major source for most of the controversies in the history of science, and for the generation of many of the most acute conceptual problems with which scientists have had to cope" [ibid., 58, italics omitted]. "[I]t is usually easier to explain away an anomalous experimental result than to dismiss out of hand a conceptual problem" [ibid., 64, italics omitted].

Referring in particular to discussions of absolute and relational theories of space and time, general relativity, and the interpretation of the field equations, W. H. Newton-Smith [1981, 89] states, "What is at stake in this debate is largely conceptual." Theories must be assessed "in terms of their power to avoid conceptual difficulties and not just in terms of their power to predict novel facts and explain known facts."

Ernst Mayr [1982, 23] rejects seeing "science merely as an accumulation of facts." In biology, "most major progress was made by the introduction of new concepts, or the improvement of existing concepts. Our understanding of the world is achieved more effectively by conceptual improvements than by the discovery of new facts, even though the two are not mutually exclusive."

A. A. Zinov'ev emphasizes how suitably chosen definitions, terms, and symbols render scientific discussion more intuitively obvious, compact, and convenient. In their absence, "the record of knowledge and operating with it become practically impossible. The search for the most convenient forms of abbreviation represents one of the most important tasks in the construction of scientific language in general" [1983, 14-5].

What ultimately counts in an empirical science, says Daniel Hausman [1992, 298] is identifying regularities in the world. "But science does not proceed by spotting correlations among well-known observable properties of things. The construction of new concepts, of new ways of classifying and describing phenomena is an equally crucial part of science. Such conceptual work has been prominent in economics."

DEFINITIONS AND EMPIRICS: WALRAS'S LAW AND THE EQUATION OF EXCHANGE

Two notable tautologies in economics illustrate certain relations between definitional truths and empirical reality. Walras's Law illuminates interrelations among supplies of and demands for goods, services, securities, and money and among their supply/demand imbalances. The Law emphasizes that no one thing or group of things can be in excess supply or excess demand by itself. It thereby helps focus attention on the role in macroeconomic disorder of a distinctively functioning object of exchange — money. Similarly, it emphasizes that no change in tastes or technology can affect the supply or demand of a single thing alone; at least two things must be involved.

In one formulation, Walras's Law states that if a general-equilibrium equation system specifies equality between quantities supplied and demanded of all goods in the economy but one, then an equation for the one remaining good would be otiose. Instead of being mathematically independent, it would merely duplicate information already contained in the other equations. Supply-demand equilibrium for all goods but one already implies equilibrium for whatever the remaining good may be.

A second formulation, which straightforwardly implies the first, holds in disequilibrium as well as in equilibrium: the total value of all goods supplied equals the total value of all goods demanded. (The term "goods" is inclusive here, covering not only commodities but also labor and other services, securities, and money.) Quantities are valued at the prices at which exchanges are accomplished or attempted, as the case may be. With excess supplies counted as negative excess demands, the sum of the values of all excess demands is identically zero. ("Excess demand" and "excess supply" refer here to market disequilibrium and frustration of attempted transactions. Someone acting to increase his holdings of some good is *not* said to have an excess demand for it — not if he meets no frustration on the market.) [Lange, 1942; Patinkin, 1965, 73, 229, 258-262, and *passim*; Patinkin, 1987; Baumol, 1965, 340-42.]

Walras's Law is "an identity, ... little more than an accounting relationship" [Baumol, 1965, 341]. Where it does not hold, "people must, by definition, be planning to exchange goods which are not equal in value — an odd assertion for any monetary economy" [Baumol, 1960, 30]. The Law holds because budget constraints operate and market transactions are two-sided. Anyone trying to acquire something is by that very token offering something in exchange of equal value at the price contemplated. Anyone trying to sell something is demanding something of equal value in return. An attempted but frustrated transaction, like a successful one, involves two goods and not just one. Each frustrated transaction leaves two excess-demand values, equal in size but opposite in algebraic sign.

