Faulty Watch Towers—'Structural' Models in Norwegian Monetary Policy Analysis*

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Abstract

Structural models carry postive connotations in economics. Hence proponents of rival theories and modelling strategies compete about priority to label their models as structural. Rhetorics of this type is found in a recent report on monetary policy analysis in Norway, which defines "structural models" as synonymous with systems of equations that are lifted from modern open economy macroeconomics and which include forward looking expectations.

This note discusses a wider operational definition of structural property of an empirical model. Structural property is a many faceted model feature, e.g., theory content, explanatory power, stability and robustness to regime shifts. It follows that structural properties are not guaranteed by a close connection to theory. Instead, theory driven models are prone to well known econometric problems, which may signal misspecification with damaging implications for policy recommendations. An example taken from "Euroland" inflation substantiates the argument.

1 Introduction

In a recent review of monetary policy and institutions in Norway, Svensson et al. (2002) make several remarks on research at Norges Bank [The Norwegian Central Bank].[1] The group, named Norges Bank Watch (NBW hereafter), specifically recommends that the Bank invests resources into the building of structural models of the Norwegian economy, to be used for policy simulation and forecasting. The committee is sceptical to the Bank's current emphasis on the macroeconometric model, RIMINI.[2] The committee presents a list of problems with the incumbent model: i) It builds on a flawed methodology, being based on empirical modeling rather than on modern open macroeconomic theory. ii) It does not adhere to the principle of model consistent expectations on current dated variables, and in particular it omits

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[1]The report can be downloaded from at http://web.bi.no/cme.

[2]For an overview of RIMINI, see Eitrheim et al. (1999) which also discusses the forecast properties of RIMINI.

so called forward variables. iii) Being empirically rather that theoretically derived, it is "very sensitive" to regime shifts.[3] The group recommends that the Bank makes a change in its strategy and develop structural models along the principles of modern open economy macroeconomics.

It is not difficult to go along with some of the observations made by NBW. First, the usefulness of any model is related to the purpose of analysis. For example, forecasting and policy analysis puts different demands on the model apparatus. Second, care must be taken whenever economic policy and institutions change, so that damaging effects of structural change on model properties and forecasts are minimized. Hence, it is only natural that an incumbent model, specified in another time and perhaps with different policy issues in mind, must prove its worth in the new situation. On the other hand, one must not become too opportunistic. A model that successfully represents the main functional and empirical relationships of the macroeconomy, does not become useless overnight. Moreover, as witnessed by inflation reports of inflation targeting central banks, monetary policy relies on a broad evaluation of the economy and its prospects. As pointed out by Bårdsen et al. (2003), econometric evaluation of models has a role to play as a way of testing, quantifying, and elucidating the importance of transmission mechanisms in the inflationary process.

But what is a structural macroeconomic model anyway? As we have seen, NBW gives one definition: a structural model is synonymous with a model which is made up of equations that are derived from (or at least consistent with) modern macroeconomic economic theory, i.e., each equation has a *structural interpretation*. This definition fails to grasp the distinction between a model's structural interpretation and its eventual *structural properties*, which is essential in empirical economics. There is no guarantee that a model with structural interpretation has the desirable structural properties. On the contrary, mapping directly from theoretical to empirical model may easily become a recipe for disaster: such models often leave a lot to be asked in terms of explanatory power, they forecast badly, and have unstable parameters. Hence, models may have non-structural properties, their structural interpretation notwithstanding. This thesis is substantiated in the following. In section 2 we first discuss the meaning of a model's structural properties. In section 3 we then give a demonstration of a model with structural interpretation, yet with very little structural content. The example is taken from inflation modelling, and is thus topical given the current interest in inflation targeting. Section 4 concludes.

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[3]In addition, NBW mentions the size of the model as a problem in itself, and laments that the model is "constantly being revised and further developed". We have little spesific to add about the size issue. It is obviously a matter of resources and of the type of model usage which one have in mind. Aggregation bias is also an issue, and some dissagregation may be needed to avoid problems of confluent relationships. It is a concern that model documentation (by model builders) and model evaluation (by users and critics) become more costly the larger the system of equations—but it can been done, see e.g., Wallis et al. (1984) (and later evalutions of UK models). It is more difficult to share the commitee's worry about "constant" model revision and development, unless such changes are haphazard. As the real economy is evolving, developments in a model of the economy is more a sign of health than of ailing. Re-modelling may also be triggered by theoretical breakthroughs, changes in the data measurement system and in computer power.

