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The Formal Logic of Testing Structural Change in Meat Demand: A Methodological Analysis

George C. Davis

DEPARTMENT OF AGRICULTURAL ECONOMICS
TEXAS A&M UNIVERSITY
COLLEGE STATION, TEXAS

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George C. Davis
gdavis@tamu.edu

Department of Agricultural Economics
Texas A&M University
College Station, Texas 77843-2124

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Abstract

In the past two decades, the profession has expended valuable resources testing structural change in meat demand with mixed results. Overlooked to date is a fundamental methodological problem that transcends *all* of the methods of testing for structural change. In this study, a formal logic framework is utilized in which methodological problems associated with *any* hypothesis test can be analyzed. Within this framework, it is proven that there is no valid test of *any* single hypothesis, including structural change. Because of this result, additional criteria from the methodology literature are then used to evaluate the literature on structural change in meat demand.

Key words: logic, meat demand, methodology, structural change.

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Introduction

In the past two decades, the profession has expended valuable resources attempting to answer the question: "What has caused the change in the pattern of meat consumption?" The most frequently cited explanation is a change in preferences (i.e., structural change). In their survey of research literature, appearing in *The Economics of Meat Demand* (a compilation of studies edited by Buse), Smallwood, Haidacher, and Blaylock cite 11 studies conducted between 1982 and 1986 that reportedly tested for structural change. The results were mixed: seven investigations found structural change of some type and four did not. The general conclusions drawn from Buse's compiled studies were: (a) The preferred test for structural change of varying parameters is uninformative, (b) hypotheses other than structural change should be pursued to explain the change in meat consumption, and (c) testing for structural change is intractable.[1] While these conclusions may appear obvious, a look at the literature since 1986 reveals that they are not obvious, and are almost invariably ignored, as Alston and Chalfant (1991a p. 36) have observed.

Since 1986, at least 20 articles have been published that focused on testing structural change in meat demand and 17 of these are shown in table 1.[2] Of these 17 articles, 13 found structural change and four did not. Perhaps the most striking feature of table 1 is the type of research that has been conducted in light of the conclusions reached in Buse's *The Economics of Meat Demand*. First, with the exception of the nonparametric studies and contrary to the admonitions in the *Economics of Meat Demand*, structural change is most often tested by some form of a varying parameters test. Second, most of the alternative hypotheses put forth only alter the testing framework for structural change (i.e., dynamic or inverse demands, measurement error, and nonparametric tests). With the notable exceptions of Eales and Unnevehr (1988), McGuirk et al., and Gao and Shonkwiler, once the structural change test is conducted within the new framework and structural change is found, no explanation of the structural change is rigorously pursued. Finally, the continued attempts to test for structural change suggest that structural change testing is not thought to be an intractable problem. Is this research agenda indicative of a "failure by the discipline," as Purcell claims, or does this "failure" represent a more fundamental problem?

This paper pursues two objectives to determine if there is a fundamental problem associated with testing structural change in meat demand. The first objective is to use formal logic to develop a general framework that allows methodological problems associated with *any* hypothesis test to be succinctly discussed and analyzed. Within this general framework it can be proven that there is no valid test of *any* single hypothesis, including structural change. The lack of a valid test for any single hypothesis is a fundamental methodological problem that transcends *all* methods used to test for structural change, and this fundamental methodological problem is not easily seen when insular methods are pursued. Indeed, though Alston and Chalfant (1991a, b), Chalfant and Alston, and McGuirk et al. have correctly pointed out the limitations of parametric methods in a series of articles, the problem is more pervasive than their parametric criticisms suggest.

The general result that no single hypothesis is testable is well known in the philosophy of science (i.e. methodology) literature as the 'Duhem thesis,' named for the French physicist/philosopher who wrote of this problem in 1906. Although the Duhem thesis has been sporadically alluded to in the agricultural economics literature (e.g., Ladd; Randall), the data in table 1 suggest that its implications are not fully acknowledged or appreciated. Furthermore, in the few instances where the Duhem thesis is cited, no discussion is provided to describe how the thesis may be addressed—which leads to the second objective of the paper.

The second objective of the paper is to evaluate the research in table 1 according to criteria developed in the methodology literature that are specifically designed to address Duhem's thesis. These criteria must be considered in addition to standard methods of theory testing (e.g. statistical testing) because Duhem's thesis undermines the standard methods of theory testing. The general conclusion drawn from this evaluation is that while only five of the 17 articles listed in table 1 satisfy all of the additional criteria, 13 of the 17 articles satisfy some of the additional criteria. Thus there does not appear to be a "failure by the discipline," but there is room for improvement.