Yet complications arise, and Walras's Law has itself sometimes been called into question. In addressing fringe doubts, it is necessary to clarify some of the very concepts that enter into the Law. In particular, one must distinguish between "notional" and "effective" supplies and demands and between stock and flow conceptions of quantities. This paper's purpose does not require rehearsing these technicalities (although comments about the balance of payments in a later section will be suggestive). Its purpose, instead, is simply to cite Walras's Law as one example of a useful tautology.

Another familiar example is the equation of exchange MV=PQ. Interpreted as a tautology, the equation is necessarily true because of how its terms are defined. It provides two different but reconcilable ways of looking at nominal income (gross domestic product or some such magnitude). Its left side interprets income as the product of the quantity of money and its income velocity of circulation; its right side, as output in physical units valued at the average price of a unit. (All four terms must be defined in more careful detail, of course, than would serve our purpose here.) The equation focuses attention on questions of how changes in nominal income are split between price and output changes and on the confrontation between the actual quantity of money and the demand for holdings of money. The latter is what velocity relates to, and saying so reminds us of how to make a transition from the tautological equation to the condition for equilibrium between money's supply and demand.

The equation of exchange enters into examples of what I call the translation test.[2] How plausible does the theory of an inflationary wage-price spiral unfueled by monetary expansion look when its implications about Q and V are drawn out? How well does the Keynesian theory of the determinants of aggregate spending, conceptualized with the aid of its tautology that nominal income = consumption + investment + government spending + exports − imports, translate into terms of MV=PQ? Conversely, how well does the monetarist formulation translate into the Keynesian formulation? Trying to translate a proposition from one conceptual framework into another can sometimes suggest new insights or expose concealed error.

Suppose someone maintains that the equation of exchange is false — not just trivial, not just lacking in applications, but false. He thereby shows that he does not understand what the equation means and how its terms are defined in interlocking ways. His position would be like that of someone claiming to have met an unusual person, a married bachelor, or a married man who, although not married to any particular woman, is nevertheless married.

The equation of exchange also illustrates the point that whether a particular tautology is useful in illuminating reality hinges on facts of reality. (Compare the discussion of Poincaré's conventionalism below.) Validity and usefulness, falsity and uselessness, are not the same things. A proposition lacking empirical application is not false merely for that reason.

We can readily imagine a "chairs" version of the equation of exchange. In CV_c=PQ, P and Q would be the same as before, C would be the number of chairs in existence in the country on average during a year, and V_c would be the "velocity" of chairs, meaning the ratio of nominal income to the number of chairs. Thanks to interlocking definitions, CV_c=PQ is just as formally valid as MV=PQ; but because of facts about how money functions that are not also true of chairs, the money version of the equation has a usefulness that the chairs version lacks. (One might quibble over exactly what counts as a chair, just as over what counts as money, but such quibbles would be relatively peripheral to the logic and usefulness of either equation.)

As this example illustrates, the tautological validity and empirical applicability of a proposition are not the same thing. Being a tautology ordinarily bars a proposition from being an exact description of reality, although it may be a stylization. The tautologies mentioned so far are tools, guides, reminders, illuminators, organizing devices that may prove useful in coming to grips with reality.

CONVENTIONS IN SCIENCE

The mathematician and physicist Henri Poincaré emphasized the role of conventions in science [Copleston, 1985, Ch. IX, 271-3; Dantzig, 1954, esp. 52-53, 64-68; Poincaré, 1952; 1958]. He did not maintain, of course, that all scientific propositions are true by mere stipulation, agreement, habit, or custom. He warned of too sharp a dichotomy between convention and empirical fact. He criticized his disciple Edouard Le Roy for maintaining that science consists only of conventions and owes its apparent certitude to this fact [Poincaré, 1958, Ch. X, esp. 112]. To suggest that the scientist actually *creates* scientific fact itself is going much too far toward nominalism. Scientific laws are not artificial creations. We have no reason to regard them as accidental, though it is impossible to prove they are not [ibid., 14].