2 Structural interpretation and structural properties

When economists attribute structural interpretation to an equation of an econometric model, it is usually implied that the equation in question has been explicitly derived by the use of economic theory. Economic theory develops over time, so the hallmark of structural interpretation changes its valour over time, e.g., static optimization and ad hoc expectations formation have been replaced by dynamic programming, game theory and model consistent expectations formulation. Economic analysis has the advantage of being based on explicit assumptions, which can be assessed both by introspection and formal confrontation with the data. Theoretical results (e.g., regarding policy) are logically derived. Parameters of interest can be defined without ambiguity.

However, there are also costs to theoretical simplification, elegance and rigour. Since economic data are non experimental, theoretical ceteris paribus clauses and simplifying assumptions cannot be trusted to carry over to the empirical analysis. As a result, model residuals do not reflect the assumed properties of the disturbances (making inference difficult), omitted variables induce bias in the estimates of the parameters of interest, and the econometric model becomes unstable with respect to extensions of the data set. Econometric techniques have been invented in order to rectify some of these problems, but the validity of these correction methods remain dependent on the initial assumption that the model is basically sound, and that e.g,. autocorrelated residuals are indeed a sign of autocorrelated disturbance of the true model and not of misspecification. Section 3 provides an example of the problem.

A main thesis in the following is that an empirical model's structural properties are different from its structural interpretation. Heuristically, we take a model to have structural properties if it is robust to shocks, and is able to fence off challenges from rival models. A model with structural properties does not disintegrate that easy! Structural properties are nevertheless relative, to the history, nature and significance of regime shifts. There is always the possibility that the next shocks to the system may incur real damage to a model with high structural content hitherto. Contrary to the views conveyed by NBW, instances of "poor forecasting", or downright forecast failure, do not by implication remove all structural properties of a model. Conversely, models with high structural content will nevertheless lose regularly to simple forecasting rules, see e.g., Clements and Hendry (1999), Eitrheim et al. (1999). So different models may be optimal for forecasting and for policy analysis, which incidentally fits well with NBW's recommendation of a suite of models.

Our definition implies that a model's structural properties must be evaluated along several dimensions, and the following seem particularly relevant

1. Theoretical interpretation.

2. Ability to explain the data.

3. Ability to explain earlier findings, i.e., encompassing the properties of existing modes.

4. Robustness to new evidence in the form of updated/extended data series and new economic analysis suggesting e.g., new explanatory variables.

Economic analysis (#1) is a main guidance in the formulation of econometric models. Clear interpretation also helps communication of ideas and results among researchers and it structures the debate. However, since economic theories are necessarily abstract and build on simplifying assumptions, it seems self evident that direct translation of a theoretical relationship to an econometric model must lead to such problems as biased coefficient estimates, wrong signs of coefficients, and/or residual properties that contradict any initial assumption of white noise disturbances. The main distinction seems to be between seeing theory as representing *the* correct specification, (leaving parameter estimation to the econometrician), and viewing theory as a guideline in the specification of a model which also accommodates institutional features, attempts to accommodate heterogeneity among agents, addresses the temporal aspects for the data set and so on, see e.g., Granger (1999).

NBW re-iterate widely held arguments against what they call "largely empirical models", e.g., sample dependency, lack of invariance (the Lucas-critique), unnecessary complexity (in order to fit the data) and chance finding of "significant" variables. Yet, ability to characterize the data (#2) remains an essential quality of useful econometric models, and given the absence of theoretical truisms, the implications of economic theory have to be confronted with the data in a systematic way. Moreover, the mentioned pitfalls of empirically based models can avoided, see e.g., Granger (1999), Hendry (2002). Due to recent advances in the theory and practice of data based model building, we know that by using general-to-spesific (gets) algorithms a researcher stands a good chance of finding a close approximation to the data generating process, see Hoover and Perez (1999), and Hendry and Krolzig (2000), and that the danger of over-fitting is in fact (surprisingly) low.[4] Conversely, acting as if the specification is given by theory alone, with only coefficient estimates left to "fill in", is bound to result in the econometric problems noted above and which section 3 below will demonstrate.

There is usually controversy in macroeconometrics , so a new model's capability of encompassing earlier findings is an important aspect of structure (#3). There are many reasons for the coexistence of contested models for the same phenomena, some of which may be viewed as inherent (limited number of data observations, measurement problems, controversy about operational definitions, new theories). Nevertheless, the continued use of flawed "textbook" methodologies do not help tidying up the field, since such practices inadvertently hinder cumulation of evidence taking place. There would be huge gains from a breakthrough for new standards of methodology and practice in the profession.

