Professor Hendry's Econometric Methodology Reconsidered: Congruence and Structural Empiricism

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Abstract

The empirical modeling methodology of the LSE school of econometrics is twofold. The theory of reduction explains how econometric models are intrinsically a kind of empirical model, derived from the data-generating process (DGP). The general-to-specific approach mimics the theory of reduction, and directs econometricians to obtain the final econometric model. The theory of reduction and the general-to-specific approach demonstrate the fact that the LSE approach is an empiricist methodology in which econometric models are said to match the phenomena in all measurable respects. This concept is known as congruence. Thus diagnostic tests in econometrics are construed as congruence tests. In addition, the LSE methodology is parallel to the structural approach in philosophy of science in which models are regarded as structural representations of the world. This paper studies the LSE methodology and argues that its empiricist methodology is compatible with the "structural empiricism" of van Fraassen.

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1 Introduction

The semantic approach clearly distinguishes between theoretical models and empirical models: theoretical models represent theories while empirical models represent the world. In economics and econometrics, however, few approaches have provided the distinction between theoretical models and empirical models. Yet, this issue is clearly addressed in the *LSE school of econometrics*, led by David Hendry and his collaborators[1].

The LSE econometricians, such as Hendry, are eager to tell colleague econometricians how to do econometrics. On the one hand, the LSE econometricians have developed a full account of methodology of econometrics in a series of theoretical papers. On the other hand, as practitioners of econometrics, LSE econometricians build empirical models according to their econometric methodology. But econometrics was not built in a day. David Hendry, obsessed with measuring models, often "experiments" with his methodological concepts in two famous empirical models that he returns to again and again like "laboratory mice": the demand for money model (Hendry and Mizon, 1978, Hendry, 1979, Hendry and Ericsson, 1983, Hendry, 1985, Hendry and Ericsson, 1991, and Ericsson, Hendry, and Prestwich, 1998a and 1998b) and the aggregate consumption function model. The latter is known as the *DHSY model* of consumption that was first published as Davidson et al. (1976). As this paper will discuss, the LSE approach marks the difference from other schools of econometrics who regard econometric models as models of economic theory, i.e., theoretical models. According to this latter approach, econometric models are constituted by a function derived from economic theories, indicating conjectured relations between variables, and an error term. According to the LSE approach, on

[1] Mizon (1995) offers a brief history of LSE econometrics.

the contrary, econometric models are construed as originating from the *data-generating process* (DGP) that produces data.

The LSE school of econometrics proposes the empirical modeling methodology in order to be consistent with their view of econometrics. At the theoretical level, the *theory of reduction* explains how econometric models are intrinsically a kind of empirical model, derived from the DGP. At the practical level, the *general-to-specific approach*, which intends to mimic the theory of reduction, directs econometricians to obtain the final econometric model from a general unrestricted model. The theory of reduction and the general-to-specific approach demonstrate the fact that the LSE approach is an *empiricist methodology* in which econometric models are said to match the phenomena in all measurable respects. This concept is known as *congruence*. Thus diagnostic tests in econometrics are construed as congruence tests. In addition, the LSE methodology is parallel to the structural approach in philosophy of science in which models are regarded as structural representations of the world. This paper studies the LSE methodology and argues that its empiricist methodology is compatible with the *structural empiricism* of van Fraassen.

2 Constructive Empiricism

Van Fraassen (1980, p.2) points out two sorts of studies in philosophy of science. One is foundational study that concerns the content and structure of the theory. The other sort of study in philosophy of science concerns the relation of a theory to the world. In the semantic approach, models are central to both discussions. Their view on the structure of the theory differentiates the semantic approach from the syntactic approach. The semantic approach argues that theory is constituted as a family of models that are independent of the theory’s linguistic formats. For example, Patrick Suppes's idea of presenting a theory is accepted by van Fraassen, that is, to "define the class of its models directly, without paying any attention to questions of axiomatizability, in any special language, however relevant or simple or logically interesting that might be" (van Fraassen, 1989, p.222). Regarding the theory-world relation, models are means of representing the world, up to a certain way of mapping, in certain respects and degrees. In particular, van Fraassen's *constructive empiricism* provides a characterization of science, which is defined by the following statement:

> Science aims to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate. This is the statement of the anti-realist position I advocate; I shall call it constructive empiricism. (Van Fraassen, 1980, p.12)

Empirical adequacy is such that theory only aims for accountability for observables. A theory is empirically adequate if theories only give a true account of what is observable. The adjective "constructive" at first glance implies that constructive empiricism is a "constructive alternative to scientific realism" (van Fraassen, 1980, p.5). The deeper meaning is that science does not aim at "discovery" of the truth concerning the unobservables, rather it aim at the construction of models that are adequate to the phenomena (van Fraassen, 1980, p.5).

Take van Fraassen's example of Newton's laws of motion to illustrate constructive empiricism: Newton has distinguished between the theoretical entities "absolute magnitudes", that appeared in his axioms, from measured entities "sensible measures", that are experimentally determined (van Fraassen, 1976, p.624). Accordingly, the empirical domain and the theoretical domain are distinguished. On the one hand, there are *empirical relational structures*. Apparent motion is defined as the difference between one planet's true motion to another, and is distinguished from true motions, which are defined theoretically. Thus the definition of apparent motion has something to do with its measurability[2]. Apparent motions form relational structures that van Fraassen calls *appearances.* Appearances are a kind of empirical relational structure for they are defined by measured entities such as relative distances, time intervals, and so on. On the other hand, there are theoretical relational structures. They are mathematical models provided by Newton's theory in which theoretical entities, namely absolute motions, are involved. These theoretical models are supposed to define (theoretical relational) structures that are "exact reflections of those appearances" (van Fraassen, 1980, p.45). In van Fraassen's terminology, the appropriate part of the theoretical model that is expected to account for the empirical relational structure is called the *empirical substructure* (i.e., empirical substructure is a part of the *theoretical relational structure*). Theory is regarded as *empirical adequate* if it has some models such that all actual appearances are identifiable with (isomorphic to) an empirical substructure in at least one of the theory's models[3]. In other words, if certain parts of the models were to be identified as empirical substructure, then they can be considered as a representation of the observable phenomena (appearances) (van Fraassen, 1989, p.227).

3 Theoretical models and empirical models

3.1 Models: general idea

In the LSE methodology, models are formal representations of phenomena. This definition of model is offered by Hendry and Richard (1982, p.4), that:

[2] See Ellis (1966) for the issues of measurement.
[3] See van Fraassen (1976) p.63.

> A model of any set of phenomena is a formal representation thereof in which certain features are abstracted while others are ignored with the intent of providing a simpler description of the salient aspects of the chosen phenomena: ‘a model always represents only some but not all the features of the original’ (Hayek, 1963, p.14). Models comprise sets of structures each of which is a well-defined characterization of that which is to be explained.

Although the distinction between theoretical models and empirical models is not made, Hendry and Richard have pointed out two major features of models: (1) a model is a formal representation, and (2) the representation is partial, not whole. However, these two features only indicate the form and range of models. The above quotation does not specifically point out a feature that is crucial to the LSE methodology, that is: (3) the origins of models. As Hendry (1995b) puts it: “all models are not born equal”. The origins of models are related to what models attempt to represent. This viewpoint is similar to Patrick Suppes’s distinction between models of data and models of theory (Suppes, 1962). As will be discussed later, theoretical models and empirical models are distinguished by what they aim to represent. Therefore, the LSE methodology provides a criterion to categorize models according to their origins.

3.2 Theoretical models and empirical models

The notion of theoretical models is best understood by an example (Hendry and Richard, 1982, sec.3). In a mortgage market, each period’s repayment (**R**) of mortgage principal (**M**) is a constant proportion ($\mathbf{N}^{-1}$) of the mortgage loan, such that the theoretical model can be written as

$$\mathbf{R}=\mathbf{N}^{-1}\mathbf{M}$$

given that the world is of static equilibrium, and all stocks and flows are constant.

This example of a theoretical model is close to common understanding of economic models. Theoretical models, according to Hendry and Richard, propose the theoretical relationships between latent variables — usually referred to as unobservables— whereas the imposed relationships are restricted by the *ceteris paribus* clause. Hendry and Richard's view is that theoretical models do not contain empirical content, so that theoretical connectives such as "causal dependence" and theoretical concepts such as "equilibrium" gain empirical meaning only through the "correspondence conditions" or "measurement equations" to *map* latent variables onto observable variables.