Poincaré's position, rather, is that conventions fruitfully *stylize* reality (although I am not aware of his using that particular word). Often the scientist sharpens up rough or vague concepts, categories, and principles. He reaches propositions that are true by convention or definition and so are not open to falsification. But neither are they arbitrary. They have proved convenient for dealing with reality, just as a decimal coinage is more convenient (though not truer) than a nondecimal coinage. The properties of reality enter into determining whether a particular definition or convention is useful in dealing with it.

In mathematical physics, what was originally an empirical generalization may be so interpreted as to become a disguised definition, not open to falsification [Copleston, 1985, Ch. IX, 273]. When an experimental law has received sufficient confirmation, Poincaré says, we may either (1) leave it open to incessant revision, ending in demonstration that it is only approximate or (2) elevate it into a *principle* by adopting conventions that make it certainly true. A crystallized principle "is no longer subject to the test of experiment. It is not true or false, it is convenient" [1958, 124-25]. Proceeding that way has often been advantageous, but "if *all* the laws had been transformed into principles *nothing* would be left of science" [ibid., 125].

Actual bodies become slightly deformed when moved, expand when warmed, and so forth. Yet it would be hopelessly complicated for every statement about the motion of a body to allow for its bending and dilation. (Compare trying to formulate Walras's Law and the principles of balance-of-payments accounting to allow even for misunderstanding whether a particular property transfer was a sale or a gift.) For convenience, we invent rigid bodies and idealized types of motion [ibid., 125-26]. The propositions of mechanics refer to these idealizations, which are nevertheless useful because they are somehow close enough to reality.[3] They are convenient, but convenience — not only for you or me but for all of us and our descendants — has an objective aspect [ibid., 140].

Poincaré instructively compares science to a library. Experimental physics buys the books. Mathematical physics — the tautological aspect — draws up the catalogue, making the library much more useful to readers. It also reveals gaps in the collection and so helps the librarian use his limited funds judiciously [1952, 144-5].

The laws of science, then, are far from *mere* conventions. They relate to a reality existing independently of how human beings describe it. However, conventions do enter into stating its laws. Some prove more convenient than their alternatives, and this difference hinges on the nature of reality. Again, compare the "chairs" version with the "money" version of the equation of exchange.

The world of classical mechanics is an imaginary, sharpened world describable by infallibly true propositions that nevertheless aid in understanding the real world. This imaginary world is a model. Model-building involves use of conventional or tautological propositions.[4]

FURTHER TAUTOLOGIES IN THE NATURAL SCIENCES

Mathematics is probably the standard example of a body of useful tautologies.[5] (Conant [1953, 105] calls mathematics a vast tautology; for Ayer [1946/1969, 33], "the truths of logic and mathematics are analytic propositions or tautologies", and J. S. Mill was wrong in supposing that a situation overthrowing any of them could arise.) Although — or because — the propositions of geometry and trigonometry are tautologically true, they are indispensable in surveying.[6] The concept of zero radically simplifies arithmetic and accounting.

In the natural sciences, classical (Newtonian) mechanics perhaps comes closest to sharing the tautological character of mathematics. The formula "force = mass x acceleration" pertains to reality, to be sure, but it also represents the interlocking of definitions. "[T]he formula which connects static force and acceleration ... is a tautology" [Dantzig, 1954, 103]. "If one wishes, one may say mass is defined in this manner, provided one already knows what force is. One might prefer to assume that mass is the known quantity and define force by this equation. What is seen here ... is the establishing of relations between various concepts in order to define terms. Which comes first and which comes later is often a matter of choice" [Teller, 1980, 39].[7]

The same formula $f=ma$ illustrates the tautological element in defining units of measurement, whose importance in science is undeniable. In the meter-kilogram-second system, force is measured in newtons, one newton being the force required to give a mass of one kilogram an acceleration of one meter per second per second. (The unit of work or energy, the joule, is a force of one newton operating over a distance of one meter; and 1055 joules = one British thermal unit, a unit of some notoriety in U.S. tax-policy discussions of early 1993.)

Electrical identities are broadly similar in character to the mechanical identities. The definitional interrelations among such units as joule, watt, volt, ampere, coulomb, and newton again illustrate tautologies at work.