Ideally, empirical modelling is a cumulative process where models continuously become overtaken by new and more useful ones. By useful we understand in particular models that are relatively invariant to changes elsewhere in the economy, i.e., they contain autonomous parameters, see Haavelmo (1944), Johansen (1977),

[4]Naturally, with a very liberal specification strategy, overfitting will result from gets modelling, but with "normal" requirements of levels of significance, robustness to sample splits etc, the chance of overfitting is small. Thus the documented performance of gets modelling now refutes the view that the *axiom of correct specification* must be invoked in applied economerics, Leamer (1983). The real problem of empirical modelling may instead be to keep or discover an economically important variable that has yet to manifest itself stronlgy in the data, see Hendry and Krolzig (2001). Almost by implication, there is little evidence that Gets leads to models that are prone to forecast failure, see Clements and Hendry (2002).

Aldrich (1989), Hendry (1995b). Models with a high degree of autonomy represent structural properties: They remain invariant to changes in economic policies and other shocks to the economic system, as implied by #4 above.[5] However, structure is partial in two respects: First, autonomy is a relative concept, since an econometric model cannot be invariant to every imaginable shock. Second, all parameters of an econometric model are unlikely to be equally invariant, and only the parameters with the highest degree of autonomy represent structure. Since elements of structure typically will be grafted into equations that also contain parameters with a lower degree of autonomy, forecast breakdown may frequently be caused by shifts in these non-structural parameters.[6]

A strategy that puts a lot of emphasis on forecast behaviour, without a careful evaluation of the causes of forecast failure *ex post*, runs a risk of discarding models that actually contain important elements of structure. Hence, for example Doornik and Hendry (1997) and Clements and Hendry (1999, Ch. 3) show that the main source of forecast failure is deterministic shifts in means (e.g., the equilibrium savings rate), and not shifts in such coefficients that are of primary concern in policy analysis (e.g., the propensity to consume). This represent a much deeper understanding of the causes and implications of forecast failure than Svensson et al. (2002), who seem stuck with the idea that whole classes of models automatically becomes redundant if they have once failed in forecasting (either relative to their own within sample fit, or in a forecast competition). Specifically, they state that "a largely empirical model is also obviously very sensitive to the problem of being estimated on data from different monetary-policy regimes...". Structural breaks are always a main concern in econometric modelling, but like any hypothesis of theory, the only way to judge the quality of a hypothesized break is by confrontation with the evidence in the data. Moreover, given that an encompassing approach is followed, a forecast failure is not only destructive but represent a potential for improvement, since respecification follows in its wake, cf. Eitrheim et al. (2002).

3 Non-structural properties of a structural equation

There is usually a gulf between measurable complexities of the real economy and what econometric model can hope to incorporate. Hence, starting with the idea that theory is complete (or that we can act as if it is complete) does not solve any of the problems of empirical modelling in economics, and specifically does not guarantee a high degree of structure.

The New Keynesian Phillips Curve, NPC, has emerged as a consensus theory of inflation in modern monetary economics, largely because of its stringent theoretical derivation. Hence it is an equation that Svensson et al. (2002) would recognize

[5] see e.g., Hendry (1995a, Ch. 2,3 and 15.3) for a concise definition of structure as the invariant set of attributes of the economic mechanism.

[6] This line of thought may lead to the following practical argument against large-scale empirical models: Since modelling resources are limited, and some sectors and activities are more difficult to model than others, certain euations of any given model are bound to have less structural content than others, i.e., the model as a whole is no better than its weakest (least structural) equation.

as a structural equation.[7] In terms of the previous section's list of structural characteristics, the NPC scores high on theory consistency (#1).

As an econometric model, the NPC states that inflation, defined as $\Delta p_t \equiv p_t - p_{t-1}$ where p_t is the log of a price level index, is explained by expected inflation one period ahead, $\mathsf{E}(\Delta p_{t+1} \mid \mathcal{I}_t)$, and marginal costs x_t (e.g., output gap, the unemployment rate or the wage share in logs), see e.g., Clarida et al. (1999):

$$\Delta p_t = \alpha \mathsf{E}(\Delta p_{t+1} \mid \mathcal{I}_{t-1}) + \beta x_t + \epsilon_t. \tag{1}$$

The disturbance ϵ_t is an innovation relative to the information set $\mathcal{I}_{t-1}$. In empirical applications, the NPC is often modified by inclusion of Δp_{t-1} and is referred to as the hybrid model, see Gali et al. (2001)—hereafter GGL. With actual, rather than expected inflation on the right hand side, the model can written as

$$\Delta p_t = \alpha^f \Delta p_{t+1} + \alpha^b \Delta p_{t-1} + \beta x_t + \varepsilon_{p,t}. \tag{2}$$