The paper makes three contributions to the literature. First, the paper provides the methodological foundations for the conclusions reached in *The Economics of Meat Demand* (Buse), as well as those reported by Alston and Chalfant, and more generally, by Bessler and Covey. Second, the additional methodological criteria discussed here suggest fertile research agendas in the area of meat demand. Finally, and most importantly, the paper provides a general framework for discussing and evaluating empirical results across methods of analysis.

In the next section, the formal logic needed for this paper is presented. In the following section, the general steps for constructing a typical empirical model are laid out along the lines of Darnell and Evans; and Kim, De Marchi, and Morgan. This typical empirical model then provides the foundation for the argument forms in which the methodological analysis is carried out. Next, additional criteria from the methodology literature are discussed for comparing theories, followed by an evaluation, according to these criteria, of the studies listed in table 1. The paper ends with a summary and implications.

The Formal Logic of Hypothesis Testing

The difficulty in assessing the arguments for and against structural change is that there is no general unified framework that can accommodate all the different assumptions and methods under which the discussion can take place. Formal logic is a language designed specifically for such problems and, for that reason, is used extensively in the methodology literature. Because the focus of formal logic is on argument forms rather than specific arguments, results obtained using a formal logic framework will apply to all arguments—regardless of whether the testing is done with parametric, semi-parametric, or nonparametric models. For this reason, any perceived cost associated with understanding the formal logic are far outweighed by the breadth of understanding it brings to the general problem of hypothesis testing.

There are many formal logics of varying complexity; however, simple propositional logic will suffice to demonstrate the main points of the paper. The major components of propositional logic required for the paper are presented in the text, while the more specific aspects are relegated to the appendix.

Propositional logic deals with the logical relation between statements termed *propositions*. *Simple* propositions make a single claim, whereas *complex* propositions make more than a single claim. Propositions are then used to form *arguments*. An argument is defined as a sequence of propositions in which some propositions, called *premises*, are used to support a proposition (or propositions) termed a *conclusion*. In the logic of hypothesis testing, there are two premises: the hypothesis and the test evidence.

The first premise is the hypothesis, which is a *conditional* statement. A conditional statement is a statement of the form 'if ϕ, then ψ,' and is written in logical form as $\phi \rightarrow \psi$. The symbol ϕ is a *propositional variable* called the *antecedent*, and represents a proposition. The antecedent in the scientific hypothesis is usually a *complex* proposition, which means it consists of many simple propositions. The symbol ψ, also a propositional variable, is termed the *consequent*, and represents another proposition. The second premise is the test evidence and may be one of two types: either the consequent ψ is believed true, or *not* ψ is believed true, where *not* ψ is denoted as $\sim\psi$.[3] From the hypothesis and the test evidence, the conclusion is drawn and the argument completed.

An argument form is *valid* if there is no case in which the premises are true and the conclusion false. An argument form is *invalid* if the premises can be true and the conclusion false. A simplistic example of a valid argument is: 'If Karl ate **C**hicken, then **K**arl ate meat. Karl ate **C**hicken. Therefore, '**K**arl ate meat.' When placing a specific argument in logical form, propositional variables are replaced with *propositional constants* that represent specific propositions and are usually capital letters. The argument is then written in logical form as $(\mathbf{C} \rightarrow \mathbf{K})$, $\mathbf{C} \vdash \mathbf{K}$. A comma is used to separate premises, and a turnstile is used to separate premises from the conclusion.

Because the scientist is attempting to draw inference about the antecedent (ϕ) from the test result of the consequent (ψ), there are two possible argument forms that are internally consistent: $\phi \rightarrow \psi,\ \psi \vdash \phi$ or $\phi \rightarrow \psi,\ \sim\psi \vdash\ \sim\phi$. The question is then: Are these argument forms both valid? Since these argument forms are so common and are thoroughly discussed in any introductory logic text, the results regarding validity are given here as lemmas:

LEMMA 1. The argument form $\phi \rightarrow \psi,\ \psi \vdash \phi$ is invalid.

LEMMA 2. The argument form $\phi \rightarrow \psi,\ \sim\psi \vdash\ \sim\phi$ is valid.

Lemma 1 is a fallacious argument form known as 'affirming the consequent.' Consider the previous argument: 'If Karl ate **C**hicken, then **K**arl ate meat.' Suppose we are told only that '**K**arl ate meat' is true. From this it would be invalid to conclude that 'Karl ate **C**hicken,' because he may eat only beef. So (**C**→**K**), **K** |– **C** is invalid.

Alternatively, Lemma 2 is known as 'denying the consequent' and is valid. Note that if we were told '**K**arl did not eat meat,' we could correctly conclude that 'Karl did not eat **C**hicken'—so **C**→**K**, ~ **K** |– ~ **C** is valid. Lemmas 1 and 2 capture the essence of Popper's falsificationist philosophy of science. Popper pointed out that no single experiment proves a theory (Lemma 1), but a single experiment may falsify a theory (Lemma 2).