Gustav Robert Kirchhoff's laws for direct-current circuits are reminiscent of Walras's Law. They guide the formulation of equations to be solved for the currents and voltages in parts of complicated circuits [Nau, 1958, 39-43, 52, 72-3, 213, 305].[8] The current law states that the sum of the currents directed toward a node equals the sum of currents directed away from the node; with algebraic sign given proper attention, the sum of all the currents directed toward a node is zero. According to the voltage law, "the potential difference between two points in a circuit is the algebraic sum of the potential differences (scalar quantities) across each of the elements traced between the points;" the sum of all the voltages around any closed loop is thus zero [Nau, 1958, 39-40]. Nau remarks [ibid., 39, 41] that the voltage law holds "[b]y definition" and that "[b]ookkeeping will be facilitated" by certain conventions of notation.

Biology tells us that organisms possessing traits conducive to survival in their environments tend to survive and reproduce; others do not. This principle of natural selection, though practically a tautology, yields insights.

Classifying organisms into species, genera, and higher orders serves gathering and assessing evidence bearing on heredity and evolution. Ideal conceptualizations (never fully achieved) would make it tautologically true of a particular organism that, on the basis of its characteristics, it falls into predefined classes. Ever since Darwin, taxonomists have recognized that more than mere resemblance — rather, propinquity of descent — is involved in classification. Darwin warned against confusing similarities due to common descent with spurious similarities due to convergent evolution under environmental circumstances [Mayr, 1982, 210-12]. Controversies have arisen among taxonomists of various phenetic schools, which refrain from taking evidence from descent into consideration, and adherents of cladistics, which does try to consider descent, and by a virtually automatic method that would force careful analysis and proper weighting of all characters. Both groups of taxonomists strive to eliminate subjectivity and arbitrariness from classifications [Mayr, 1982, 209-33]. The relevant point is that biologists have found it worthwhile to investigate and argue over the most expedient method of framing classifications, concepts, and tautologies.

Suitable classifications are important in linguistics also. Examples include the structural classification of languages as agglutinating, isolating, and inflecting, in their classification by families or descent, and in the classification of consonants as aspirated or unaspirated, voiced or unvoiced. It is tautologically true that in English the sound of *g* is the voiced and unaspirated counterpart of *k*, which is unvoiced and aspirated. The very meaning of "phoneme" implies that in any particular language, two (similar) sounds either do or do not constitute the same phoneme; there can be no in-between degree of resemblance in this respect.

Many more examples of tautology and truth by convention appear available in natural science. The several conservation laws,[9] the principle of least action, and the time-minimizing path of light [Gleick, 1992, 361, 366] are worth attention. So is the inverse-square feature common to Newtonian gravitation, Coulomb's law of electrostatic attraction and repulsion, the intensity of sound (subject to interferences), and the intensity of light and other electromagnetic radiation. This property accords with empirical observation, but one wonders whether it may not have a mathematical aspect making it more than a brute fact. The area of a sphere is 4 times the square of its radius, suggesting that the intensity of anything emanating from a central point is diluted over a larger area the greater the distance from that point, and diluted in such a way that the intensity is inversely proportional to that squared distance. Teller [1980, 39-42] speaks in this connection of the thinning out of lines of gravitational force.) The formula for the area of a sphere "implies that the total energy crossing any sphere surrounding a point source is independent of the radius. Thus, the inverse-square law for the intensity of radiation at a distance *r* from a point source is in accord with the law of conservation of energy — the total energy of a wave remains the same even though the wave is spread over a greater area" [Ditchburn, 1981, 933].

FURTHER TAUTOLOGIES IN ECONOMICS

Mathematical tautologies are familiar in microeconomics. Maximizations of profit, utility, and welfare entail equalization of various marginal magnitudes. Descriptions of long-run equilibrium under perfect competition are tautological yet illuminating. In macroeconomics, working out interlocking definitions of various quantifiable national income and product concepts has been deemed worthy of the Nobel prize.