The origin of empirical models is the *data-generating process*, which is well-known by the acronym DGP. The DGP is regarded as an underlying mechanism that produces the observed data. Empirical models, do not inherit the properties of the theoretical model, but are built as *representation* of the DGP. If the empirical model is derived from the theoretical model, one problem that Hendry and Richard observe is the following. There exist many equivalent theoretical models yielding different empirical models with different empirical properties such as residual variance, heteroscedasiticity and autocorrelation (p. 365). To use the mortgage example, the following theoretical models are equivalent to $\mathbf{R}=\mathbf{N}^{-1}\mathbf{M}$:

$$\mathbf{R}=\mathbf{N}^{-1}\mathbf{M}_{-1}\,,$$

$$\frac{\mathbf{R}}{\mathbf{M}_{-1}}=\mathbf{N}^{-1}\,,$$

$$\frac{\mathbf{R}}{\mathbf{P}}=\mathbf{N}^{-1}\left(\frac{\mathbf{M}}{\mathbf{P}}\right)=\mathbf{N}^{-1}\left(\frac{\mathbf{M}}{\mathbf{P}}\right)_{-1}\,,$$

where subscript indicates time period. **P** denotes price index. Because the theoretical model is a static equilibrium world, $\mathbf{M} = \mathbf{M}_{-1}$, $\mathbf{P} = \mathbf{P}_{-1}$. Although these models are theoretically equivalent, they yield different empirical models.[4]. Thus the theoretical model is not "identifiable" (in the sense that we cannot identify the theoretical model by empirical models because of the lack of empirical equivalence).

3.3 Empirical models and DGP

The goal of the LSE econometrics is clear: to represent the DGP. Theoretical models are built as a *conjecture* of the DGP and are not necessarily static and equilibrium: we have many examples in macroeconomics where theoretical models are dynamic and disequilibrium. But for LSE econometrics, the problem for the theoretical model, as well as for economic theories, is their empirical adequacy. Following Hume, Hendry and Richard argue that: "since any given theory may not correctly and completely characterize the perceived world, the perceptibility of *necessary* connections among observed events is open to doubt" (Hendry, 2000a, p.363. Original italics). Therefore, it would be unpromising to regard a theoretical model as a model for the DGP. To represent the DGP means to understand the observed events. No unobservable needs to be constructed and accounted for. Because empirical models are a "recombination of whatever process generated the data" (Hendry, 2000a, p.364), they are built via a reduction process from the DGP.

Empirical models on the one hand are built by making reductions from the DGP; on the other hand the aim is that they should be representations of the DGP. In order to make empirical

[4] See Hendry (2000a), p.365.

models good representations of the DGP, the criterion of *congruence* is imposed to evaluate the empirical modeling.

4 **Congruence: the idea**

The idea of congruence was first known as the "tentatively adequate conditional data characterization", or the acronym TACD (Hendry and Richard (1982)). As the name suggests, a model is TACD if it adequately characterizes the DGP in the way that the model represents all investigated features of the data. Later the name "congruency" was introduced to Hendry by Christopher Allsopp to replace TACD (Hendry, 2000a, p. 271). The meaning of "congruency" or "congruence"[5] suggests a relation between two objects in which one object is rightly in accordance with the other in the corresponding aspects. The reason for its use may be to analogize the meaning of congruence in mathematics. But in mathematics, as Hendry realized (Hendry, 2000a, p.271), congruence means the relations of two objects of the same kind. Hendry wanted to use this terminology to indicate the relations between empirical models and the Haavelmo distribution, or the DGP, which he regarded as two distinct kinds of entities[6], like a triangle and the top of a (sliced off) pyramid, as between triangle A and three-dimensional segment of the pyramid, C, in Figure 1. (In figure 1, **B** is a small face, **D** is the whole face, **C** is the top segment of the pyramid.)

The concept of congruence in mathematics requires that all the corresponding parts of the object considered are congruent. Take the example of congruent triangles: two triangles are congruent if and only if their corresponding parts are congruent, e.g., two sides and the included angle on one triangle are congruent to the corresponding parts of another. Therefore, congruency

[5] Hendry switches from "congruency" to congruence" in recent articles.
[6] Hendry and Richard make it explicit that a TACD is not a DGP, but simply an adequate representation of the DGP.

between every part of the triangle is a sufficient and necessary condition. For example, in Figure 1, triangle A is congruent with triangle B if and only if the above conditions are met.

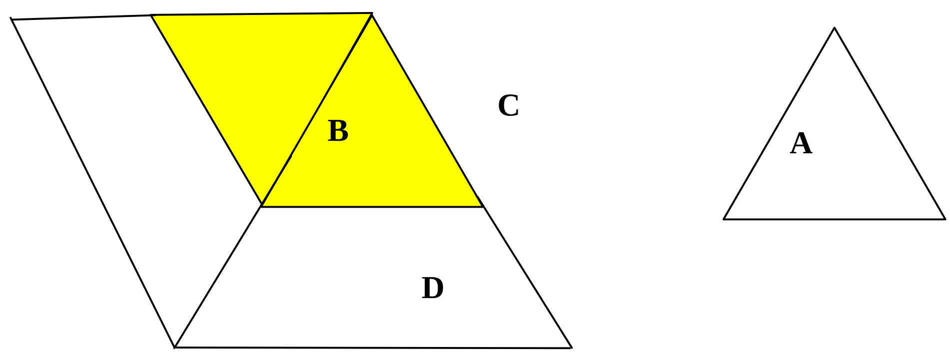

Figure 1 Congruence

In econometrics, the sufficient and necessary condition for congruence is too restricting because we are comparing the empirical model to the unknown DGP. Since we do not know whether the observable or measurable parts of the DGP are enough to delineate the whole picture of the DGP, congruence in the econometrics sense does not lead to the conclusion that the model and the DGP is similar in *all* respects. In this sense, even though Hendry's example of congruence is between triangle A and the top segment of the whole pyramid, C (which is also a pyramid), I argue that congruence only exists between two observed objects.

Consider the following two cases. First, suppose people can only observe one side of the pyramid that they face, e.g., face D, then they can have triangle A as a model for B because triangle A is congruent to triangle B. Triangle A won't be a model for segment C since they are not congruent (triangle A is two-dimensional while segment C is three-dimensional). Imagine that the pyramid is the DGP, which is not totally observed, and triangle A is an econometric model. All we know is that A is congruent to triangle B—which is observed, and not enough to delineate the DGP—the pyramid.

The other case is that suppose people can move around the pyramid, but they can only measure segment C because the pyramid is too big to be measured. Hence they have data for segment C but not for the whole pyramid. In this case people would build a small pyramid, instead of a triangle, as a model for segment C. Accordingly, the whole pyramid is the DGP, a small pyramid that is congruent to segment C is the econometric model.

Nonetheless, both cases emphasize how the concept of congruence allows an interpretation of LSE econometrics that it is only concerned with the measurable aspects.

4.1 Definition of congruence

Comparing the definition of TACD offered in 1982 and the settled definition of congruence we have today, we found that they are not exactly equal. The definition of TACD that Hendry and Richard provided includes encompassing, which now becomes a criterion of model specification distinct from congruence. Encompassing is a relationship between models, aiming to select the best representation among the available ones. Congruence, on the contrary, is a criterion checking whether a model is a valid representation. An up-to-date definition of congruence, provided by Hendry (2000b), and Bontemps and Mizon (2001) is summarized as the following.

Congruence. An econometric model is congruent if and only if it has (C1) homoscedastic, innovation errors; (C2) weakly exogenous conditioning variables for the parameters of interest; (C3) constant, invariant parameters of interest; (C4) theory consistent, identifiable structures; (C5) data admissible formulations on accurate observations[7].

Each concept corresponds to a type of information. Five types of information are categorized as past, present and future data, a measurement system and a priori theory. Each condition of congruence mentioned above corresponds to a type of information: C1 corresponds to past data; C2 to present data; C3 to future data; C4 to a priori theory and C5 to measurement system[8].

[7] See Bontemps and Mizon (2001, p.12) for the formal definition of congruence.
[8] There is a question about distinguishing between information about rival models and encompassing. Mizon (1995) argues that they are not equal. A model, which is congruent to the information about rival models, does not suggest they are nested. Rather they are nonnested models. An encompassing model is nested to encompassed models and dominating.

The key point in this step, as Hendry writes (2000a, p.359), is the taxonomy of information sets. Since information is revealed by data, the taxonomy of information sets is designed to categorize data into different groups. Each group of data reveals a certain type of information. If we see data as a single entity, the taxonomy of information is to specify the different aspects of the data. Thus the concept of congruence can be applied to the relationship between data and the model that represents them. A model is congruent if all the aspects of the model are congruent with the information sets. By this, diagnostic tests can also be grouped according to the types of information, and are understood as securing the congruence of the specific aspects of econometric models.

4.2 Congruence as a criterion of representation

Congruence is an "operational criterion" of evaluation of econometric models. As a relation between (empirical) models and the real world (the DGP), congruence can be understood as a criterion of a specific function of the model: representation. In Mizon (1995), if a model is congruent, then it is a "valid" representation of the DGP. Gilbert (1986), on the contrary, seems to agree with Faust and Whitman's (Faust and Whitman, 1995) criticism on the vague meaning of "validity". He prefers to use "adequacy" to describe model's congruence with the DGP. This usage is much closer to the meaning of congruence, for it directly relates to TACD. Nonetheless, both validity and adequacy should be understood in the context of congruence, and the evaluation of the model's function as representation of the DGP. Both Mizon's and Gilbert's papers rightly illustrate this point.