To prove that there is no valid argument form for a single hypothesis such as structural change, one additional lemma is required:

LEMMA 3. (Duhem's Thesis). Let ϕ be the conjunction of *n* propositions, written in logical form as $\phi = (\phi_1 \wedge \phi_2 \wedge \ldots \wedge \phi_n)$, where each ϕ_i is called a *conjunct* and represents the *i*th proposition. The argument form $\phi \rightarrow \psi$, $\sim\psi \vdash\ \sim\phi_i$ for any *i* is invalid.

Proof. Refer to the appendix.

An simple example of Lemma 3 is the following argument: Let 'if Karl eats **C**hicken *and* Pierre eats **B**eef, then both **K**arl *and* **P**ierre eat meat' be a simple hypothesis. Let 'it is not true that both **K**arl *and* **P**ierre eat meat' be the evidence. From this evidence it cannot be concluded, however, that either 'Karl does not eat **C**hicken' *or*

'Pierre does not eat **B**eef.' It may be that Karl does eat chicken, but Pierre is a vegetarian. All that can be concluded is: 'It is not the case that Karl eats **C**hicken *and* Pierre eats **B**eef.' Thus, the argument forms $(\mathbf{C}\wedge\mathbf{B})\rightarrow(\mathbf{K}\wedge\mathbf{P})$, $\sim(\mathbf{K}\wedge\mathbf{P}) \vdash \sim\mathbf{C}$ and $(\mathbf{C}\wedge\mathbf{B})\rightarrow(\mathbf{K}\wedge\mathbf{P})$, $\sim(\mathbf{K}\wedge\mathbf{P}) \vdash \sim\mathbf{B}$ are each invalid.

Popper (1968, chpt. 3) refers to the conjunction ϕ in a scientific setting as a *theoretical system*. A theoretical system is just the conjunction of all the assumptions that generate an empirical model. As Lemma 3 proves, a single hypothesis within a theoretical system is not falsifiable and this is Duhem's thesis. The immediate corollary to Duhem's thesis is that if the theoretical system is false, it may be because any subset of the propositions or assumptions is false—but it cannot be determined which subset is false without further information. For this reason, philosophers of science refer to theories as being 'underdetermined' (Salmon et al.). With this formal logic background, the arguments for testing structural change can now easily be analyzed.

Construction of a Typical Empirical Model

To employ the logical tools of the previous section, a typical argument for testing structural change must be specified. This can be accomplished by first constructing a typical empirical model along the lines of Darnell and Evans. This construction is a specific application of the more general discussion recently given by Kim, De Marchi, and Morgan. After the typical empirical model is constructed, the formal methodological analysis can begin.

Whenever empirical work is based on theoretical foundations, four types of assumptions must be made to generate an empirical model: (a) *ceteris paribus assumptions* made at the outset to restrict the range of the phenomenon under consideration (e.g., institutional structure is constant); (b) *theoretical conceptual assumptions* that formalize the conceptual theory and from which the implications of the theory are derived (e.g., quasi-concave utility function); (c) *theoretical bridging assumptions* that make the theory empirically accessible (e.g., functional form); and (d) *empirical bridging assumptions* that connect the empirically accessible theory to the data of interest (e.g., measurement variables).

The term "bridging assumption" comes from Hempel and helps distinguish between the different types of assumptions that are made in constructing a typical empirical model. In going from (a) to (d), no clear delineation exists between specific assumptions, though the hierarchy of assumptions (Stewart) and general delineation between types of assumptions is considered an accurate taxonomy. Furthermore, there is likely a hierarchy within each type of assumption, and it is accepted that the classification of specific assumptions is debatable. Because the *ceteris paribus* assumption in the present context is self explanatory, attention turns directly to assumptions (b) through (d).

Theoretical Conceptual Assumptions

The standard realist assumption that there exists a representative consumer who maximizes a classical static utility function subject to a budget constraint (which is so prevalent in the literature) will be utilized here. The optimization process leads to a system of theoretical demand functions:

(1) $Y^* = F(X^*; B)$,

where $Y^* \in R$ is the theoretical set of goods and services consumed by the representative consumer, $X^* \in R$ is the theoretical set of demand determinants, $F: X^* \rightarrow Y^*$ is the 'true' theoretical functional form of the demand system, and $B \in R^p$ is the set of 'true' theoretical parameters associated with F. All the implications of the theory are captured by the demand system.

