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CONDITIONAL AND STRUCTURAL ERROR CORRECTION MODELS

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ABSTRACT

A "structural" error correction model (in Boswijk's sense) is a representation of a conditional error correction model that satisfies certain restrictions. This paper examines the conditions under which such a structural error correction model exists and when the associated representation is of interest. To clarify the nature of such models, several analytical and empirical examples are considered, which violate those conditions. Structural error correction models are economically appealing, but their limitations imply that some care must be taken when applying them in practice.

Key words and phrases: Boswijk, cointegration, conditional models, dynamic specification, encompassing, error correction, exogeneity, general-to-specific modeling, sequential reduction, structural models, vector autoregression.

Conditional and Structural Error Correction Models

Neil R. Ericsson*

1 Introduction

In his innovative paper "Efficient inference on cointegration parameters in structural error correction models," Boswijk (1994) proposes the notion of a "structural error correction model," which is a representation of a conditional error correction model (ECM) that satisfies certain restrictions. His Section 2 discusses the relations between vector autoregression, conditional ECM, structural ECM, and static regression approaches to cointegration; and it formulates an identification procedure for cointegrating vectors. Boswijk's Section 3 derives various estimators and associated test statistics for the structural ECM, and states their asymptotic properties. Section 4 presents Monte Carlo evidence comparing the estimators' properties.

Boswijk (1994) carefully develops the analytical structure, historical perspective, and statistical framework for this new model class; and Boswijk (1992) additionally demonstrates how to implement structural ECMs, using data on money demand in the United Kingdom. Given such thorough coverage, I will focus on the nature of the structural ECM itself, employing its relation to the conditional ECM. That leads to examining the conditions under which the structural ECM exists and when such a representation is of interest.

Conditional ECMs are very popular empirically; cf. Davidson, Hendry, Srba, and Yeo (1978), Hendry, Pagan, and Sargan (1984), Ericsson and Hendry (1985), Hendry and Ericsson (1991), and the papers in Ericsson (1992) and Ericsson and Irons (1994) *inter alia*. If weak exogeneity is valid, neglect of

*Forthcoming in the *Journal of Econometrics* as invited discussion of Boswijk (1994). The author is a staff economist in the Division of International Finance, Federal Reserve Board, Washington, D.C. The views expressed in this paper are solely the responsibility of the author and should not be interpreted as reflecting those of the Board of Governors of the Federal Reserve System or other members of its staff. I am grateful to Peter Boswijk, Julia Campos, Jon Faust, David Hendry, John Irons, and Michel Lubrano for helpful comments and discussions.

the marginal process is without loss of information; and conditional ECMs are almost invariably much simpler to model than the whole system. A structural ECM enforces a certain economic interpretation on a conditional ECM, with corresponding restrictions. Thus structural models are very appealing in that they offer the empirical, statistical, and economic advantages of a conditional ECM within a given economic framework.

The restrictions associated with a structural ECM lend it strength by providing structure; they are also a weakness in that they need not be satisfied in practice. To clarify the nature of structural ECMs, several analytical and empirical examples are considered, which violate those conditions. Most examples are under the condition of weak exogeneity, in which case a valid conditional ECM exists but a structural ECM does not. While structural ECMs offer an important and economically appealing subclass of conditional ECMs, their limitations imply that care must be taken when applying the former in practice. Section 2 derives the structural ECM from a vector autoregression via the conditional ECM and comments on some essential elements of that derivation. Section 3 provides the examples.

Before continuing, a semantic point is in order. The adjective "structural" has many meanings in econometrics. Boswijk has added his own definition, so "structural" is used in Boswijk's sense in Sections 2 and 3 below. Caution is required, however. The examples in Section 3 are not structural in Boswijk's sense. Yet, they *are* structural in their authors' sense, which corresponds to Hendry's (1993, p. 1) definition of structural, i.e., being "invarian[t] over extensions of the information set in time, interventions or variables." The examples also are all ECMs, so they are structural ECMs, albeit not in Boswijk's sense.

2 Cointegrated Vector Autoregressions

The nature of the structural ECM is best understood by considering the standard cointegration analysis of a vector autoregression (VAR). Transformations of and restrictions on the VAR lead to the structural ECM (Sections 2.1 and 2.2) and suggest a sequential modeling strategy for obtaining it (Section 2.3).