4.3 Congruence, isomorphism and similarity

Theory and the world can be related in different ways. Conventionally, semantic philosophers argue that a model's representation of the world is a mapping up to an isomorphism, which is accepted in measurement theory and by van Fraassen. However, the concept of isomorphism is too restricting to some philosophers, for the model does not represent the world in *all* respects. Ladyman (1998) suggests to call this correspondences *partial isomorphism* (Ladyman, 1998, p.416). The most well known alternative to isomorphism is due to Ronald Giere. Giere (1988, p.80) points out that in the cases of mechanics, isomorphism is rarely found. He proposes a weaker interpretation of the relationship between model and world in terms of *similarity*. According to this, a model is a valid representation of the world if they are similar to each other in specified respects and degrees.

Giere's concerns about the respects and degrees of similarity do not enable us to draw a radical distinction between isomorphism and similarity. For example, when van Fraassen talks about isomorphic mapping, he clearly emphasizes the mapping between models and empirical substructures instead of the whole world. The one-to-one mapping between empirical models and empirical substructures can be also be understood in the sense of similarity between models and the whole world with respect to those features which appear in the empirical substructure. Take Giere's example of planetary movement, that "the positions and velocities of the earth and moon in the earth-moon system are very close to those of a two-particle Newtonian model with an inverse square central force" (Giere, 1988, p.81). Giere argues that the Newtonian model is similar to the real system in the respects of "position" and "velocity", and the degree of similarity is claimed to be "very close". However, this example can be rewritten in terms of an isomorphic mapping between two relational structures:

$\mathbf{M} = <P_1, P_2, P_3, P_4>$, and

W = <earth, moon, position, velocity>,

where P_1, P_2, P_3, P_4 are properties. We can say that **M** represents **W** up to isomorphism in the sense that each component in **M** exclusively corresponds to a component in **W**.

Nonetheless, whether the theory-world relation is one of isomorphism or similarity, the semantic approach provides an understanding of the LSE methodology. Van Fraassen's constructive empiricism particularly fits the LSE methodology. The concept of congruence is compatible with the empiricism emphasized in van Fraassen's account in many ways. First, empirical models in the LSE econometrics are not designed to account for the entire DGP. Empirical models only match *all measurable aspects*. Second, empirical models are representations of the DGP with respect to those measurable aspects. Gilbert's (or Hendry and Richard's) concept of empirical adequacy (that is, congruence) is similar to that in constructive empiricism, for both are only concerned with observed respects. Since a model is designed to be congruent with available information sets, there is no way for an empirical model to account for those unobservable aspects. The LSE methodology on the construction of models is illustrated in their *theory of reduction* and *general-to-specific approach.*

5 Theory of Reduction and General-to-Specific Approach

5.1 Theory of reduction

Since the term "DGP" has been introduced by the LSE econometricians, it has becomes popular even among other schools of econometrics that the DGP is an underlying mechanism that produces data. However, the LSE approach specifically provides a theory relating the DGP to econometric models. This theory is called *the theory of reduction*. The theory of reduction offers an explanation of the origins of empirical models by describing “all steps involved in mapping from the actual data generation process in the economy…to an empirical model thereof “ (Hendry, 2000b, p.1). The reduction process starts with the DGP. Statistically the DGP is defined as a joint distribution of all the sample data – both endogenous and exogenous (Gilbert, 1986). It can be formally presented as (Hendry and Richard, 1982):

$$D(X_T^1 \mid X_0, q) = \prod_{t=1}^{T} D(x_t \mid X_{t-1}, q_0, q_t) \qquad (1)$$

where

D(·) = the joint density function,

$X_T^1 = (x_1, \ldots, x_t)'$, where x_t are a *sample* of *T* observations on *K* variables,

q = a vector of unknown parameters. *q Î Q*,

X_0 = the matrix of initial condition,

$X_t' = (X_0' X_t^{1'})$.

The conditional densities on the right hand side are assumed to be constant over time. D_x is called the “Haavelmo distribution”. It generates the complete sample of random variables given population parameter values. Hendry regards the DGP as complicated: “The data-generating process (DGP) of the complete set of random variables relevant to any economy under investigation over a time period t=1,...,T is far too complicated even to understand or model. Consequently, reduction to a manageable size is essential for any form of analysis."[9] Hence, operational restrictions are imposed as a sequence of data reductions. The purpose is to ensure that the features of the data obtained —indicating the properties of the DGP—are faithfully involved in the derived empirical models. So the empirical models can be construed as a good representation of the DGP in the observed respects. The theory of reduction contains twelve steps to achieve the empirical model from the DGP. Each step involves an econometric concept or concepts that are regarded as measures of no loss of information. The full account is given in Hendry (2000b, p.9) (also Hendry, 1995a, and see my Appendix).

But not every step is a reduction. For example, data transformations (R1, see Appendix) and functional form approximations (R10, see Appendix) involve no reduction but only "transformations". Reductions are not transformations, for transformations are one-one mappings from one representation of data to another. Reductions require econometricians' articulations of data conditioned on certain sets of information retained.

5.2 Reduction and model discovery

The "constructive" sense of theory in the semantic approach is similar to that of the LSE econometricians. On more than one occasions, Hendry has spoken of the distinction between the context of justification and the context of discovery in the philosophy of science (Hendry, 2000a, pp.176-7), and he strongly argues that the discovery of a true model of representation of the DGP is untenable. To Hendry, the discovery of true model needs those non-scientific ingredients such

[9] The Menu of *PcGets*, chapter 9.

as brilliance, creativity and luck. Therefore, he suggests econometricians focus on the context of justification of models in terms of congruence[10].

Nonetheless, models have to be constructed somehow, and the theory of reduction illustrates Hendry's recommended procedure of "model discovery"[11]. Hendry's approach is in contrast to much other philosophy of science, where "discovery" usually indicates the discovery of the truth about unobservables. Contrary to the discovery of unobservables, the theory of reduction, a theoretical account of model construction suggested by the LSE methodology, does not aim for discovery of unobservables. The theory of reduction contains two ingredients. The first is that empirical models are constructed to guarantee no loss of information from data. It means that empirical models are not concerned with those things which are not in the data sets (non-observed). The second ingredient is that the theory of reduction shows the origins of the empirical models: the DGP. Each empirical model that is adequate (congruent) must be a reduction of the DGP. It implies that there can exist a number of models that are all congruent with the DGP. In order to select the most adequate one among these congruent models, econometricians are advised to run the encompassing tests to find the parsimonious encompassing model.

These two ingredients of the theory of reduction are compatible with constructive empiricism. The congruence, or no loss of information, involved in each step of reduction suggests an empiricist approach in which empirical models aim to account for the observed data. Furthermore, the theory of reduction is well-suited to the "constructive" sense, for the aim of

[10] Note that in Gilbert's account the LSE approach is said to use econometrics to "discover" a view of the economy in order to make a contrast with the conventional "AER" (average economic regression) approach using econometrics to "illustrate" the theory we believe independently (1986, p.280). It is understood that Gilbert uses "discover" and "construct" here interchangeably. But according to Hendry's rejection of the context of discovery and the meaning of "constructive" in philosophy of science, the term "discovery" seems less proper.

[11] "…we focus on the context of model discovery,…" (Hendry, 1995a, p.344).

econometrics is specified as constructing models representing the data. The theory of reduction suggests an abstract procedure of deriving the empirical model. Practically, however, Hendry suggests a *general-to-specific* approach to derive the final econometric model from the general unrestricted model.

5.3 General-to-specific approach

The theory of reduction explains that adequate empirical models are supposed to be an imitation of the actual data generating process, which may be known but in most of the cases the DGP is unknown. The tests listed in each step of the reduction process quality-control no loss of information; hence the derived model can be construed as a good representation of the DGP. But since we do not really know the DGP, the reduction theory is difficult to apply to the practice. Hendry (2000b, p.1) illustrates the general-to-specific approach that:

> General-to-specific modelling seeks to mimic reduction by commencing from a general congruent specification that is simplified to a minimal representation consistent with the desired criteria and the data evidence (especially represented by the local DGP).

The theory of reduction indicates a contrasting methodology to the conventional theory-driven approach. Hendry (1985) argues that the conventional approach contains the following steps: (i) postulate an arbitrary theory; (ii) find a set of data with the same names as the theoretical variables contained in the postulated theory; (iii) make auxiliary simplifying assumptions in constructing the theoretical model; (iv) fit the theoretical model to data to see the degree of match; (v) process tests to see whether rejection is possible against interesting alternative hypotheses. If the theoretical model is rejected, then economists start with another arbitrary theory. But due to the Duhem-Quine thesis, it is impossible to reject the whole theoretical model. Therefore, only minimal tests are taken. Consequently, very few models are rejected. Worst of all, these tests might lead to contradictory empirical results (i.e., non-encompassing). Moreover, the conventional modeling is characterized as a “specific-to-general” approach. The starting (theoretical) model is specific because a wide range of auxiliary assumptions restrict the model to present a specific or simple relation between variables. When the original theoretical model fits poorly, to the data, econometricians relax one or many auxiliary assumptions such that the model becomes more general. Gilbert (1986, p.282) describes this as “patching the original theoretical model”.