Theoretical Bridging Assumptions

As is well recognized, the demand system characterized by (1) is far too general to be empirically tractable, and therefore requires two types of theoretical bridging assumptions. First, some type of assumption must be made to reduce the prohibitively large dimensions of Y^* and X^*. Therefore, some type of aggregation assumption (i.e., Hicks's composite commodity theorem or separability) or incomplete demand system assumption must be made. In either case, only subsets of Y^* and X^* are then defined as $y^* \subset Y^*$ and $x^* \subset X^*$. Second, since the 'true' functional form is unobservable, a functional form f is chosen, such that $f: x^* \rightarrow y^*$. Thus, a partial theoretical model of (1) is expressed as

(2) $y^* = f(x^*; \beta)$,

where $\beta \in R^k$ is the set of 'true' model parameters.

Empirical Bridging Assumptions

Theory provides no guidelines to observational units or measurement variables; thus the researcher is forced to assume that the theory applies to a specific observational unit and that selected measurement variables correspond to the theoretical variables. Let the observational units be denoted by t, which may represent weeks, months, or years in a time-series context, or households, states, or countries in a cross-sectional context. Let the measurement variables for y^* and x^* be denoted by y and x. The empirical model then becomes

(3) $y_t = f(x_t; b)$,

where b is the observable measure of β.

At this point, the only unknown component of (3) is b. Obtaining an accurate measure of b is the province of econometrics, and while econometric assumptions and techniques are certainly important, they are irrelevant when it comes to the logic of hypothesis testing. Because b possesses a probability distribution, there is, technically speaking, no way to ever prove or disprove anything with any measure of b. While this fact would further bolster the argument made here, it will be assumed that a 'divine econometrician' reveals the true value of b such that it is known with certainty. This assumption immediately removes econometric technique or method from the argument.

The Logic of Structural Change Testing

As outlined in the discussion, the empirical model is constructed by conjoining several types of assumptions. By using propositional constants to denote the different assumptions, the two theoretical systems (i.e. antecedents) for structural change occurring and not occurring can be defined as

(4) Structural Change: $T_0 \equiv_{df} (C \wedge A_1 \wedge A_2 \wedge A_3 \wedge A_4 \wedge A_5 \wedge \Delta S)$;

(5) No Structural Change: $T_1 \equiv_{df} (C \wedge A_1 \wedge A_2 \wedge A_3 \wedge A_4 \wedge A_5 \wedge \sim \Delta S)$.

The symbol '$\equiv_{df}$' means "is by definition". The propositional constants representing all the assumptions that are acceptable *a priori* are: C = all *ceteris paribus* assumptions, A_1 = all theoretical conceptual assumptions made in order to generate the theoretical demand system (1), A_2 = the dimension reduction assumptions made in order to reduce the variable space to y^* and x^*, A_3 = the functional form assumption f, A_4 = the observational units t assumption, A_5 = the chosen measurement variables y and x assumption, and ΔS = the structural change assumption. Clearly these conjuncts are themselves complex propositions, as there are many specific assumptions embedded within each one of these major headings; however, these capture the major assumptions.

The common claim in the literature is that the consequent of structural change is varying parameters in the empirical model (3) (i.e., Δb). Following that convention, the hypothesis of structural change would then be written in logical form as $T_0 \rightarrow \Delta b$, which is read as: 'If all the assumptions listed are unproblematic and there is structural change, then the parameters in the empirical model will vary.' The alternative hypothesis of no structural change would be similarly written and interpreted. The available evidence from the empirical model (3) would be either that the parameters are varying (Δb) or that they are not ($\sim \Delta b$), but not both. Using the lemmas, the metatheorem may now be stated.

METATHEOREM. There is no valid argument form for structural change tests.

Proof. There are four possible argument forms: (i) $T_0 \rightarrow \Delta b,\ \Delta b \vdash \Delta S$; (ii) $T_1 \rightarrow \sim \Delta b,\ \sim \Delta b \vdash \sim \Delta S$; (iii) $T_0 \rightarrow \Delta b,\ \sim \Delta b \vdash \sim \Delta S$; and (iv) $T_1 \rightarrow \sim \Delta b,\ \Delta b \vdash \Delta S$. By Lemma 1, arguments (i) and (ii) are invalid. By Lemma 2, it is valid to conclude for arguments (iii) and (iv) that $\sim T_0$ and $\sim T_1$ are true, but it is invalid by Lemma 3 to conclude in argument (iii) that $\sim \Delta S$ is true, or in argument (iv) that ΔS is true.

As the metatheorem demonstrates, even if all of the parameters of a model were known with certainty, there is still no valid test of structural change. The only valid test is of a theoretical system. More explicitly stated, there is no valid test of structural change, only a test of the conjunction of the ceteris paribus assumptions, the theoretical conceptual assumptions, the dimension reduction assumptions, the functional form assumption, the observational units assumption, the measurement variables assumption and the structural change assumption.