The money-multiplier formula of money-and-banking textbooks, which involves various reserve and currency/deposit ratios, is tautologically true when the ratios in it are interpreted as actual ratios. When its ratios are reinterpreted as desired ones and the formula itself reinterpreted as an equilibrium condition, the discussion centering around it becomes a theory rather than a tautology. (Compare the transition, mentioned earlier, between the tautological equation of exchange and the condition of monetary equilibrium.)

The government budget constraint points out the logical, not merely empirical, necessity that government spending be covered by the aggregate of tax and similar revenues, borrowing, and money issue. Any proposition or proposal contradicting this tautology is immediately discredited. Sheer arithmetic, if heeded, should bring some discipline into political discussion. If a politician proposes to increase government spending, reduce taxes, and reduce the budget deficit, he is coming awfully close to implying the issue of money, to be counted as a kind of revenue, unless he can give a plausible Lafferesque explanation of how reduced tax rates will nevertheless increase tax revenues. President Bush's 1992 campaign proposal for letting taxpayers designate 10 percent of their payments to go for reducing the national debt — debt, not deficit — came awfully close, in its context, to implying the issue of new money.

Paul Samuelson reports that the mathematician Stanislaw Ulam

> used to tease me by saying, 'Name me one proposition in all of the social sciences which is both true and non-trivial.' This was a test that I always failed. But now, some thirty years later, on the staircase so to speak, an appropriate answer occurs to me: The Ricardian theory of comparative advantage; the demonstration that trade is mutually profitable even when one country is absolutely more — or less — productive in terms of every commodity. That it is logically true need not be argued before a mathematician; that it is not trivial is attested by the thousands of important and intelligent men who have never been able to grasp the doctrine for themselves or to believe it after it was explained to them. [1969, 1972, 683]

Significantly, Samuelson calls the proposition "logically true", in other words, a tautology. The principle of comparative advantage is best seen, in my concurring view, not as a substantive empirical proposition but as a piece of reasoning useful in exposing a common fallacy.[10] That fallacy rejects the possibility of mutually beneficial trade between two countries one of which is more efficient or enjoys greater productivity or lower real cost than the other across the entire range of potentially tradable goods. Instead of quibbling about the meaning or possibility of such comparisons, the principle of comparative advantage concocts, for the sake of argument, an extreme case in which the postulated difference is unequivocal. It goes on to show that even then, in the case supposedly most embarrassing for free trade, gains from trade are available to both parties. It provides an "even-if/even-then" argument.

BALANCE-OF-PAYMENTS CONCEPTS AND ANALYSIS

Further examples in international economics are instructive enough to merit a separate section. The concepts of balance-of-payments accounting, as of ordinary accounting, are tautologies. Just as the two sides of a firm's balance sheet have identical totals, thanks to carefully formulated interlocking concepts, the same is true of the credit or plus and debit or minus sides of a country's balance-of-payments statement for a definite time period. This equality of the two totals presupposes complete and accurate information on all aspects of all relevant transactions. In practice, inadequacy of information plagues presentation of an actual statement. Conceptual difficulties (concerning, for example, the uncertain classification of transactors as residents or nonresidents, the ambiguous dating of some transactions, and the handling of smuggled goods) require adopting somewhat arbitrary conventions.

Quibbles can thus arise. The balance-of-payments concept, like other accounting conventions, the equation of exchange, and Walras's Law, may be defended against quibbles by expounding the nature and rationale of analytical tautologies. An analogy comes to mind with what Stephan Körner calls "more or less near-empirical, but still non-empirical mathematics" [1966, Ch. VII, esp. 98, 106-07]. In reality, boundaries between various classes may be fuzzy, and a proposition about a particular entity being a member or nonmember of a particular class may be "neutral" rather than "true" or "false". Still, we may treat inexact predicates and classes as if they were exact, so replacing neutral propositions by nonneutral ones. We can exhibit arithmetical concepts that are naturally and frequently identified — though never identical — with empirical ones. Discussion of these "complexes" is not empirical; it amounts at best to a "near-empirical" arithmetic.[11] In balance-of-payments accounting, we idealize and sharpen the concepts involved, arriving at propositions that are logical rather than brute empirical truths.