The general-to-specific methodology directs econometricians to start with a general model containing all information that the DGP or a part of the DGP is supposed to have. To be more specific, the general-to-specific approach has a modeling process start with a “general unrestricted model” (GUM). GUM is the “most general estimable, statistical model that can reasonably be postulated initially”, given the available information including “the present sample data, previous empirical and theoretical research, and any institutional and measurement information” (Hendry, 1995a, p.361). From this general, congruent model, econometric concepts (regarded as no-loss-of-information restrictions suggested by the theory of reduction) are imposed to make the econometric model more specific. Such a specific model is an improvement on the general unrestricted model since it conveys all of the information that the GUM has, but in a simpler form.

5.4 Local DGP

However, the theory of reduction encounters the problem of epistemological accessibility of the DGP. Hendry realizes that the complexity of the DGP must prevent it from being epistemologically accessible. The second thing is that the theory of reduction does not seem to explain how the derived model maps the DGP. Because the empirical models derived after transformation, marginalization and factorization only contains a handful of variables of interest, the derived model must not be able to represent the whole range of the DGP. The later invention of the local DGP (LDGP) was designed to fill the gap between empirical model and the DGP. The LDGP is defined as a generating mechanism of variables under analysis. Thus, the theory of reduction does not attempt to relate the empirical model to the DGP, but to the LDGP.

The shift becomes obvious in the latest menu of the software *PcGets*, where the theory of reduction does not change, but is reinterpreted in the last two stages where it indicates that the theory of reduction derives the LDGP. When factorizing the density of x_t into endogenous variables y_t and non-modeled variables z_t (step R7), and deciding the function form (step R10, see Appendix), the function form maps y_t into $y_t^* = h(y)$, z_t into $z_t^* = g(z_t)$ that makes $D_{y^*|z^*}$ approximately normal. Therefore:

$$D_{y|z}(y_t \left| z_t, X_{t-1}^{t-s}, x_{0,} f_a \right.) = D_{y^*|z^*}(y^*{}_t \left| z^*{}_t, X^{*t-s}_{t-1}, x_{0,} t \right.) \qquad (2)$$

such that a linear representation for y_t^* is obtained in terms of z_t^*. Then the right-hand side of equation (2) is the LDGP: a reduction of the DGP. To name the right-hand side of equation (2) the LDGP suggests that the LDGP is nested within DGP, and its properties are fully explained by the reduction process. Then from the LDGP we derive the econometric model.

6 Case Study: the DHSY Model

As has been mentioned in the introduction of this paper, the DHSY model (Davidson et al. 1978) and money demand model are two famous examplars and objects for experiments, as "laboratory mice" for Hendry. He frequently tests his ideas on them once there is a revision in the econometric methodology. The origin of the DHSY model results from the issue of encompassing in two aspects.

(1) To encompass the existing consumption theory, to be specific, the permanent income hypothesis and life-cycle income hypothesis. The new model should also contain seasonality, which is an empirical feature that both earlier theories leave out of account.

(2) To encompass several rival models that used the same data set but derived different empirical models.

6.1 The Model

The model selection procedure in of the DHSY model was described as follows. First they studied the existing consumption models, namely, Hendry (1974), Ball et al. (1975), Wall et al. (1975):

$$(Hendry) \quad C_t = a_0 + a_1 Y_t + a_2 C_{t-1} + S_t + \sum_{j=1}^{4} d_j Q_{jt} t + e_t \,, \qquad (3)$$

where *C* denotes aggregate consumption; Y denotes aggregate income; subscript *t* denotes the time period. $S_t = \sum_{j=1}^{3} b_j Q_{jt}$. Q_{jt} is a dummy variable for the *j*th quarter.

$$(Ball) \quad (C-G)_t^a = a_0 + a_1(Y-G)_t^a + a_2(C-G)_{t-1}^a + (f_1 D_t + f_1 D_{t-1}) \, , \tag{4}$$

where *G* denotes direct transfer payments to individuals. D_t is a dummy variable. $D_t = 1$ at 1968(i) and (ii), otherwise are zero values.

$$(Wall) \quad \dot{C}_t^* = a_0 + a_1 \dot{Y}_t^a + a_2 \dot{Y}_{t-1}^a \tag{5}$$

where $\dot{x}_t = 100 \frac{(x_t - x_{t-1})}{x_{t-1}}$; C^* is total consumption expenditure; superscript *a* denotes seasonally adjusted data.

The next step was to examine the differences of these three models, and transform the differences such that they could be compared to each other:

(i) Data period: examine the role of the data period. Arbitrarily choose 1971(i) to 1975(iv) for forecast test.

(ii) Seasonal adjustment procedures: prefer to use raw data rather than seasonally adjusted data. For a vector of variables, *Z*, use $\Delta_4 Z_t \equiv Z_t - Z_{t-4}$ (in raw data) to replace $\Delta_1 Z_t^{SA} \equiv Z_t^{SA} - Z_{t-1}^{SA}$ (in seasonally adjusted data).

(iii) Data transformation: assume $\Delta_1 \ln x_t \cong \Delta_1 \frac{x_t}{x_{t-1}}$

(iv) Functional form: model in differences: (a) as a filter or operator to eliminate the trend; to specify the autocorrelation properties of v(t); and to specify the form of all the non-dummy variables. (b) as a set of coefficient restrictions: to eliminate independent regressors and transform variables.

Combining these approximations, the following model was obtained:

$$c_t = l_0 + l_1 y_t + l_2 y_{t-4} + l_3 y_{t-1} + l_4 y_{t-5} + l_5 C_{t-4} + e_t \quad (6)$$

In implementation of the three models (H) (B) (W), they found they were a special case of:

$$\begin{aligned} C_t &= x_0 + x_1 Y_t + x_2 Y_{t-4} + x_3 \Delta_1 Y_t + x_4 \Delta_1 Y_{t-4} + x_5 C_{t-4} \\ &+ \sum_{j=1}^{3} x_{+5=j} Q_{jt} + x_9 D_t^0 + x_{10} D_{t-4}^0 + x_{11} C_{t-1} + x_{12} t \\ &+ \sum_{j=1}^{3} x_{12+j} Q_{jt} t + e_t \end{aligned} \quad (7)$$

The above function could be regarded as a *general unrestricted model*. It was hoped that the important features of those three models remained in the standardization sequences.

Then a series of diagnostic tests were done in order to mimic the reduction procedure. First, multicollinearity was checked. Multicollinearity was treated as an issue of choice of parameterization rather than choice of regressors. Orthogonalizing transformations were selected as corresponding to parameters of interest, and related to a simple theory-model of agent behavior.

Whereas several variables were ruled out due to the orthogonality test, a parsimonious description of equation (7) was:

$$\Delta_4 C_t = b_0 + b_1 \Delta_4 Y_t + b_2 \Delta_1 \Delta_4 Y_t + b_3 \Delta_4 D_t^0 + e_t \tag{8}$$

The next step was to turn to economic theory for help, to see whether the econometric model was theory consistent. As noted in the recent preamble of the reprint of the DHSY paper (Hendry, 2000a, pp.175-6), the idea was to borrow the concept of the error-correction mechanism (ECM) from Denis Sargan’s wage-price model and from A. W. Phillips’s use of servomechanisms, and make it consistent with long-run economic theory. Economic theory imposes the long-run relationship between consumption and income, i.e., $C_t = KY_t$. In log form it can be represented as $c_t = k + y_t$. A more useful format is in the differences. That is:

$$\Delta_1 c_t = \Delta_1 y_t \,.$$

This could be represented in the form:

$$a(L) c_t = k^* + b(L) y_t + v_t \tag{9}$$

where *a(L)* is the lag operator, and v_t is a stochastic term, thus a simple consumption relation could be represented as:

$$c_t = k^* + b_1 y_t + b_2 y_{t-1} + a_1 c_{t-1} + v_t \tag{10}$$

In steady state, the long run equation was that:

$$\Delta_1 c_t = k^* + b_1 \Delta_1 y_t + g\,(y_{t-1} = c_{t-1}) + v_t \text{ [12]} \tag{11}$$

Now combine $(c_{t-4} - y_{t-4})$ with equation (7) that survived from the encompassing tests:

$$\Delta_4 c_t = k^* + b_1 \Delta_4 y_t + g\,(c - y)_{t-4} + \Delta_4 D_t^0 + v_t \text{ [13]} \tag{12}$$

Unfortunately, the derived model did not predict well. But Deaton's work provided a solution (Hendry, 2000a, pp.176-7):

> This time, Angus Deaton's work came to the rescue by suggesting an important role for (unanticipated) inflation in the consumption function. On the very first try with our ECM augmented by inflation (and its change) we struck gold: a well fitting and constant model which had no difficulty predicting the first half of the 1970s. Had Angus Deaton not proposed his 'unanticipated inflation' hypothesis, the DHSY model might have been stillborn….

[12] In the steady state, $c_t = c_{t-1}$, $y_t = y_{t-1}$, therefore $a_1 + b_1 + b_2 = 1$. This relation can be represented as $b_1 + b_2 = g$,and $a = 1 - g$ such that $b_1 + b_2 = g$ and $a_1 = 1 - g$.