While it would seem the metatheorem result should be obvious and well known, table 1 indicates otherwise. As Alston and Chalfant (1991a p. 36) have stated in their parametric analysis: "That results are therefore always conditional on specification choices is equally obvious but almost invariably ignored…This is noticeably so in the large number of recent studies of structural change in the demand for meat." Because the result holds even in the hypothetical situation of the parameters being known with certainty, it also implies that even if all econometric assumptions were diagnosed as satisfactory as advocated by McGuirk, et al. there would still be no valid test of structural change. What is clearly demonstrated here by the metatheorem is that the results extend beyond parametric models. Even if a nonparametric technique is used and no functional form is assumed, there is still no valid test of structural change. In fact, the metatheorem applies to all hypothesis testing. There is no proof or disproof of a single hypothesis. Thus, the scientist is caught in what may be termed the Popper-Duhem dilemma: While Popper's falsification criteria is the only logically correct way to test a theory, Duhem's thesis nullifies falsification of a single hypothesis.

Additional Methodological Criteria

The metatheorem, or Popper-Duhem dilemma, is the central reason why there is presently no consensus in the philosophy of science literature. From the Popper-Duhem dilemma, it is clear that any subset of the assumptions could be altered such that the theoretical system would not be falsified. Thus the researcher who believes there has been no structural change can always claim the finding of structural change is because one of the other assumptions in the theoretical system is incorrect (e.g. the dimension reduction assumption is problematic or the functional form assumption is problematic or the selected measurement variables are problematic). The researcher can therefore reconsider any assumption(s), that initially may have been considered correct or innocuous, in order to generate a new theoretical system (T_1) that may not be falsified. This process of reconsidering assumptions that initially were assumed true by default is known as diagnostic reasoning. (Janssen and Tan provide an introduction and case study of diagnostic reasoning in economics.) Thus, the researcher can be seen as diagnosing which component of the theoretical system needs to be adjusted to explain the falsification or 'anomaly.' The relevant methodological question becomes: How are alternative diagnoses to be critically evaluated? This is the problem addressed by Lakatos.[4]

Lakatos retains Popper's notion of science by accepting a theory as scientific only if there is an *empirical basis*. The empirical basis is the set of potential falsifiers, i.e., the set of those observational propositions which may disprove (p. 98). However, recognizing that Duhem's thesis allows the scientist to alter any assumption, and therefore create a new theoretical system T_1 in an attempt to avoid falsification, Lakatos defines a theoretical system (T_0) as falsified if and only if another theoretical system (T_1) has been proposed with the following characteristics:[5] (a) T_1 has excess content over T_0 by predicting novel facts that are improbable or even forbidden by T_0; (b) T_1 explains the previous success of T_0, and all the unrefuted content of T_0 is included in the content of T_0; and (c) some of the excess content of T_1 is corroborated.

If the alternative theoretical system T_1 satisfies (a) and (b), then there is *theoretical progress*. If all three conditions are satisfied, there is *empirical progress*. De Marchi (p. 134) points out that Lakatos identifies another type of progress, which will be termed *empirical basis refinement* (Lakatos, p. 121, footnote 4). Empirical basis refinement occurs when the technique for testing a theory is altered in a manner that provides a more accurate and appropriate test of the theory. Consider a simple example of these concepts. Let an original theoretical system specify a linear demand function but a new theoretical system specify a quadratic demand function. The quadratic specification would possesses empirical basis refinement because hypothesis testing occurs within a more general framework. The quadratic specification is theoretically progressive because it would predict an interaction effect that is forbidden by the linear specification. The quadratic specification would also be empirically progressive if the significance of the interaction terms was corroborated. In the process of evaluating a diagnosis, there are then three types of progress to consider: theoretical, empirical, and empirical basis refinement.

Methodological Appraisal of the Literature

Within the general methodological framework presented, the diagnosis that there has been a change in preferences (i.e., structural change) is clearly only one of an infinite number of diagnoses that could account for the changing pattern of meat consumption. The studies cited in table 1 emphasized seven diagnoses to account for this change: (a) a change in preferences, (b) measurement error, (c) inverse demand, (d) nonparametrics (e) dynamics, (f) separability, and (g) causal factors. Based on the methodological criteria set out in the previous sections, these seven approaches now can be critically evaluated according to how many of the criteria they satisfy.

