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A CENTROID IDENTITY AS A ZERO-COST CONSISTENCY CHECK FOR PUBLISHED MULTIVARIATE URODYNAMIC REGRESSION MODELS

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Introduction

Multivariate linear models relating a urodynamic outcome to several measured predictors are published as a list of fitted coefficients, usually accompanied by a table of group means and standard deviations and a statement that the model is significant by the Fisher criterion. A reader has no way to refit the model and therefore no way to detect a transcription error, a lost decimal exponent or a mismatch between the estimation sample and the summary table. We show that the published material is in fact sufficient for an exact arithmetic check, and we propose it as a routine step in preparing and reviewing such papers.

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The identity

Consider the linear model

$$y = a_0 + \sum_{j=1}^{m} a_j x_j + \varepsilon, \tag{1}$$

estimated by ordinary least squares with an intercept. The normal equation associated with a_0 is

$$\frac{\partial}{\partial a_0} \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 = 0 \quad \Longrightarrow \quad \sum_{i=1}^{n} (y_i - \hat{y}_i) = 0, \tag{2}$$

so the fitted surface passes exactly through the centroid of the data:

$$\bar{y} = a_0 + \sum_{j=1}^{m} a_j \bar{x}_j . \tag{3}$$

Dividing (3) by the sample mean of the response and introducing the partial elasticity of y with respect to the j-th predictor, evaluated at the centroid,

$$E_j = \frac{\partial y}{\partial x_j} \cdot \frac{\bar{x}_j}{\bar{y}} = \frac{a_j \bar{x}_j}{\bar{y}}, \tag{4}$$

yields the identity

$$\frac{a_0}{\bar{y}} + \sum_{j=1}^{m} E_j = 1 . \tag{5}$$

Relation (5) is exact, not asymptotic: it holds for any least-squares fit with an intercept, whatever the sample size, the residual variance or the degree of collinearity among the predictors. Define the consistency index

$$\Delta = \frac{a_0}{\bar{y}} + \sum_{j=1}^{m} E_j , \quad \Delta \equiv 1 \text{ for a consistent report.} \tag{6}$$

Departures of Δ from unity are attributable only to rounding of the reported coefficients, to error in transcribing them or the summary table, or to the coefficients having been estimated on a sample other than the one the table describes. Rounding alone produces departures of order 10^{-3} for coefficients reported to four significant figures.

Application

We applied (6) to six published models of the urethral resistance coefficient K_u in children with posterior urethral valves, one for each of three surgical techniques

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before and after operation, with m = 6 predictors: maximum bladder capacity, bladder wall thickness, post-void residual volume, mean flow rate, effective urethral cross-section and detrusor muscular tension. Element-wise elasticities and the resulting index are given in Table 1.

Table 1. Partial elasticities at the centroid and the consistency index Δ

Model	$a_0/\bar{y}$	E_{Vmax}	E_h	E_{PVR}	E_Q	E_S	E_{Td}	Δ
I, pre	−0.130	−0.242	0.670	0.494	0.208	0.205	1.656	**2.86**
I, post	0.080	−0.934	1.527	0.934	23.717	22.062	3.538	**50.92**
II, pre	−0.156	−0.661	1.628	0.435	1.029	0.711	0.085	**3.07**
II, post	−0.093	−0.504	1.434	1.064	3.484	2.826	0.726	**8.94**
III, pre	−0.024	0.576	0.952	0.722	−0.035	0.356	1.253	**3.80**
III, post	0.004	0.419	0.047	1.256	0.107	0.298	12.103	**14.23**

A consistent report gives Δ = 1. Equivalently, substituting the tabulated means into each equation should return the tabulated mean of K_u; the observed ratios were 2.9 to 50.9.

None of the six models satisfies (5). The departures are far too large to arise from rounding and are systematic in structure: the three preoperative models cluster in a narrow band (Δ = 2.86 to 3.80), which is the signature of a common scaling discrepancy, whereas the postoperative models diverge individually (Δ = 8.94 to 50.92), which is the signature of errors in particular coefficients.

The elasticity decomposition localises the discrepancy. In model I-post two terms, $E_Q = 23.7$ and $E_S = 22.1$, account for 90 % of Δ, and their magnitudes stand in a ratio of roughly 10^2 to the corresponding preoperative elasticities of 0.21 and 0.21 — the pattern produced when a decimal exponent is lost in transcription. In model III-post a single term, $E_{Td} = 12.1$, accounts for 85 % of the departure. In the

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preoperative models no single term dominates, which points instead to a difference in units or in the estimation sample.

Discussion

The check costs nothing beyond arithmetic already available in the published tables, requires no access to raw data and returns a single number with an exact reference value. It is therefore suited both to authors preparing a manuscript and to reviewers assessing one. Its scope is precisely delimited: passing the check does not establish that a model is correctly specified, well conditioned or clinically meaningful, since (5) constrains only the position of the fitted surface at one point. Failing it, by contrast, is decisive — a reported model that does not reproduce its own reported mean cannot be used for prediction in the units in which it is stated.

The elasticities have a second use independent of the audit. Unlike standardised coefficients, which express change per standard deviation and therefore depend on the dispersion of the sample, elasticities express proportional change per proportional change and are invariant to the units of both predictor and response. For an outcome such as urethral resistance, where the clinically relevant question is what percentage reduction follows a given percentage change in urethral calibre, they are the more directly interpretable quantity.

Conclusion

The centroid identity (5) provides an exact, zero-cost consistency check applicable to any published linear regression reported together with the means of its variables. Applied to six urodynamic models it detected departures of one to one and a half orders of magnitude and localised them to individual coefficients. We recommend that the value of Δ be computed before submission and, where journal format permits, reported alongside the coefficient of determination and the Fisher statistic.

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