[13] Note that the short-run equation is $\Delta_1 c_t = k^* + b_1 \Delta_1 y_t$. The steady state growth path g is $g = \Delta_1 c_t = \Delta_1 y_t$, thus it can be derived as $g = \dfrac{k^* + g\,(c_{t-1} - y_{t-1})}{1 - b_1}$. K is solved as $K = \exp\left\{\dfrac{1}{g}\left(k^* - (1 - b_1)g\right)\right\}$. Therefore $C = \exp\left\{\dfrac{1}{g}\left(k^* - (1 - b_1)g\right)\right\}Y$. To explain the seasonal data, lag length is equal to four periods. Thus,

$$c_t - y_t = k^* + (1 - g)(c - y)_{t-4} + (b_1 - 1)\Delta_4 y_t$$

Therefore, the inflation effect was added. The equation (13) is what we know now as the DHSY model that represents the LDGP.

$$\Delta_4 c_t = k^* + b_1 \Delta_4 y_t + g\,(c - y)_{t-4} + c\Delta_4 D_t^0 + a_1 \Delta p_t + a_2 \Delta_1 \Delta_4 p_t + v_t \quad (13)$$

[14]

6.2 Comments on DHSY

Even though, in his methodological writings, Hendry looks down on theories, the development of the DHSY models shows that it is still important to be consistent with accepted theories of consumption. But this does not mean that econometric models originated from theoretical models. This property of theory-consistence is involved in the concept of congruence, even though the whole concept of congruence was not clear at the time of Davidson et al. (1978). Rather the emphases there were on the general-to-specific approach and the concept of encompassing. Because the concept of congruence is closely related to tests of econometric concepts, congruence is only evaluated when all the congruence tests have been conducted.

The addition of inflation seems to be in contrast to the general-to-specific approach, for it looks like "patching" the model. The encompassing of previous models also seems to suggest that, at the start of model-building, it is impossible to be theory-free since previous models are theory-involving. These two points seem to suggest that the DHSY model is in fact an example of the specific-to-general approach. But this view is not correct for the following reasons. First, encompassing previous models does not mean "starting with theory". It is true that each of the previous models might involve a theory explaining consumption phenomena, but this does not

[14] Usually $c\Delta_4 D_t^0$ is omitted (see below).

mean that the DHSY model in the initial stage of encompassing previous models implies any economic theory, nor can it be explained by a existed economic theory. Moreover, theories implied by previous models might contradict each other; it seems doubtful to claim the discovery of a new theory from a model just because the model encompasses contradicting theories, without even looking at the final model.

Second, it is true that "reduction" usually refers to elimination of variables, and the relaxation of assumptions in the specific-to-general approach usually proceeds by means of adding variables. But it does not mean that eliminating variables is the general-to-specific approach, and adding variables is specific-to-general approach. The story of adding unexpected inflation sheds further light on the rejection of the context of discovery. Following the general-to-specific approach, we can obtain a congruent model. But congruent models are not necessarily true (see Cook and Hendry, 1994, pp.72-3). They are only the best models that econometricians can have given existed data. For this reason Hendry argues over and again that econometricians need "luck" for empirical modeling.

What the DHSY modelers learnt from theories is is the effect represented by $(y-c)_{t-1}$, later recognized as the error correction mechanism (ECM)[15]. The ECM is a theoretical device developed according to Sargan's and Phillips's feed-back mechanism. In the consumption theory, $(y-c)_{t-1}$ is an ECM for it indicates a feedback mechanism from the previous consumption-income ratio to the long-run target outcome $c_t = k + y_t$. At the time when the DHSY paper was published (1978), the importance of the ECM was not explicitly recognized. The empirical importance of the ECM was not fully recognized until Granger (1981) stressed the

[15] See Davidson et al., 1978, pp.684-5, Hendry (2000a), p. 176.

phenomena of cointegration. Then, the ECM can be construed as representing the cointegrated phenomena between consumption and income, rather than just a hypothetical relation.

The DHSY model provides an example of a process of building empirical models, and a clear distinction between theoretical models and empirical models. The general model is first built to encompass previous models, then reductions are processed to reach a parsimonious encompassing model. It also shows the essence of the progressive research strategy, that does not regard previous theories as the wrong ones. Rather, the current model has to account for the results obtained by previous studies. In this sense the DHSY is successful for its properties can be found in both the permanent income hypothesis and life-cycle income hypothesis.

6.3 Congruence Testing

In the original 1978 paper, the DHSY model was not 'rigorously' tested. It was not until Hendry, Muellbauer and Murphy (1990) that the DHSY model was tested in light of the theory of reduction. In this paper, they conducted a series of tests. Note that most of the diagnostic tests in the LSE approach are F tests. Gilbert (1986) calls the models that pass these tests "F-acceptable". Such specification is an "F-acceptable simplification". In 1990, the sequence of these tests was (Hendry, Muellbauer and Murphy (1990)):

1. Cointegration.
2. Reduction sequence (see theory of reduction above) (Hendry et al. 1990, pp.316-8):
    2.1. AR 1-5 (an F test for fifth-order residual autocorrelation).
    2.2. ARCH 1-4 (an F test for fourth-order ARCH residuals).
    2.3. F test for Heteroscedasticity.

2.4. F test for functional form mis-specification.

2.5. Chi-square (2) for normality.

2.6. Test the significance of seasonal variable Q (Hendry et al. (1990) found the seasonal variable insignificant thus drop it.)

2.7. Chow test (an F test) on constancy.

2.8. Super exogeneity test.

3. Break-point Chow test on the Lucas critique (invariance test) (The Lucas critique was rejected.)

When the DHSY model sustains the above tests, it is said that the DHSY model is congruent. That is, the DHSY model matches the data in all measurable respects. Hendry once said that the three golden rules of econometrics are test, test and test (Hendry, 1980). In light of congruence, tests are not a kind of one-shot test, but aim to check whether the model preserves all empirical knowledge. Hence, no econometric concept can be claimed to be in the econometric model without passing the diagnostic test(s). For example, Hendry et al. (1990) show that there is no evidence to claim the existence of the Lucas critique in the DHSY model. The rejection of the theoretical concepts which are empirically unjustified suggests that the practice of econometrics according to the LSE school is one of empiricism.

7 LSE methodology as an example of the structural empiricism

One of the practices amongst current philosophers of science is to rationally reconstruct the history of science. That means philosophers provide their own accounts to justify the scientific practices. For such a reason Newton's laws have been used by rival schools as an example to which explanations are given. But this does not mean that Newton did practice science in such a way. However, I argue that the LSE econometrics does provide an example of actual practice as which matches that suggested by van Fraassen's empiricist methodology. The crucial point is that the LSE econometrics is concerned with the congruence between the econometric model and corresponding aspects of the world. It is part neither of these econometricians' intuition, nor their econometric models' capacities, to account for unobservable aspects of the world.

7.1 Realism about entity and realism about theory

This methodology reflects an epistemological concern in contrast to realism, matching the fact that van Fraassen himself is a keen opponent of realism. Nonetheless, this discussion about realism ought to be able to answer the question: "Realism about what?". Ian Hacking (Hacking, 1983) distinguishes between "realism about entities" and "realism about theory". Realism about entities is concerned with whether an entity investigated exists independently to our knowledge; realism about theory is concerned with whether our knowledge is true to the world. However, empiricists can be either realists about entities or realists about theory. Van Fraassen, as Hacking suggests, holds the position of realism about entities since he does not deny the existence of the world. His empiricist view results from the belief that theories can never go beyond what we observe, so that he is an anti-realist about theory.

Those who pinpoint Hendry as a realist (e.g., Keuzenkamp (1995), (2000)) refer to Hendry as a realist about entities. Their argument basically rests on the messages appearing in Hendry's work like "the actual DGP". Such messages appear to subscribe to entity realism about the DGP since the DGP refers to the "actual economy" or the "real economy". Entity realism is an ontological realism that is concerned with the existence of the entity. But Mäki (1996) points out that, in natural sciences, the entity realism deals with unobservables. Economics, on the contrary, usually deals with observables (like firms, households, and money) or "commonsense entities" (like aims and beliefs) (Mäki, 1996, p.428). In this sense, it is not difficult to find that when econometricians say that the economy is real, they regard the economy as an observable like household and money. The actual economy is real, for we can recognize its existence, like we recognize the existences of trees and flowers. However, the DGP is not an observable entity. The LSE methodology considers the economy as too complicated to be fully understood, and this implies *epistemological anti-realism* or anti-realism about theory. For instance, the LSE methodology contains nothing that can be seen as a scientific theory explaining the details of the DGP. Like constructive empiricism, the LSE methodology contests the use of economic theory without empirical adequacy. As a result, theoretical models and empirical models are intuitively distinguished[16].