No one, to my knowledge, denies that these "near-empirical" categories and propositions are useful in analyzing empirical reality. In particular, if transactions are classified into separate "accounts" of the balance of payments (say current account, private capital account, and official-settlements account), then the "principle of compensating balances" comes into play: imbalance in one direction in one or more of the accounts must be matched by opposite imbalance in one or more of the remaining accounts. (Compare Walras's Law: excess demand or supply of one thing must be matched by opposite imbalance of one or more other things.) If a country is running a deficit on current account, the balance-of-payments tautology underscores the question of how that deficit is being "financed". An enlightening truism is sometimes forgotten: no deficit can arise or persist unless it gets financed somehow or other. It is similarly enlightening to recognize a country's balance of payments as the aggregate of the individual balances of payments of the persons, firms, government agencies, and other organizations composing the national economy.

The central formula of each of the three leading approaches to balance-of-payments analysis — the elasticities, absorption, and monetary approaches — is valid because of interlocking definitions of the terms it contains. The question of how these three approaches interrelate points to the application of Niels Bohr's "principle of complementarity" [Teller, 1980, 93, 105-106, 138-40] beyond its original range, as Bohr himself had foreseen. He recommended treating the wave and particle theories of light as complementary: physicists could legitimately employ each theory where it seemed to work, even if they did not (yet) know how to reconcile those seemingly contradictory theories. In balance-of-payments analysis, similarly, economists may legitimately draw whatever insights they can from each of the three approaches, if necessary leaving their possible reconciliation until later.

The absorption approach relates a country's international surplus (or deficit) on current account to its excess (or shortfall) of national production in relation to national absorption, the latter being output absorbed in consumption, investment, and government activity. Equivalently, it relates the country's current-account surplus (or deficit) to the excess (or shortfall) of national saving in relation to national investment, a government surplus or deficit counting as part of or as a deduction from national saving.

The monetary approach relates a country's overall international surplus or deficit (roughly, its balance on the official-settlements concept) to changes in the aggregate balance sheet of its monetary institutions. Its central formula, like the absorption-approach formula, hinges on interlocking definitions of its terms. Whether the approach is useful in practice depends largely on whether monetary and nonmonetary accounts can be distinguished clearly enough. One must avoid reading causal significance into mere tautological truths. It is a mistake, in particular, to suppose that growth of a country's money supply necessarily represents *intentional* buildups of cash balances.

The elasticities approach centers around an algebraic expression whose sign supposedly indicates whether currency devaluation "improves" or "worsens" the country's balance of payments. This "stability" formula features terms for demand and supply elasticities of imports and exports. The mathematics of its derivation makes the formula tautologically valid, presupposing in it special though often tacit definitions of the elasticities (involving in what respects they are *mutatis mutandis* rather than *ceteris paribus* elasticities). Whether or not the approach is useful for analysis of the real world depends largely on whether the conceptions of elasticity necessary to make the formula correct are near enough to or too far from ordinary conceptions of price elasticity.

Sidney S. Alexander [1952; 1959] criticized the elasticities analysis of exchange-rate adjustment as mere implicit theorizing. The formula for "normal" response of the balance of payments derives purely from manipulation of definitions and has no operational content, he said, unless the import and export demand and supply functions whose elasticities enter into it are independently specified. Those functions can hardly be specified so that their elasticities are "partial" elasticities, indicating how sensitively the quantities respond to their own prices when incomes and other prices remain unchanged; for exchange-rate adjustment simply cannot leave these other things unchanged. Alternatively, the elasticities might be interpreted as "total", indicating how the quantities respond when not only their own prices but also everything else change as in fact they will change in direct or indirect response to the exchange-rate adjustment. The stability formula then becomes tautologically correct but empty. No one could know the sizes of its "total" elasticities without *already* having a complete analysis of how domestic and foreign economies respond to the exchange rate. Carried to its ultimate degree, the total-elasticities approach would assert — emptily — that what happens depends on the elasticity of the country's balance of payments with respect to the exchange rate [Pearce, 1970, *passim*].