2.1 Transformations of the VAR

For an $n \times 1$ vector of variables x_t at time t, the ℓ^{th}-order Gaussian VAR can be parameterized as:

$$\Delta x_t = \pi x_{t-1} + \sum_{j=1}^{\ell-1} A_j \Delta x_{t-j} + \varepsilon_t \qquad \varepsilon_t \sim \mathsf{NI}(0, \Sigma) \qquad t = 1, \ldots, T, \tag{1}$$

where Δ is the difference operator, π and the A_j are $n \times n$ matrices of coefficients, and ε_t is the $n \times 1$ vector of independently and normally distributed disturbances. The rank of π (denoted r, $0 \leq r \leq n$) determines the number of cointegrating vectors, so (1) may be written as:

$$\Delta x_t = \alpha\beta' x_{t-1} + \sum_{j=1}^{\ell-1} A_j \Delta x_{t-j} + \varepsilon_t \tag{2}$$

for an $n \times r$ matrix of r cointegrating vectors β and an $n \times r$ weighting matrix α. Partitioning x_t into subvectors of g and k variables as $(y_t' : z_t')'$, (2) may be rewritten as a conditional model for y_t given z_t:

$$\Delta y_t = B_0^* \Delta z_t + \alpha_c \beta' x_{t-1} + \sum_{j=1}^{\ell-1} A_{1j}^* \Delta x_{t-j} + v_t^* \quad v_t^* \sim \mathsf{NI}(0, \Sigma_v^*) \tag{3}$$

and a marginal model for z_t:

$$\Delta z_t = \alpha_2 \beta' x_{t-1} + \sum_{j=1}^{\ell-1} A_{2j} \Delta x_{t-j} + \varepsilon_{2t} \qquad \varepsilon_{2t} \sim \mathsf{NI}(0, \Sigma_{22}) \tag{4}$$

without loss of generality, where $B_0^* = \Sigma_{12}\Sigma_{22}^{-1}$, $\alpha_c = \alpha_1 - B_0^*\alpha_2$, $A_{1j}^* = A_{1j} - B_0^* A_{2j}$, $v_t^* = \varepsilon_{1t} - B_0^* \varepsilon_{2t}$, $\Sigma_v^* = \Sigma_{11} - \Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21}$, matrices are partitioned conformably with $(y_t' : z_t')$, and subscripts indicate the relevant submatrix.

Premultiplying (3) by a nonsingular $g \times g$ matrix Γ_0 obtains another conditional model, isomorphic to (3):

$$\begin{aligned} \Gamma_0 \Delta y_t &= B_0 \Delta z_t + \Lambda(\Gamma y_{t-1} + B z_{t-1}) \\ &\quad + \sum_{j=1}^{\ell-1} (\Gamma_j : B_j) \Delta x_{t-j} + v_t \quad v_t \sim \mathsf{NI}(0, \Sigma_v), \end{aligned} \tag{5}$$

where $B_0 = \Gamma_0 B_0^*$, $\Lambda = \Gamma_0 \alpha_c$, $(\Gamma : B) = \beta'$, $(\Gamma_j : B_j) = \Gamma_0 A_{1j}^*$, $v_t = \Gamma_0 v_t^*$, and $\Sigma_v = \Gamma_0 \Sigma_v^* \Gamma_0'$ for suitable partitionings of matrices. Equations (1), (2), (3), (4), and (5) are equations (3), (5), (10), (12), and (17) in Boswijk (1994), with the notation modified slightly for convenience of the discussion below. Under the assumptions detailed in Section 2.2, (5) above is a structural ECM. It is the focus of Boswijk (1994), with (4) as the accompanying marginal model.

2.2 Restrictions on the VAR

Equation (1) is the basis for Johansen's (1988, 1991) and Johansen and Juselius's (1990) complete system analysis of cointegration. Because π may be of full rank, neither (2) nor (3)–(4) nor (4)–(5) as such entails any loss of generality relative to (1). Under the assumptions below, (2), (3)–(4), and (4)–(5) are *with* loss of generality with respect to the unrestricted VAR.