$\varepsilon_{p,t}$ is a composite disturbance made up of the expectations error and the structural equation disturbance, ϵ_t. It is useful to complete the model with an equation for the 'forcing variable' x_t:

$$x_t = \gamma \Delta p_{t-1} + \lambda x_{t-1} + \varepsilon_{xt}. \tag{3}$$

The qualitative dynamic properties of the system (2)-(3) depend on the three roots of the associated characteristic polynomial. If x_t is AR(1) and strongly exogenous, the solution depends on the parameters of the NPC itself. For example $\alpha^f = 0.65$, $\alpha^b = 0.25$, $\lambda = 0.7$ implies the 3 roots $\{1.22, 0.7, 0.31\}$ and thus Δp_t is stationary (the solution will be a function of $\varepsilon_{p,t+j}$ $j \geq 0$).

In the empirical NPC literature, one often encounters the homogeneity restriction $\alpha^f + \alpha^b = 1$, which forces a unit-root on the system in the case where x_t is exogenous.[8] For example $\alpha^f = 0.75$, $\alpha^b = 0.25$, $\lambda = 0.7$ gives $\{1.0, 0.7, 0.33\}$ implying that there is no unique stationary solution for Δp_t. In this case, the existence of a unique steady state solution requires equilibrating mechanisms in the process governing x_t, which logically cannot be exogenous.

Thus, the forward coefficient α^f and the joint coefficent $\alpha \equiv \alpha^f + \alpha^b$, are main parameters of interest of the NPC. Therefore an important issue is whether (2), when viewed as a statistical model, give rise to valid (Neyman-Pearson) tests of hypotheses about α^f and α. In other words, the statistical adequacy of the model for testing purposes is a main issue, the more so since existing econometric models of inflation suggest that (2) may be misspecified, both in terms of too simple lag structure and because explanatory variables are omitted from the specification.

In this perspective, the unanimous practice of estimating NPCs by GMM is problematic, since one then tacitly assume that for example serial correlation in the

[7] Probably in the same manner as proponenets of the NPC, for example: "The structural equation for inflation that we estimate for the Euro area is in the spirit of the new Phillips curve literature. It evolves explicitly from a model of staggered nominal price setting by monopolistically competitive firms" (Gali et al. (2001, p. 1238)).

[8] Effectively, the homogeneity restriction turns the hybrid model into a model of the *change* in inflation.

(uncorrected) residuals is symptomatic of serial correlation in the true disturbances. Put differently, the estimation of the NPC by GMM implies that the specification of the econometric model used for testing a substantive hypothesis (regarding α^f and/or α) incorporates the alternative hypothesis associated with a misspecification test (i.e., of residual autocorrelation). As stressed by several authors, this is usually not a good idea in econometrics, since the underlying cause of the residual misspecification may be quite different, see Hendry and Mizon (1978). Instead, when departures from the underlying assumptions of the statistical model have been established, there is need for respecification, with the aim of finding a statistical model which does a better job in capturing the systematic variation in the rate of inflation.

As an example of this approach, consider the hybrid NPC estimated by 2SLS without any correction, using GGL's data for the Euro area, and their choice of forcing variable x_t, namely the wage share denoted ws_t, Bårdsen et al. (2002) has more details.

$$\Delta p_t = \underset{(4.84)}{0.655}\,\Delta p_{t+1} + \underset{(2.39)}{0.280}\,\Delta p_{t-1} + \underset{(0.827)}{0.071}\,ws_t + \underset{(0.844)}{0.1027} \tag{4}$$

2SLS, 1972 (2) to 1998 (1)   Residual properties: fails   Stability: ok

The estimates of the coefficients of the inflation terms are representative of GGL's results, as well as of hybrid model estimates on US data. Importantly, the hybrid model's residuals are characterized not only by 1st order autocorrelation (which is implied if the NPC is indeed the true model), but also by 2nd order autocorrelation and by heteroscedasticity due to squares and products of regressors. Hence, the model fails on standard model evaluation criteria, it is inadequate as a statistical model of the rate of inflation, and it does not provide the basis for reliable inference about parameters of interest (e.g., a^f and α). It also means that the appearant stability of the equation (suggested by the ok below the equation) is unfounded, since the assumptions underlying the costancy testing are invalidated by the residual autocorrelation etc.