But the futility of an approach carried to its ultimate does not imply futility carried judiciously part way. The analyst seeks some compromise between meaningful but unmanageable realism and detail at one extreme and apparent simplicity but emptiness at the other extreme. In balance-of-payments analysis, such a compromise may well involve ignoring or stripping away complications concerning the exact specification of the elasticities. An admittedly tautological formula does nevertheless prove useful in contemplating what conditions would contribute and what ones would impair "normal" response of the balance of payments to the exchange rate.[12]

CONCLUSION

The examples presented here help one recognize a particular style or ingredient of argument and better understand its application in particular contexts from its perhaps more familiar use in others. This recognition should help a writer forestall or answer illegitimate objections, such as empirical quibbles raised against tautologically true propositions like Walras's Law and the equation of exchange.

Concepts may legitimately be formulated so that certain propositions about relations among them are not merely true but necessarily true. Many propositions of science are true as a matter of convention, yet conventions are not arbitrary. Whether a convention is useful and convenient hinges on whether and how it makes contact with reality.

NOTES

1. I am particularly thinking of trouble in making readers understand Alan Rabin's and my paper on "Monetary Aspects of Walras's Law and the Stock-Flow Problem".
2. Thomas Hobbes [1651/1968, Chs. 8 and 46] suggested that one might test whether a piece of abstract philosophizing means anything by seeing how readily it could be translated from the original language into another.
3. For similar remarks about astronomical systems, space, time, and the measurement of time, see Poincaré [1958, 2728, 30, 36, 69, 140-141; 1952, 90-91] and Dantzig [1954, 52-3, 64-8]. On the kinetic theory of gases, see Poincaré [1958, 131; 1952, 147] and Campbell [1957, 126-31]. For a general distinction between "empirical" and "abstract" objects and processes, see Zinov'ev [1983, 57-9, 170-71, and *passim*].
4. On relations between models, theories, and reality in economics and on the "category mistake" of trying to test models, see Hausman [1992, 76-9, 245, 273, and *passim*].
   The usefulness of model-building in some cases and for some purposes hardly justifies insistence on it as the only acceptable method; it hardly justifies badgering researchers with routine cries of "What is your model?" and "How can your model be tested?"
5. Sometimes tautologies look deceptively like brute facts of reality. It seems a brute fact that might quite conceivably have turned out otherwise that exactly 143 prime numbers occur in the range of 100 to 1000. Yet this specific count follows rigorously from the very concepts of number and prime number.
6. Although experience played an indispensable role in its genesis, geometry is not an experimental science. "[E]xperience does not tell us which geometry is true, it tells us which is the most *convenient*" [H. Poincare, *Space and Geometry*, quoted without page number in Dantzig, 1954, 52].
7. Poincaré [1952, Ch. VI, esp. 97-106] makes similar but more detailed remarks on the meanings and interrelations of force, mass, and acceleration. Compare Meyerson [1991, esp. 439-40] on the deductive nature of "rational mechanics".
8. I am indebted to Roger Garrison for calling my attention to Kirchhoff's laws and for this reference.
9. Compare Richard Feynman's view of the conservation laws as sketched in Gleick [1992, 361].
10. While one might sensibly do empirical research related to comparative advantage in some way or another, it would be a category mistake to embark on *testing* the principle of comparative advantage, just as on testing the Heckscher-Ohlin theorem or the Rybczynski theorem or the equation of exchange.
11. Körner maintains that "[d]eductive abstraction, the cutting out of irrelevancies, ... the elimination of inexactness, the drawing of sharp demarcation-lines through indefinite conceptual borders" [1966, 167] are applied, for example, in the various systems of geometry [ibid., 112] and in classical mechanics [ibid., 159].
12. Still other examples of tautology in economics may be found. James R. Wible [1982-83] gives an insightful if unenthusiastic review of tautological strands in the macroeconomic literature of rational expectations.

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