The first diagnosis of changing preferences (Al-Kahtani and Badr El-din; Anderson and Goddard; Choi and Sosin; Moschini and Meilke), is the least progressive of all diagnoses because it is not theoretically or empirically progressive and it does not refine the empirical basis. The major shortcoming of this diagnosis is that changing preferences are claimed to be captured by varying parameters. The metatheorem clearly indicates that regardless of functional form, data, or any specification choice, varying parameters are neither necessary nor sufficient for changing preferences. While researchers often acknowledge this fact, most studies go on to infer from changing parameters that there is structural change. Given that this inferential procedure seems to have become pervasive within the profession, assume momentarily that it is valid and let us see if it withstands closer methodological scrutiny.

Closer methodological scrutiny requires answering the question: “Does stable preference theory disallow varying parameters in an empirical model?” The answer to this question is no. Stable preference theory also permits varying parameters in a parametric model and therefore the changing preference assumption does not account for any result that is not also accounted for by the stable preference assumption. Hence, the assumption that changing preferences are causing the varying parameters represents no theoretical or empirical progress over the stable preference theory. But, let us weaken the argument still further and suppose this is not the case. That is, suppose that varying parameters do indicate changing preferences. Does the fact that preferences are changing possess any excess content? Perhaps, but very little. The key question science seeks to answer is “why?” Knowing there has been a change in preference is an example of descriptive knowledge, but growth in science comes from explanatory knowledge (Salmon). Explanatory knowledge is achieved by identifying causal factors, and it is from this identification that excess content can be generated. Therefore, a more progressive approach is one in which the factors causing the parameters to change (i.e., the so-called changing preferences) are identified and incorporated in the analysis.

From table 1, the studies focusing on measurement error, inverse demand systems, and nonparametrics are all examples of diagnoses that are progressive, but only in terms of refining the empirical basis. A diagnosis that a variable is incorrectly measured (Atkins, Kerr, and McGivern) represents no theoretical or empirical progress because there is no improbable novel fact associated with the new measurement that was not also associated with the old measurement. However, using a more appropriate measurement variable clearly tightens the correspondence between the theory and the empirical model, and therefore is progressive because it refines the empirical basis.

The studies listed under the heading inverse demand systems (Eales and Unnevehr 1993; Dahlgran 1987, 1988; Thurman) question the default assumption that prices are exogenous, and instead propose that perhaps quantities are exogenous. As these authors discuss, this is an issue dealing with the difference between a representative agent theory and a market theory where supply may not be perfectly elastic at the market level. With regard to demand behavior, there is nothing theoretically or empirically progressive about altering this assumption because the price-dependent form predicts nothing improbable or forbidden by the quantity-dependent form. However, this approach is progressive from the standpoint of refining the empirical basis because, until supply is correctly accounted for, tests for varying parameters may be misleading.

Because the choice of functional form is always debatable, the studies classified as nonparametric (Burton and Young 1991; Chalfant and Alston; Sakong and Hayes) offer an alternative way of testing certain assumptions or hypotheses. Structural change is supposedly tested using nonparametric techniques to observe periods in which violations of optimizing behavior occur. However, as shown by the metatheorem, even if the default assumption regarding the functional form specification is removed, the argument form for claiming a nonparametric method test for structural change is still invalid. It could be argued that a nonparametric method actually represents a degenerative approach relative to a parametric approach because the former has less empirical content than the latter (e.g., no elasticity estimates). But because the nonparametric approach relaxes a rather stringent default assumption (i.e., a specific functional form), it is progressive because it refines the empirical basis.

Because static theory can be considered nested within dynamic theory, the dynamic specifications (Burton and Young 1992; Chen and Veeman) refine the empirical basis. The dynamic specifications also represent theoretical and empirical progress because they allow for lagging and leading variables to influence consumption, which is not captured by static models. Similarly, considering alternative separability conditions (Eales and Unnevehr 1988) and, hence, product aggregation schemes, refines the empirical basis because a more appropriate theoretical framework is used for conducting the hypothesis test. Considering more appropriate aggregation schemes also produces excess content in the form of different cross-price and expenditure relationships.

The only studies in table 1 that consider causal factors for the so-called structural change are Gao and Shonkwiler; and McGuirk et al. Where the other studies only speculate that changes in nutrition concepts or demographics may explain the observations of varying parameters, Gao and Shonkwiler; and McGuirk et al. proceed to incorporate some of these causal factors into the model. Because their general empirical approach is consistent with a more general theory of demand and they attempt to answer the “why” question, these studies must be considered the most progressive of all the approaches because they are both theoretically and empirically progressive. The incorporation of these other variables generates theoretical and empirical excess content over all other models. Furthermore, because the hypothesis is considered in this more general framework, the empirical basis is refined in both studies.