In terms of structural properties this equation fails on #2 (it does not explain the data) despite the high score on #1 (structural interpretation). As pointed out, the popular route around this is either to 'whiten' the residuals (GMM estimation), and/or to correct the 2SLS coefficient standard errors. However, another way of whitening the residuals is to *respecify* the model, with the aim of attaining innovation error processes and a firmer basis for testing hypothesis within the respecified equation, and to attain an encompassing equation, i.e., #3 above.

As a simple exercise in respecification, we moved the lagged output-gap ($emugap_{t-1}$) and the fourth lag of inflation (Δp_{t-4}) from the list of instruments used for estimation of (4), and included them as explanatory variables in the equation.[9] The results

[9] The instruments used are five lags of inflation, and two lags of the wage share and the output gap.

(using 2SLS without corrections) are:

$$
(5)\quad
\begin{aligned}
\Delta p_t \;=\;& \underset{(0.238)}{0.068}\ \Delta p_{t+1} + \underset{(1.49)}{0.248}\ ws_t + \underset{(3.13)}{0.4421}\ \Delta p_{t-1} \\
& + \underset{(1.92)}{0.1799}\ \Delta p_{t-4} + \underset{(2.33)}{0.1223}\ emugap_{t-1} + \underset{(1.54)}{0.5366}
\end{aligned}
$$

2SLS, T = 104 (1972 (2) to 1998 (1))

Residual properties: ok   Stability: ok

When compared to (4), two results stand out. First, the estimated coefficient of the forward term Δp_{t+1} is reduced by a factor of 10, meaning that despite its structural interpretation, model (1) has non-structural properties (#3). Second, the diagnostic tests no longer indicate residual autocorrelation or heteroscedasticity, so we can undertake substantive inference in a reliable way and the claimed structural interpretation is in fact encompassed by (4). Specifically, we can test the significance of the Δp_{t+1} by a conventional t-test: Clearly, the forward term is insignificant in this model. A third point relates to the homogeneity restriction: In (4) that restriction can obviously not be rejected, but in the respecified model, the sum of the inflation coefficients is much lower. Moreover, imposing $\alpha^f = 0$ and estimating the model without the forward term produces a "Dicky-Fuller type" test of -3.19 (2SLS), indicating that an interpretation of the dynamics along conventional causal lines may be appropriate, rather than saddle-path equilibria (although investigation of the system involving x_t is needed to fully characterize the dynamics).

It is interesting to note that when the NPC is applied to other data sets, i.e., to such diverse data as US, UK and Norwegian inflation rates, very similar parameter estimates to (4) are obtained, see Bårdsen et al. (2002). Is this a sign of structure? Proponents of the NPC claim so, see e.g. Gali and Gertler (1999) and Gali et al. (2001). An altogether different interpretation is that the NPC is almost void of explanatory power, and that it captures only one common feature among different countries data sets, namely autocorrelation. If that is the right interpretation then we infer that each NPC will disintegrate once relevant characteristics of each country specific inflation process is introduced, which is exactly what Bårdsen et al. (2002) find. Thus, finding that the US New Keynesian Phillips curve is corroborated by the Euro-area NPC or the UK and Norwegian NPC is in fact a sign of non-structure, rather than structure.

4 Conclusions

"Structural models" have a positive ring in economists' ears. It is no surprise then that proponents of different modelling strategies in econometrics compete over the "right" to label their models as structural, and that alternative models are described as reduced form, ad hoc, data based or other words with similar negative connotations. The authors of the NBW report are no exception, labelling as "structural" models that are "eclectic applications of modern open economy macroeconomics where the equations have structural interpretations.." (p. 56).

Yet, care must be taken if the meaning of structural interpretation is stretched to convey truth or robustness of econometric models. In this note we specifically challenge the view that structural interpretation is the single most important aspect of structure and robustness in econometric models. Like beauty in people, theoretical elegance of economic models is only skin deep, and does not guarantee that their econometric counterparts have the structural properties discussed above (explanatory power, constancy and autonomy of parameters, encompassing). These hallmarks of useful econometric models cannot be postulated, but are likely to be hard earned features of models that have been developed and tested over time with the aim of maximizing their degree of structural content. The empirical section showed that a model with structural interpretation, the New Keynesian Phillips curve, fails on each measurable structural property when applied to Euro-area data. Does this mean that models with high structural content cannot be established for that data set? Since little work have so far been done on this data set one might say that the jury is still out out. However, the literature on the empirical modelling of wages and prices using equilibrium correction models and general-to-specific modelling makes us optimistic that models with structural properties can be established also for "Euroland".

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