Boswijk (1994) analyzes the class of structural ECMs. A structural ECM is a certain representation of a VAR such as (1) that satisfies restrictions involving cointegration [Assumption (i)], weak exogeneity [Assumptions (ii) and (iii)], and structurality [Assumptions (iv)–(viii)]. For ease of discussion in Section 3, these assumptions are presented below in greater detail than they appear in Boswijk (1994).

i. The number of cointegrating vectors is r and satisfies $0 < r < n$ with x_t being integrated of order one;

ii. the parameters of interest are β;

iii. $\alpha_2 = 0$;

iv. $g = r$;

v. $\text{rank}(\Lambda\Gamma) = r$;

vi. β is identified by a set of restrictions $\{R_i\beta_i = 0,\ i = 1, \ldots, r\}$, where the matrices R_i are known and satisfy certain rank conditions;

vii. the matrix Λ is diagonal with nonzero elements on the diagonal; and

viii. the matrix Γ_0 is normalized to have unit elements on the diagonal.

Assumptions (i)–(viii) map into Boswijk's (1994) assumptions as follows. Assumption (i) is Boswijk's Assumption 1; (ii) is implicit for the most part; (iii) is explicit in the text (e.g., Section 1), when used; (iv) and (v) are Boswijk's Assumptions 3(i) and 3(ii); (vi) is Boswijk's restriction for the generic identification of β (his Assumption 2); and (vii) and (viii) are Boswijk's restrictions for identifying Γ_0, Λ, and Σ, conditional on the identification of β.

Assumptions (i), (ii), and (iii) together imply weak exogeneity of z_t for β; see Engle, Hendry, and Richard (1983). That is, the parameters of interest, which are *all* the cointegrating vectors, can be obtained from the conditional model (3) alone without loss of information. Assumptions (i) and (iii) are both testable, as discussed in Johansen (1988, 1991, 1992a, 1992b) and Boswijk (1992), whereas Assumption (ii) is (supposedly) guided by economic theory and the purpose of the model. Even if the parameters of interest depend on B_0^*, α, Σ_v^*, and the A_{1j}^* as well, the conditions for weak exogeneity remain the same, provided that $(\alpha, \beta, B_0^*, \{A_{1j}^*\}, \Sigma_v^*)$ and $(\{A_{2j}\}, \Sigma_{22})$ are variation free.

Assumption (ii) appears in Johansen (1992a, 1992b) as well as Boswijk (1994), albeit with both authors generally including α in the parameters of interest. However, if the parameters of interest include only some of the cointegrating vectors, (iii) is an overly strong condition for the weak exogeneity of z_t. Any individual empirical investigation might reasonably restrict its focus to only a subset of the cointegrating vectors in the economy, so the examples below consider this situation in greater detail.

Assumption (iv) states that the number of equations (g) in the conditional model equals the number of cointegrating vectors (r). Weak exogeneity and Assumption (iv) jointly imply that $\mid \alpha_c \mid \neq 0$, and so all the cointegrating vectors enter the conditional model. Assumption (iv) is testable in that g need not equal r. For instance, for a given r and a given partitioning of x_t, (iv) implies (iii), which is testable.

Assumption (v) prohibits the conditional equations from including cointegration relations that involve the z_t only, noting that $\Lambda\Gamma = \Gamma_0\alpha_c\Gamma$. Both α_c and Γ must be of full rank.

In one common version of Assumption (vi), the set of cointegrating vectors is identified such that each of the g variables in y enters one and only one cointegrating vector: that is, $\beta' = (I_r : B)$. For instance, Phillips (1991, 1994), Phillips and Loretan (1991), and Stock and Watson (1993) assume a given number of cointegrating vectors with Γ of full rank and identify β by $(I_r : 0)\beta = I_r$. While the "problem" of identifying multiple cointegrating vectors is often associated with Johansen's procedure, it arises from dealing with more than one cointegrating vector and is not related to estimation *per se*.

Assumption (vii) is without loss of generality, provided Assumptions (iv) and (v) are satisfied. Assumption (vii) restricts each cointegrating vector to enter one and only one conditional equation, with the normalized variable in the cointegrating vector matching the normalized endogenous variable of the conditional equation.

Assumption (viii) is without loss of generality because Γ_0 is nonsingular. Even so, the interpretability of the conditional model may be affected by imposing (vi), (vii), and (viii). While these three assumptions may uniquely identify the parameters of the structural model, they do not guarantee a model interpretable in light of economic theory; cf. Hendry (1993, pp. 25ff).