Summary and Implications

The first objective of this paper was to develop a general logical framework that allows methodological problems associated with *any* hypothesis test to be succinctly discussed and analyzed. This objective was easily achieved by employing some formal logic, and it was proven that there is no valid test of *any* single hypothesis, including structural change. Given this result, the second objective was to appeal to the methodology literature for additional criteria for evaluating the research on structural change in terms of its progress. The criteria used were those proposed by Lakatos related to theoretical progress, empirical progress, and empirical basis refinement. The 17 articles in table 1 addressing structural change in meat demand were appraised based on how many of these criteria were satisfied. Four of the articles did not satisfy any of these criteria, eight of the articles satisfied only the empirical basis refinement criterion and five of the articles satisfied all three criteria. However, of the five articles that satisfied all three criteria, the articles by Gao and Shonkwiler, and McGuirk, et al. specifically incorporated the factors that were speculated by other articles as inducing the so called structural change, and for this reason, are the most progressive of the 17 articles.

The implications of this methodological appraisal indicate that utilization of a more generalized demand framework is a progressive approach to pursue for future research. A generalized demand framework recognizes that an indirect utility function is a function of many other variables, in addition to contemporaneous prices and expenditures. While generalized demand functions can be generated in several ways, perhaps the two most common are either through translating and scaling variables or through household production theory. (Lewbel demonstrates a very general procedure for incorporating other variables into a demand function.) The generalized demand approach produces substantial excess content over the classical approach because it can account for so many phenomena not addressed by the standard demand theory, thereby achieving substantial theoretical and empirical progress. Furthermore, this approach refines the empirical basis because the hypothesis is cast in a more general and appropriate framework. (Examples of such analysis would be Jorgenson and Slesnick, or Gao and Spreen.) This conclusion is in agreement with Buse's 'alternative hypotheses' recommendation, and is supported by the conclusions of other studies (Haidacher; Wohlgenant; Capps and Schmitz) seeking to explain the change in meat consumption.

Until now, no methodological foundations have been offered to support the three general conclusions drawn in Buse's *The Economics of Meat Demand*: (a) The preferred test for structural change of varying parameters is uninformative, (b) hypotheses other than structural change should be pursued to explain the change in meat consumption, and (c) testing for structural change is intractable. By providing the methodological foundations for these conclusions, hopefully these points will no longer be overlooked.

Appendix

Because formal logic may be unfamiliar to some, this appendix summarizes the rules of propositional logic needed to prove Lemma 3. A more thorough treatment of propositional logic can be found in any introductory logic textbook (Nolt is followed here). There are two aspects of any formal logic: the syntax and the semantics.

Syntax for Propositional Logic

Formulas in propositional logic are constructed from four sets of characters:

1. Propositional constants—capital letters used to symbolize a proposition.
2. Logical operators—symbols denoting connectives ($\sim$ for negation, $\wedge$ for conjunction, and $\rightarrow$ for conditional).
3. Brackets—symbols to separate formulas, {[()]}.
4. Numerals—positive integers to subscript sentence letters.

From this character set, the formation rules for propositional logic define a well-formed formula. The formation rules for propositional logic needed here are:

1. Any propositional constant is a formula.
2. If ϕ is a formula, then $\sim\phi$ is a formula.
3. If ϕ and ψ are formulas, then so are $(\phi\wedge\psi)$ and $(\phi\rightarrow\psi)$.

From the character set and the formation rules, complex propositions or arguments may be formed.

Semantics for Propositional Logic

The central concept in the semantics of a logic is truth value. If a formula ϕ is true, its truth value is denoted as $\upsilon(\phi) = T$. If ϕ is false, its truth value is denoted as $\upsilon(\phi) = F$. For any formula ϕ and ψ, and for any valuation υ, there are valuation rules. The valuation rules relevant for this paper are:

(i) $\upsilon({\sim}\phi) = T$ iff $\upsilon(\phi) = F$,
$\upsilon({\sim}\phi) = F$ iff $\upsilon(\phi) = T$;

(ii) $\upsilon(\phi \wedge \psi) = T$ iff $\upsilon(\phi) = T$ and $\upsilon(\psi) = T$,
$\upsilon(\phi \wedge \psi) = F$ if either $\upsilon(\phi) = F$ or $\upsilon(\psi) = F$;

(iii) $\upsilon(\phi \rightarrow \psi) = T$ if either $\upsilon(\phi) = F$ or $\upsilon(\psi) = T$,
$\upsilon(\phi \rightarrow \psi) = F$ iff $\upsilon(\phi) = T$ and $\upsilon(\psi) = F$.

Because interest here lies in valid versus invalid arguments, validity must be defined:

DEFINITION 1. An argument form is valid if there is no valuation on which its premises are true and its conclusion is false.

DEFINITION 2. A form is invalid if there is at least one valuation on which its premises are true and its conclusion is false.