[16] Hendry's empiricist position can be highlighted in his recent exchange with McCallum on the issue of cointegration (Backhouse and Salanti (eds.), 2000). McCallum thinks that cointegration should not bother econometricians since it is theoretically impossible. Hendry replies in terms of empiricist argument (pp.241-2, italics added):

> [Kevin Hoover] went back to Hume and Hume's criticisms. Absolutely wonderful. Let's apply Hume's criticism to Newton. Newton wrote about absolute time and absolute space. He made these assumptions – complete rubbish as we now know. They don't exist. There is no meaning attach to them. Did it matter? No, it turned out it didn't matter at all. The planets behaved pretty much according to his gravitational rules. It would have looked a bit different if we had had a much bigger sun – we might have got to relativity more quickly – but the whole idea is that this needs to take place in a progressive research strategy….
>
> McCallum comes along and says everything has got a unit root in it. Well, in that case you would simply not find cointegrating relations. It is not a theoretical issue. If we go back to the period of the 1880s, Alfred Marshall and Francis Edgeworth were both giving evidence to the House of Commons on technological change in money-demand equations. Edgeworth was extremely concerned about the introduction of the telegraph. It was going to allow people to have just one bank account in London and they could just telegraph money to people when they needed it. What an enormous effect this was going to have on money-demand equations. Edgeworth was even more concerned about the cheque book. This newfangled gadget had just been invented, and people could write cheques – they did not even need to telegraph it to Manchester. Has it changed the money-demand structure of the British economy? In my view, not at all. Nor have money machines, for you still need the money at the end of the month to pay the credit card. There have been detailed studies of the impact of technological change on money demand. We have

Realizing the difference between realism about entities and realism about theory, we can conclude that the idea that Hendry is a realist about the *unknown* DGP results from confusion on the difference between these two types of realism. His acceptance of the existence of the unknown DGP should not be regarded as an ontological realism, for the DGP is not regarded as observables. Neither is Hendry's view that of an epistemological realism, for the DGP is unknown because it is epistemologically inaccessible.

As in constructive empiricism, the LSE methodology involves a realism about entities and an anti-realism about theory. Just as it would be inappropriate to apply the label "realist" to van Fraassen solely because of entity realism, so it would be inappropriate to label the LSE methodology "realist" solely because of their realism about the DGP. The point is that, van Fraassen's account is concerned with theories, not the existence of the entity. Similarly, the LSE methodology is concerned with modeling the DGP, rather than with the existence of the DGP. For LSE econometricians this is what econometrics is about.

7.2 Hendry versus structural realism

John Worrall's structural realism switches the focus from theoretical entities to theoretical models. His "epistemological form of structuralism" argues that the *mathematical structure* involved in the theoretical models asserts the actual relations of the world, even they are not observed. This is a kind of epistemological realism since it states that all we know are structures, while the objects are still not epistemologically accessible.

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measurement of it, of numbers of machines, of the number of transactions on credit cards, and the Bank of England finds essentially noting out of that kind of approach. *So let's let empirical evidence come in and alter the theorists' view of these things. Let's build models and if they do find cointegration it is an important restriction and it will let us build what is really crucial – a progressive research strategy that is looking for regularities that turn out to persist for long period*.

The difference between constructive empiricism and various types of realism (entity realism and structural realism) can be illustrated by the pyramid example mentioned above (see Figure 1). In the case that people only stand in front of the pyramid, triangle A is taken as a model for the top of the pyramid (triangle B). A may be taken as a scale model of triangle D, which is observable. But there is no way to consider A as a model of the whole pyramid, neither it is econometricians' intention to build a three-dimensional model to represent the pyramid. But for a structural realist, a model for a pyramid is also a pyramid for s/he thinks the model needs to capture the structure of the phenomena—even it is not observable. For LSE econometricians, on the contrary, there is no evidence, which would lead them to build a small model pyramid according to what they observe. For, even though theory tells us that it could be a pyramid and it has a solid object with a square flat base and four triangular sides, we only observe one side of them, therefore we can not be sure how many sides it has—maybe three or five!

7.3 Hendry as an empiricist

Hendry argues that: "we do not know what undiscovered entities exist and hence cannot know in advance how best to discover them" (1995a, p.9). Even though sometimes he writes as if he is aware of the existence of the DGP, the anti-realist position can be finely described in the so-called "American anti-realism" tradition in philosophy of science (Papineau, 1996), of which van Fraassen is taken as a representative. Papineau (1996) takes realism to involve two theses: (1) the independence thesis which argues that the world is independent to our awareness to it; (2) the knowledge thesis which argues that our knowledge to the world is true. In terms of the discussion on realism, the independence thesis is equivalent to the issue of ontological or entity realism dealing with the existence of unobservables; the knowledge thesis is equivalent to the epistemological realism that is concerned with the epistemological accessibility. Papineau concludes that American anti-realism rejects the knowledge thesis but maintains the independence thesis. That is, they might not reject the existence of unobservables that are independent to the human mind, but they definitely reject any scientific claims about the unobservables.

Thus, though it is claimed that there must exist a DGP such that empirical models can be reduced from them, it is not epistemological accessible. The LSE approach must reject the knowledge thesis and thus is counted as an (American) anti-realist position. Econometrics is an empirical science. It only is concerned with observed phenomena and not interested in undiscovered entities. Hence, in order to study Hendry's econometric methodology, we need to ignore his possible realist message and move on to seek for an empiricist interpretation.

8 Van Fraassen versus Hendry

8.1 Structuralism in philosophy of science

The type of structural approach that is represented by van Fraassen and others is now named "structuralism", which indicates the view that science describes only the structure, but not the content of its domain[17]. Even though in philosophy of science the name structuralism usually refers to the "Continental approach" proposed by Sneed (e.g, Sneed, 1971), Stegmüller (e.g., Stegmüller, 1979) and others, it is no surprise that philosophers of science now categorize van Fraassen's and Worrall's structural approach as a kind of structuralism[18]. The reason is that they all share the same view on the semantic approach (especially Tarski's axiomatic method). Van

[17] See van Fraassen (1997). "Structuralism (one variety of): the view that science describes only the structure (and not the content) of its domain."
[18] Especially the British philosophers in Leeds such as Steven French and their corroborates.

Fraassen was influenced by the "west coast" model theory of Patrick Suppes[19] developed two or three decades earlier than the Sneed-Stegmüller's Continental approach.

The concepts of "structure" and "model" are both important to the semantic approach. A straightforward idea on structures in mathematics, as van Fraassen puts, is that "any structure which satisfies the axioms of a theory is called a model of that theory" (1980, p.43). The definitions of model and structure in the semantic approach are similar to those in mathematics, but not quite the same[20]. In van Fraassen (1980), a structure is characterized in terms of relevant parameters; a model is referred to as a specific structure, in which all relevant parameters have specific values (van Fraassen, 1980, p.44).

8.2 Structural empiricism

The semantic approach emphasizes structures[21]. That is, scientific theories contain models or structures that represent the real system. As an extension of the semantic approach, constructive empiricism contains an emphasis on structure, too. As mentioned above, in the semantic approach, structures are embedded in a model; in constructive empiricism, structure is represented as a parameter-specified model. In general, the semantic approach (including constructive empiricism) requires an isomorphic mapping between the theoretical model and the empirical model. In van Fraassen's example of Newton's laws, this "structural" mapping is established between the set-theoretically defined model and the selected features of the

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[19] The term "west coast model theory" is in Diederich, 1996, p.15 (quoted in Hands, 2001, p.341).
[20] "Scientists too speak of models, and even of models of a theory, and their usage is somewhat different. 'The Bohr model of the atom', for example, does not refer to a single structure. It refers rather to a type of structure, or a class of structures, all sharing certain general characteristics. For in that usage, the Bohr model was intended to fit hydrogen atoms, helium atoms, and so forth. Thus in the scientists' use, 'model' denotes what I would call a model-type. Whenever certain parameters are left unspecified in the description of a structure, it would be more accurate to say that we described a structure-type." (Van Fraassen, 1980, p.44).
[21] Ladyman (1998, p. 416) expresses the same idea. Also van Fraassen (1997) *inter alia*.

phenomena. As illustrated in the representational theory of measurement, models contain relational structures represented set-theoretically. An isomorphic mapping is said to send each component in one relational structure to the corresponding component in the other.

This view suggests that science aims to represent only selected phenomena, for the semantic approach is concerned with using models to represent the phenomena, and representation must be selective[22]. Thus, van Fraassen claims that the semantic approach implies a structuralist position, that science's description of its subject matter is solely of structure (van Fraassen, 1997, section 2.2):

> According to the semantic approach, to present a scientific theory is, in the first instance, to present a family of models – that is, mathematical structures offered for the representation of the theory's subject matter. Within mathematics, isomorphic objects are not relevantly different; so it is especially appropriate to refer to mathematical objects as "structures". Given that the models used in science are mathematical objects, therefore, scientific theoretical descriptions are structural; they do not "cut through" isomorphism. So the semantic approach implies a structuralist position: science's description of its subject matter is solely of structure.

Van Fraassen's recent work (1997) (partially results from the attempt to respond to Worrall (1989)) emphasizes the role of structure in constructive empiricism. The notion of structure hence is construed in the context of "structural empiricism" (e.g., Bueno, 1999). Even though it is difficult to provide the precise meaning of structure in philosophy of science, it can

[22] See van Fraassen (1997) section 1.

be understood as a set of properties and relations. Again, the *relational structure* in the representational theory of measurement is the best exemplar. Worrall's *structural realism* suggests that the empirical successes of old and new theories are because they contain the same mathematical structure that explains the world, including unobservables. Van Fraassen's structural empiricism argues that structure is defined in terms of certain measurable parameters which both old and new theories successfully account for. A theory is said to account for the empirical structure if there is an isomorphic mapping between the theoretical structure and the empirical structure. Thus, empirical adequacy in the context of structural empiricism means that the abstract structure of the theoretical model describes the empirical phenomena up to isomorphism[23].