2.3 Modeling the VAR

A structural ECM is equation (5) under Assumptions (i)–(viii), and it may be motivated as follows. Suppose the practitioner approaches modeling in three steps. First, r is determined by Johansen's procedure from the rank of π in (1), the unrestricted VAR. Second, g is determined, e.g., in light of exogeneity and conditioning arguments from economic theory. Third, given those values of r and g and the partitioning of x_t, the hypothesis $\alpha_2 = 0$ is tested by Johansen's (1992a) test of weak exogeneity. In practice, the number of cointegrating vectors r, the economically interesting conditioning set (which determines g), and the presence or lack of cointegrating vectors in various equations (thereby determining α_2) need bear no relation whatsoever to each other. However, *if* $g = r > 0$, $\alpha_2 = 0$, $\text{rank}(\Lambda\Gamma) = r$, and the parameters of interest are β, then analysis of (5) as a *statistically* valid (conditional) structural ECM proceeds. The *economic* interpretability of (5) under Assumptions (i)–(viii) remains an issue specific to the application at hand.

3 Examples

As Boswijk (1994) correctly argues, structural ECMs are an appealing framework for analyzing systems that satisfy Assumptions (i)–(viii). If one or more of these assumptions is violated, a different approach is required. Analysis of the system as a whole is valid in any case, and conditional modeling is valid under Assumptions (i)–(iii) alone. If Assumptions (i)–(viii) are invalid but are imposed, inferences about the supposed structural ECM may be misleading. Equally, it is feasible to discover (rather than impose) that these assumptions hold, to the extent that they are with loss of generality.

To clarify the nature of the assumptions, each example below specifies a given data generation process or empirical model, explains the interest in it, and shows how it violates one or more of Assumptions (i)–(viii). The first two examples are analytical. The remaining three examples are empirical and are taken from Hendry and Mizon (1993), Juselius (1992), and Kamin and Ericsson (1993).

3.1 Separate Subsystems

Consider the system (1) with block-diagonal π, $\{A_j\}$, and Σ. That is, y_t and z_t are generated by two completely unrelated subsystems:

$$\Delta y_t = \alpha_{11}\beta'_{11}y_{t-1} + \sum_{j=1}^{\ell-1} A_{11j}\Delta y_{t-j} + \varepsilon_{1t} \qquad \varepsilon_{1t} \sim \mathsf{NI}(0, \Sigma_{11}) \tag{6}$$

and

$$\Delta z_t = \alpha_{22}\beta'_{22}z_{t-1} + \sum_{j=1}^{\ell-1} A_{22j}\Delta z_{t-j} + \varepsilon_{2t} \qquad \varepsilon_{2t} \sim \mathsf{NI}(0, \Sigma_{22}) \ , \tag{7}$$

with $\mathcal{E}(\varepsilon_{1t}\varepsilon'_{2s}) = 0$ for all t and s. Because $B_0^* = 0$, (6) is also the conditional model for y_t given z_t and their lags. The long-run impact matrix π is:

$$\pi = \alpha\beta' = \begin{bmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22} \end{bmatrix} \begin{bmatrix} \beta'_{11} & 0 \\ 0 & \beta'_{22} \end{bmatrix} = \begin{bmatrix} \alpha_{11}\beta'_{11} & 0 \\ 0 & \alpha_{22}\beta'_{22} \end{bmatrix} . \tag{8}$$

A system such as (6)–(7) might arise when analyzing two possibly related markets or countries that have no interactions in fact.

Under Assumption (ii), z_t is not weakly exogenous unless $\alpha_{22} = 0$ because the parameters of interest are β, which include β_{11} and β_{22}. While β_{11} can be retrieved from (6) alone without loss of information, β_{22} can not even be identified from (6). However, Assumption (ii) can not be taken for granted. In analyzing a conditional model, the parameters of interest might be only those cointegrating vectors that enter the conditional model itself. For the system (6)–(7), z_t *is* weakly exogenous for those parameters of interest, which are β_{11}. The presence or lack of weak exogeneity depends upon what the parameters of interest are, and they need not include all the cointegrating vectors of the system. The *conditions* for weak exogeneity also depend upon what the parameters of interest are. For instance, weak exogeneity of z_t for β_{11} does not require Assumption (iii), noting that α_{22} may be nonzero in (7).