Proof of Lemma 3. To prove invalidity requires showing one valuation in which the premises are true and the conclusion is false. The premise ${\sim}\psi$ is taken as given evidence, i.e., $\upsilon({\sim}\psi) = T$. Without a loss of generality, let $n = 2$, $\upsilon(\phi_1) = F$, and $\upsilon(\phi_2) = T$. From valuation rule (ii), it follows that $\upsilon(\phi) = \upsilon[(\phi_1 \wedge \phi_2)] = F$, and so from valuation rule (iii), $\upsilon[(\phi_1 \wedge \phi_2) \rightarrow \psi] = T$. By valuation rule (ii), it follows that the premise is true, i.e., $\upsilon\{[(\phi_1 \wedge \phi_2) \rightarrow \psi] \wedge {\sim}\psi\} = T$, however the conclusion ${\sim}\phi_2$ is not true because $\upsilon(\phi_2) = T$, and by valuation rule (i), $\upsilon({\sim}\phi_2) = F$, and so the invalidity is demonstrated.

Footnotes

[1] These points are made several places in Buse's *The Economics of Meat Demand* (pp. 14–16, 54, 95, 103, 113, 128, and 202).

[2] After this article was completed an additional number of articles came out continuing to address this issue. The more prominent ones are Cortez and Senauer, and the special issue of the *European Review of Agricultural Economics* edited by Michael Burton and Kyrre Rickertsen, which was entitled "Analysing Consumer Behavior and Structural Change in Food Demand." This special issue contained eight articles that addressed in some form or fashion the issue of structural change.

[3] It is recognized that a scientist may not believe either of these. The possibility is easily considered with a three-valued logic, but the added complexity of considering a three-valued logic will not change the major point of the paper.

[4] Lakatos' methodology is considered to be rather pragmatic. As Blaug (p. 32) observes, the Lakatos methodology is not as rigid and prescriptive as the naive version of Popper's falsification school, whereby a single hypothesis can be refuted by a falsifying instance. But it is more rigid and prescriptive than Kuhn's descriptive and historical account of science. For this reason, it is not surprising that Lakatos is criticized from both sides. Philosophers of science reproach him for not providing a solid demarcation principle between science and nonscience; alternatively, historians criticize Lakatos for not describing the scientific process accurately. Given that practicing economists are neither philosophers of science nor historians, they may take from Lakatos those aspects of his methodology that are recognized as advantageous and leave the rest (Cross). This

approach may be referred to as a “local provisional methodology” (Randall).

[5] Popper (1992), Van Fraasen, and Pietroski and Rey have proposed similar criteria.

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Table 1. A Summary of Structural Change Studies in Retail Meat Demand, 1986–95

Authors	Year	Source*	Testing Framework	Structural Change
Dahlgran	1987	WJAE	Inverse Rotterdam model with varying parameters test	yes
Thurman	1987	AJAE	Exogeneity testing and varying parameters test	yes
Chalfant and Alston	1988	JPE	Nonparametric tests	no
Dahlgran	1988	NCJAE	Inverse Rotterdam model with chi-square tests	yes
Eales and Unnevehr	1988	AJAE	Separability testing and first difference AIDS model	yes
Atkins, Kerr, and McGivern	1989	CJAE	Alternative measure of income with chi-square tests	no
Moschini and Meilke	1989	AJAE	AIDS model with varying parameters test	yes
Choi and Sosin	1990	AJAE	Translog utility function with varying parameters test	yes
Anderson and Goddard	1991	CJAE	First difference AIDS model with varying parameters test	yes
Burton and Young	1991	JAE	Nonparametric tests	no
Chen and Veeman	1991	CJAE	Dynamic AIDS model with chi-square tests	yes
Burton and Young	1992	ERAE	Dynamic AIDS model with varying parameters test	yes
Eales and Unnevehr	1993	AJAE	Exogeneity testing and first difference inverse AIDS model	no
Sakong and Hayes	1993	AJAE	Nonparametric tests	yes
Gao and Shonkwiler	1993	RAE	Latent taste variable Rotterdam model	yes
Al-Kahtani and Badr El-din	1995	AE	Kalman Filter varying parameters tests	yes
McGuirk, et al.	1995	JARE	AIDS model with Chow tests	yes

*WJAE = West. J. Agr. Econ., AJAE = Amer. J. Agr. Econ., JPE = J. Polit. Econ., NCJAE = N. Cent. J. Agr. Econ., CJAE = Can. J. Agr. Econ., JAE = J. Agr. Econ., ERAE = Eur. Rev. Agr. Econ., RAE = Rev. Agr. Econ., AE = Agr. Econ., and JARE = J. Agr. and Res. Econ.