8.3 Hendry on structure

Hendry speaks of models and structures, too. He summarizes five different meanings of structures in econometric literature (Hendry, 1995a, 1995b and 1997):

1. Structure is a set of exact relations (Frisch, 1934).
2. Structure is a system of invariant equations which characterized the behavior of economic agents (Haavelmo, 1944, and Wold and Juréen, 1953).
3. Structure is an entity called "structural model", contrasting with a system having derived parameters (a reduced form) (Koopmans et al., 1950).

[23] In his manuscript "Structure: Its Shadow and Substance", van Fraassen claims that "Science represents the empirical phenomena solely as embeddable in certain abstract structures (theoretical models), and those abstract structures are describable only up to isomorphism." (<http://webware.princeton.edu/vanfraas/mss/Leiden-Fine.htm>).

4. Structure is a synonym for the population value q_0 of an unknown parameter $q \in \Theta$ (Bårdsen and Fisher, 1995, and Juselius, 1993).
5. Structure connotes "being derived from intertemporal optimization by economic agents," and aims to embody the "deep parameters" of the relevant theory.

Hendry himself regards structure as "the set of invariant features that directly characterize the economic mechanism" (1997, p.166), where the invariant features are represented by parameters. His view to some extents incorporates the above five meanings of structure (Hendry, 1997). According to Hendry, a parameter is structural if it is invariant to

(1) an extension of the sample period (constancy),
(2) changes in the economy (regime shifts), and
(3) an extension of the information set (adding more variables)[24].

Then he goes on to argue about the role of structure in empirical modeling (1997, p.166):

> This notion [of structure] aims to capture the idea of permanence, within an economic "framework" which is hidden from direct view and needs to be uncovered. The parameters of an economic structure generally include those of agents' decision rules. Then, q defines a structure if it is invariant and directly characterizes the relations of the economy under analysis (i.e., is not derived from more basic parameters). Structure,

[24] See Hendry (1995b).

> therefore, entails a correspondence between model and reality that is not fully open to independent testing….
>
> Succinctly, "LSE" focuses on structure as invariance under extensions of the information set over time, across regimes, and for new sources of information. Whether the model corresponds to agent behavior is less easily tested, but indirect evidence can be obtained by testing theoretically-based restrictions. However, since structure is a relation between an empirical model and reality, theory *per se* cannot endow structure, although it may lead to a model that does. Conversely, aspects of structure are amenable to empirical discovery, so as Frisch (1933) expressed it, the "mutual presentation of quantitative economic theory and statistical observation" must have center stage.

The claim that "structure is a relation between an empirical model and reality" is puzzling, and it is not clear what Hendry means by this. One re-interpretation consistent with the LSE methodology is that structure is a relation that both model and reality share. So that structure representation becomes a criterion of model construction. In other words, if a model satisfactorily represents the world, it is necessary to be *congruent* to structure; i.e. the model is constant and invariant to information extension. Even though Hendry has noted that structure is hidden, the issue of structure is similar to the issue of the DGP. That is to say, the concept of structure in the LSE econometrics is understood empirically in terms of constancy and invariance. If econometric models are congruent with the DGP in the respects of parameter invariance and constancy, we can say that the models structurally represent the DGP. In this sense the econometric models are the structural representation of the DGP.

8.4 The LSE methodology

The similarity between the LSE approach and structural empiricism can be summarized as follows. They both have an empiricist view that only measurable aspects matter, due to the recognition of epistemological inaccessibility. They both stress the importance of structure. Structural empiricism inherits the tradition of the semantic approach regarding models as the vehicle of scientific progress, so that the theory-world relation must be understood via models. Since models only represent in a certain respects, models represent the structure but not the content of the world. For the LSE school of econometrics, the concept of LDGP is derived exactly from the same concerns as this structural approach, namely the concept of the LDGP results from the recognition of epistemological inaccessibility: econometric models only deal with what econometricians are interested in and what data are obtained.

Another interesting similarity between structural empiricism and the LSE approach is on model construction[25]. Van Fraassen offers a two-stage procedure. First to construct sufficiently rich models in order to allow for the possibility of phenomena, then to narrow down of the family of models to obtain greater empirical adequacy (van Fraassen, 1989, p.230-1). It is similar to the general-to-specific approach: construct an unrestricted model first (representing the LDGP) in order to allow for possibility of features of data, then through the theory of reduction, reach the econometric model. The econometric model is necessarily empirically adequate because of passing the congruence tests. In this sense, the notion of congruence is linked to the notion of (empirical) structure.

[25] Van Fraassen calls it ‘theory construction’ for according to the semantic view, a theory is represented by a set of models.

Yet, structure in the semantic approach is understood as mathematical structure of the theory, the success of the theory lies in its matching with (i.e., isomorphism) the structure of its subject matter. While structural empiricism defines structure as a set of mathematical equations that satisfactorily represent measurable or observable aspects, the notions of invariance and constancy that are associated with the term structure in the LSE approach are not so alien to philosophers. For example, invariance and constancy can be understood as *uniqueness*. Uniqueness, which is necessary in defining relational structure in the representational theory of measurement, means that the relational structure is "invariant" to certain transformations.

Isomorphism however demonstrates the difference between the LSE econometrics and structural empiricism. Since the LSE econometrics rejects the usefulness of theoretical models, the isomorphism between theoretical models and empirical models is not of interest. Instead, in the LSE econometrics, the econometric model is similar to Suppes's "model of data" (Suppes, 1962), which, in a canonical paper, offered a place for empirical models in the semantic approach. Suppes's models of data are derived from the world, and represent the phenomena. Econometric models are derived from the DGP (entire world), while they represent the LDGP (similar to van Fraassen's phenomena: selected features of the world, that the model accounts for). Hendry, as well as Suppes, van Fraassen and other semantic approach philosophers, proposes a kind of structural(ist) approach, for they all emphasize models which represent relations in certain fragments of the world, rather than theories which supply the truth about the world.

9 Conclusion: measuring models

In conclusion, van Fraassen's view is compatible with the LSE approach of econometrics, in the sense that econometrics deals with phenomena but not the nature of the world. The notion of structure is also compatible between constructive empiricism and LSE econometrics for it indicates the forms of observed entities rather than unobservables. Interpreting the LSE approach in terms of structural empiricism suggests the impropriety of characterizing David Hendry as a realist.

References

[1] Ball, R. J., Boatwright, D. B., Burns, T., Lobban, P. W. M. and Miller, G. W. (1975) "The London Business School Quarterly Econometric Model of the U.K. Economy", in Renton, G. A. (ed.) *Modelling the Economy*, London: Heinemann Educational Books.

[2] Backhouse, Roger E and Salanti, Andrea (eds.) (2000) *Macroeconomics and the Real World*, Oxford: Oxford University Press.

[3] Bårdsen, Gunnar and Fisher, Paul G. (1995) "The Importance of Being Structured", Working Paper 1995/2, Olso: Norges Bank Research Department.

[4] Bontemps, Christophe and Mizon, Grayham E. (2001) "Congruence and Encompassing", Discussion Papers in Economics and Econometrics No. 1017, Department of Economics, Southampton University.

[5] Bueno, Otávio (1999) "What is Structural Empiricism? Scientific Change in an Empiricist Setting", *Erkenntnis*, 50, pp.59-85.

[6] Cook, Steven and Hendry, David F. (1994) "The Theory of Reduction in Econometrics", *Poznan Studies in the Philosophy of the Sciences and Humanities*, vol. 38, pp.71-100.

[7] Davidson, James E. H., Hendry, David F., Srba, Frank and Yeo, Stephen (1978) "Econometric Modelling of the Aggregate Time-Series Relationship between Consumers' Expenditure and Income in the United Kingdom, *Economic Journal*, 88, pp.661-92.

[8] Ericsson, Neil R., Hendry, David F., Prestwich, K. M. (1998a) "The demand for broad money in the United Kingdom, 1878-1993", *Scandinavian Journal of Economics*, 100(1), pp.289-324.

[9] Ericsson Neil R, Hendry David F, Prestwich, K. M. (1998b) "Friedman and Schwartz (1982) Revisited: Assessing Annual and Phase-Average Models of Money Demand in the United Kingdom", *Empirical Economics*, 23, pp.401-15.

[10] Ellis, Brian (1966), *Basic Concepts of Measurement*, Cambridge: Cambridge University Press.

[11] Faust, Jon and Whiteman, Charles H. (1997) "General-to-specific Procedures for Fitting a Data-admissible, Theory-inspired, Congruent, Parsimonious, Encompassing, Weak-exogenous, Identified, Structural Model to the DGP: A Translation and Critique", *Carnegie-Rochester Conference Series on Public Policy*, 47, pp. 121-61.

[12] Frisch, R. (1934) "Statistical Confluence Analysis by Means of Complete Regression Systems", in Hendry, David F. and Morgan, Mary S. (1995) *The Foundations of Econometric Analysis*, Cambridge: Cambridge University Press, pp. 271-3.