In general, Assumption (iv) is not satisfied by (6)–(7), noting that the number of variables in (6) need not equal the number of cointegrating vectors in the two subsystems combined. Unless y_t is stationary, rank(β_{11}) is less than the number of variables in y_t; and rank(β_{22}), as a part of (7), is unrelated to the determination of y_t. Even if $g = r$, Assumption (v) can not be satisfied because some of the cointegrating vectors involve z_t alone.

For (6)–(7), conditional modeling of y_t given z_t is feasible, provided the parameters of interest are β_{11}. Structural ECMs as defined by Assumptions (i)–(viii) do not exist for (6)–(7). Assumptions (ii) and (iii) could be modified so that the parameters of interest are β_{11}. Even then, if rank(β_{11}) $< g$, (iv) and (vii) can not be satisfied because of the dimensions of y_t and Λ; and if rank(β_{11}) $= g$, then y_t is stationary, violating (i).

3.2 Multiple Cointegrating Relations

Consider the system (1) with two endogenous variables ($g = 2$), two weakly exogenous variables, a block-diagonal Σ, and two cointegrating vectors $(\beta_{11}' \; 0)'$ and $(0 \; \beta_{22}')'$, with the cointegrating vectors entering the conditional equations only. For ease of exposition, let $A_j = 0$ except for the 2×2 submatrix A_{211}, which contains the coefficients on Δy_{t-1} in the equation for Δz_t. This system is:

$$\Delta y_t = \alpha_{11}\beta_{11}' y_{t-1} + \alpha_{12}\beta_{22}' z_{t-1} + \varepsilon_{1t} \tag{9}$$

$$\Delta z_t = A_{211}\Delta y_{t-1} \qquad\qquad\qquad + \varepsilon_{2t}\,, \tag{10}$$

where α_{11}, α_{12}, β_{11}, and β_{22} are all 2×1 matrices. The vector x_t is integrated of order one, provided the coefficients in A_{211} satisfy certain mild conditions; see Johansen [(1992b), equation (5)]. Here, as in (6)–(7), $B_0^* = 0$; so (9) is the conditional model for y_t given z_t and their lags. A system such as (9)–(10) might arise when analyzing two related markets where disequilibria in both markets affect one of the markets directly and the other market indirectly.

Equations (9)–(10) satisfy Assumptions (i)–(iii) with $r = 2$, so z_t is weakly exogenous for β, making (9) a valid conditional ECM. Equations (9)–(10) also satisfy Assumption (iv) that $g = r$, contrasting with (6)–(7). Even so, (9) is not a structural ECM: Assumption (v) is violated because:

$$\operatorname{rank}(\Gamma) = \operatorname{rank}\left(\begin{bmatrix} \beta'_{11} \\ 0 \end{bmatrix}\right) = 1 < 2 = r\ . \tag{11}$$

If β were incorrectly identified by Assumption (vi) imposing full rank on Γ, statistical inference would be adversely affected. Relatedly, regression-based cointegration techniques due to (e.g.) Phillips and Loretan (1991) and Stock and Watson (1993) are inappropriate here because one of the cointegrating vectors involves z_t alone.

3.3 U.K. Narrow Money Demand

Hendry and Mizon (1993) model narrow money demand in the United Kingdom. The data are quarterly over 1963(1)–1984(4) for nominal M_1 (M), real total final expenditure at 1985 prices (TFE), the corresponding deflator (P), and the three-month local authority interest rate ($R3$). The variables in Hendry and Mizon's cointegration analysis are $m - p$, Δp, tfe, $r3$, a constant, and a trend, where lower case denotes variables in logarithms. Hendry and Mizon [(1993), Table 18.7] derive a congruent system with the trend entering the cointegration space, with:

$$\alpha\beta'\begin{bmatrix} x_t \\ t \end{bmatrix} = \begin{bmatrix} -0.095 & 0 \\ 0 & -0.235 \\ 0 & +0.338 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 7.0 & -1 & 0.7 & 0 \\ 0 & 1 & -0.28 & 0 & 0.0014 \end{bmatrix} \begin{bmatrix} (m-p)_t \\ \Delta p_t \\ tfe_t \\ r3_t \\ t \end{bmatrix}$$

$$= \begin{bmatrix} \alpha_a & 0 \\ 0 & \alpha_b \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \beta'_1 \\ \beta'_2 \end{bmatrix} \begin{bmatrix} x_t \\ t \end{bmatrix}, \tag{12}$$

where the notation is modified to incorporate the trend. The first cointegrating vector in (12) is interpretable as a standard money demand function. The second cointegrating vector relates inflation to the output gap, noting that total final expenditure grows at approximately 0.5% per quarter over the sample.

The nonzero feedback coefficients in α are also easily interpretable. Current "excess money" lowers next period's demand for money. If inflation is above its equilibrium rate (for a given output level relative to trend), inflation falls absolutely and output grows at more than trend in the next period. Hendry and Doornik (1994) obtain similar results on an updated data set.

If the parameters of interest are both cointegrating vectors [(ii)], only $r3_t$ is weakly exogenous. That implies that $g = 3 > 2 = r$, so Assumption (iv) is not satisfied.

Even if g were equal to two, Assumption (vi) identifying β may reduce the interpretability of the resulting cointegrating vectors. Specifically, suppose β' is identified as $\beta' = (I_r : B)$, following Phillips (1991) and Stock and Watson (1993). While this identification appears innocuous, choosing any feasible pair of variables as y_t (corresponding to I_r in β) implies that at least one of the cointegration vectors in (12) is confounded with the other, and possibly both are confounded. Because $r3_t$ is weakly exogenous and the trend is deterministic, neither variable can be included in y_t. Yet, these two variables and $(m-p)_t$ are the only ones for which such an identification of β would not confound the economically interpretable cointegrating vectors.

If money demand (and so β_1) is the only relation of interest, then Δp_t, tfe_t, and $r3_t$ are weakly exogenous. Assumptions (iv)–(viii) are satisfied because $g_1 = r_1 = 1$ (where the subscripts on g and r match the subscript on the cointegrating vector), so the conditional money demand equation is a structural ECM. If the output-inflation relation (and so β_2) is the only relation of interest, then $(m-p)_t$ and $r3_t$ are weakly exogenous, but $g_2 = 2 > 1 = r_2$, violating Assumption (iv) and so Assumption (vii) as well.

3.4 Danish Inflation

Juselius (1992) models the determinants of Danish inflation, positing disequilibrium effects from the internal labor market, from domestic money demand, and from the external sector via foreign prices and foreign interest rates. Because of the large number of variables involved, Juselius analyzes the three sectors separately. She extracts four cointegrating vectors, which correspond to equilibrium conditions for wages and prices, money demand, purchasing power parity, and uncovered interest rate parity. Short-run dynamics and all four cointegrating relations are included in a single-equation model of inflation, with the feedback coefficients on the cointegrating relations reflecting the importance of the respective disequilibria in determining inflation. All error correction terms are statistically significant, with foreign disequilibria numerically and statistically dominating domestic disequilibria in the determination of inflation.

Because the number of variables ($n = 12$) and the number of cointegrating vectors ($r = 4$) are large relative to the sample ($T = 57$ quarterly observations), estimation of the complete system (1) or even the structural ECM (5) is infeasible. Juselius's two-stage approach *is* feasible and delivers data-coherent, economically interpretable results. Assumptions (iii)–(v) may or may not be satisfied; and here as in the previous example, some applications of Assumption (vi) identifying β may not deliver the most economically interpretable set of cointegrating vectors.

Assumption (vii) precludes more than one cointegrating vector from entering the inflation equation. However, multiple cointegrating vectors in a single equation are sensible in this model, given multiple equilibrium relations for the price level. By restricting Λ to be diagonal, Assumption (vii) is mathematically convenient for (e.g.) evaluating the stability of (5) and may arise naturally from certain sorts of optimization by economic agents, but the assumption also can be economically unappealing (as here).[1] In general, economic theory may suggest that more than one disequilibrium might enter a given equation, so the economic interpretability of a diagonal Λ must be specific to the problem at hand and is *not* generic. Also, if agents' decisions are sequential, economic theory may suggest that Γ_0 is upper triangular, Σ_v is diagonal, and Λ is unrestricted, which provides a different (and historically common) set of identification restrictions; see Juselius (1993).