[13] Giere, Ronald N. (1988) *Explaining Science: A Cognitive Approach*, Chicago: University of Chicago Press.

[14] Gilbert, Christopher L. (1986) “Professor Hendry’s Econometric Methodology”, *Oxford Bulletin of Economics and Statistics*, 48:3, pp.283-307.

[15] Granger, Clive W. J. (1981) “Some Properties of Time Series Data and Their Use in Econometric Modeling Specification”, *Journal of Econometrics*, 16, pp.121-30.

[16] Haavelmo, Trygve. (1944) “The probability approach in econometrics” *Econometrica*, 12, 1--118. Supplement.

[17] Hacking, Ian (1983) *Representing and Intervening: Introductory Topics in the Philosophy of Science*, Cambridge: Cambridge University Press.

[18] Hands, D. Wade (2001) *Reflection without Rules*, Cambridge: Cambridge University Press.

[19] Hendry, David F. (1974) “Stochastic Specification in an Aggregate Demand Model of the United Kingdom”, *Econometrica*, 42, pp. 559-578.

[20] – (1979) “Predictive Failure and Econometric Modelling in Macro-Economics: The Transactions Demand for Money”, in P. Ormerod (ed.), *Economic Modelling*, pp.217-42, Heinemann.

[21] – (1980) “Econometrics--Alchemy or Science?” *Economica*, 47:188, pp.387-406. Reprinted as Chapter 1 of Hendry (2000a).

[22] (1985) “Monetary Economic Myth and Econometric Reality”, *Oxford Review of Economic Policy*, 1, pp. 72-84.

[23] – (1995a) *Dynamic Econometrics*, Oxford: Oxford University Press.

[24] – (1995b) “Econometrics and Business Cycle Empirics”, *Economic Journal*, 105, pp.1622-36.

[25] – (1997) “On Congruent Econometric Relations: A Comment”, *Carnegie-Rochester Conference Series on Public Policy*, 47, pp. 163-90.

[26] – (2000a) *Econometrics: Alchemy or Science?* New edition, Oxford: Oxford University Press.

[27] – (2000b) “Econometric Modelling”, Lecture notes for “Econometric Modelling and Economic Forecasting”, Department of Economics, University of Oslo, 24. July - 28. July 2000. <http://folk.uio.no/rnymoen/imfpcg.pdf>.

[28] Hendry, David F. and Ericsson, Neil R. (1983) “Assertion without empirical basis : an econometric appraisal of monetary trends in ... the United Kingdom, by Milton Friedman and Anna J. Schwartz”, Board of Governors of the Federal Reserve System International Finance Discussion Paper No. 270.

[29] – (1991) “An Econometric Analysis of U.K. Money Demand in *Monetary Trends in the United States and the United Kingdom* by Milton Friedman and Anna J. Schwartz”, *American Economic Review* 81, pp. 8-38.

[30] Hendry, David F. and Mizon, Grayham E. (1978) "Serial Correlation as a Convenient Simplification, not a Nuisance: A Comment on a Study of the Demand for Money by the Bank of England", *Economic Journal*, 88, pp.549-63.

[31] Hendry, David F., Muellbauer, John N and Murphy, T. A. (1990) "The Econometrics of DHSY", in Hey, J. D. and Winch, D (eds.) *A Century of Economics*, pp. 298-334. Oxford: Basil Blackwell.

[32] Hendry, David. F., and Richard, Jean-François (1982) "On the formulation of empirical models in dynamic econometrics", *Journal of Econometrics*, 20, pp. 3-33.

[33] Juselius, K. (1993) "VAR Modelling and Haavlemo's Probability Approach to Econometrics", *Empirical Econometrics*, 18, pp.595-622.

[34] Keuzenkamp, Hugo A. (1995) "The Econometrics of the Holy Grail", *Journal of Economic Surveys* 9, pp. 233-48.

[35] – (2000) *Probability, Econometrics and Truth*, Cambridge University Press.

[36] Koopmans, Tjalling. C., Rubin, Herman, and Leipnik, R. B. (1950) "Measuring the equation systems of dynamic economics" In Koopmans, T. C. (ed.), *Statistical Inference in Dynamic Economic Models*, No. 10 in Cowles Commission Monograph, Ch. 2. New York: John Wiley & Sons.

[37] Ladyman, James (1998) "What is Structural Realism?", *Studies in History and Philosophy of Science*, 29, pp.409-24.

[38] Mäki, Uskali (1996) "Scientific Realism and Some Peculiarities of Economics", *Boston Studies in the Philosophy of Science*, 169, pp. 425-45.

[39] Mizon, Grayham E. (1995) "Progressive modelling of Macroeconomic Time Series: the LSE Methodology", In Hoover, Kevin D.(ed.), *Macroeconometrics: Developments, Tensions and Prospects*, pp. 107--169. Dordrecht: Kluwer Academic Press.

[40] Papineau, David (1996) "Introduction", in Papineau, David (ed.) *The Philosophy of Science*, Oxford: Oxford University Press, pp.1-20.

[41] Sneed, Joseph D. (1971) *The Logical Structure of Mathematical Physics*, Dordrecht: Reidel.

[42] Stegmüller, Wolfgang (1979) *The Structuralist View of Theories*, New York: Springer-Verlag.

[43] Suppes, Patrick (1962) "Models of Data". In Nagel, Ernest, Suppes, Patrick and Tarski, Alfred (eds.) *Logic, Methodology and Philosophy of Science: Proceedings of the 1960 International Congress*, Stanford: Stanford University Press, pp. 252-61.

[44] Van Fraassen, Bas (1976) "To Save the Phenomena", *The Journal of Philosophy*, 73:18, pp.623-32.

[45] – (1980) *The Scientific Image*, Oxford: Oxford University Press.

[46] – (1989) *Law and Symmetry*, Oxford: Oxford University Press.

[47] – (1997) “Structure and Perspective: Philosophical Perplexity and Paradox”, in M. L. Dalla Chiara et al. (eds.) *Logic and Scientific Methods*. Dordrecht: Kluwer, pp.511-30.

[48] Wall, K. D., Preston, A. J., Bray, J. W. and Peston, M. H. (1975) “Estimates of a Simple Control Model of the U.K. Economy, in Renton, G. A. (ed.) *Modelling the Economy*, London: Heinemann Educational Books.

[49] Wold, H. O. A. and Juréen, L. (1953) *Demand Analysis: A Study in Econometrics*, 2nd edn., New York: John Wiley.

[50] Worrall, John (1989) “Structural Realism: The Best of Both World?”, *Dialectica*, 43, pp.99-124.

Appendix Theory of Reduction and No Loss of Information

For the detailed definition of the theory of reduction, see Hendry and Richard (1982), Cook and Hendry (1994), Hendry (1995), Hendry (2000b) and chapter nine of the *PcGets* Menu, <http://www.pcgive.com/pcgets/>. This appendix summarizes some key features of the theory of reduction.

The theory of reduction contains ten steps of reduction. They are:

(R1) Data transformation and aggregation.

(R2) Parameter of interest.

(R3) Data partition.

(R4) Marginalization.

(R5) Sequential factorization.

(R6) Mapping to I(0).

(R7) Conditional factorization.

(R8) Complete parameter constancy.

(R9) Lag truncation.

(R10) Functional form.

Then we obtained the econometric model. Each step also involves an econometric concept referring to measures of no loss of information, that is:

(1) *Aggregation* entails no loss of information on marginalizing with respect to disaggregates when the retained information comprises a set of sufficient statistics for the parameters of interest.

(2) *Transformations* do not entail any associated reduction but directly introduce the concept of parameters of interest, and indirectly the notions that parameters should be invariant and identifiable.

(3) *Data partition* is a preliminary although the decision about which variables to include and which to omit is perhaps the most fundamental determinant of the success or otherwise of empirical modelling.

(4) *Marginalizing* with respect to contemporaneous variables is without loss providing the remaining data are sufficient for parameters of interest, whereas marginalizing without loss with respect to all their lagged variables entails both Granger non-causality for the sample of data and a cut in the parameters.

(5) *Sequential factorization* involves no loss if the derived error process is an innovation relative to the history of the random variables, and via the notion of common factors, reveals that autoregressive errors are a restriction and not a generalization.

(6) *Integrated data systems* can be reduced to I(0) by suitable combinations of cointegration and differencing, allowing conventional inference procedures to be applied to more parsimonious relationships.

(7) *Conditional factorization reductions*, which eliminate marginal processes, lead to no loss of information relative to the joint analysis when the conditioning variables are weakly exogenous for the parameters of interest.

(8) *Parameter constancy*, implicitly relates to invariance as constancy across interventions which affect the marginal processes.

(9) *Lag truncation* involves no loss if the error process remains an innovation despite excluding some of the past of relevant variables.

(10) *Functional form approximations* need involve no reduction (logs of log-normally distributed variables): e.g. when the two densities in (17) are equal.

(11) *The derived model* coincides with the LDGP, and is a reduction of the DGP. The derived model is nested within that DGP and its properties are explained by the reduction process: knowledge of the DGP entails knowledge of all reductions thereof. When knowledge of one model entails knowledge of another, the first is said to encompass the second.