3.5 Argentine Broad Money Demand

Kamin and Ericsson (1993) model broad money demand in Argentina. The data are monthly over January 1977–January 1993 for nominal M_3 (M),

[1] As another example violating Assumption (vii), Hendry and von Ungern-Sternberg (1981) find two error correction terms in their conditional consumption function: the consumption-income ratio and the liquidity-income ratio.

the domestic consumer price index (P), the interest rate on domestic peso-denominated fixed-term bank deposits (R), and the free-market exchange rate (E). The variables in their cointegration analysis are $m-p$, Δp, R, Δp^{max}, and Δe, where Δp^{max} is the maximum inflation rate to date. For $\ell = 7$, Kamin and Ericsson [(1993), Table 3] find one cointegrating vector, with $\alpha\beta' x_t$ estimated as:

$$\alpha\beta' x_t = \begin{bmatrix} -0.042 \\ 0.027 \\ 0.051 \\ 0.015 \\ -0.076 \end{bmatrix} \begin{bmatrix} 1 & 6.57 & -6.72 & 1.19 & 6.14 \end{bmatrix} \begin{bmatrix} (m-p)_t \\ \Delta p_t \\ R_t \\ \Delta p_t^{max} \\ \Delta e_t \end{bmatrix}. \quad (13)$$

The cointegrating vector in (13) is interpretable as a Cagan (1956) money demand relation, with money demand increasing in response to a higher own rate and decreasing in response to higher returns on alternative assets (domestic goods and dollars). The coefficient on the ratchet Δp^{max} is significant and implies hysteresis of money demand with respect to the inflation rate. The inflation rate is weakly exogenous at the 95% level: Johansen's (1992a) $\chi^2(2)$ test statistic for Δp and Δp^{max} jointly is 5.56 [0.062], where the asymptotic p-value is in square brackets. Real money, the interest rate, and the exchange rate are all endogenous, with the corresponding individual $\chi^2(1)$ test statistics being 9.30, 8.09, and 6.05. The nonzero feedback coefficients are all economically sensible. Current excess money lowers next period's demand for money, raises next period's nominal interest rate, and slows next period's depreciation of the peso.

An ECM of $(m-p)_t$, R_t, and Δe_t given inflation is a valid conditional model. However, no valid structural ECM exists because either or both of Assumptions (iii) and (iv) are rejected, depending upon the partitioning of x_t' into $(y_t' : z_t')$. For instance, if $y_t' = [(m-p)_t, R_t, \Delta e_t]$, then (iii) is satisfied but (iv) is not ($g = 3 > 1 = r$). If $y_t = [(m-p)_t]$, then (iv) is satisfied ($g = r = 1$) but (iii) is not (the coefficients in α for R and Δe are nonzero). The beauty of structural ECMs comes in fair part from having weak exogeneity and just as many cointegrating vectors as endogenous variables. The specificity of structural ECMs also arises from those conditions.

3.6 A Synthesis

As the examples above illustrate, structural ECMs require assumptions about the rank and identification of certain matrices in addition to the assumption of weak exogeneity. When conditioning is acceptable, the additional assumptions still may be invalid or economically unappealing. Thus, it would be helpful to develop formal testing procedures for Assumptions (iv)–(viii), to the extent that they are testable. The structural ECM [equation (5)] is nested in the VAR [equation (2)] from which it is derived, so Hendry and Mizon's (1993) VAR-encompassing test is a natural one to use. Even when the assumptions for a structural ECM are statistically valid, the economic interpretability of the identified β and diagonal Λ will depend upon the particular data and economic theory being examined.

More generally, conditional ECMs may be structural in senses other than Boswijk's. Hendry and Mizon's (1993) money demand model is structural in Hendry's (1993) sense, and Hendry and Mizon (1993, p. 272) explicitly refer to their model as a "structural econometric model." The cointegrating vector β_{11} in Sections 3.1 and 3.2 also is structural in Hendry's sense, since it remains invariant to the addition of z_t and its lags to a VAR of y_t alone. Likewise, the empirical models in Juselius (1992) and Kamin and Ericsson (1993) are structural in this sense, noting that those authors find empirically constant parameters for their models over extensions of their data sets.

4 Remarks

Boswijk has masterfully developed a new and special class of conditional ECMs, called structural ECMs. They generalize the empirically successful single-equation conditional ECMs in a direction that adds more economic structure. Suitable testing procedures are easy to implement. Many tests of weak exogeneity are readily available; and a test of structurality can be calculated as a test of over-identifying restrictions, but with a new interpretation. While the examples above have indicated some limitations of structural models in particular instances, the general empirical importance of structural ECMs remains to be seen. With the statistical foundations now in place, I thus look forward to seeing the modeling of conditional ECMs as structural ECMs in practice.

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