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NON-LINEAR TECHNICAL PROGRESS IN TRANSLOG COST FUNCTIONS: IMPLICATIONS FOR ENERGY-CAPITAL SUBSTITUTABILITY

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This paper revisits the seminal results of Berndt and Wood (1975, 1979) who place an empirical value on the elasticity of substitution between energy and capital [for US Manufacturing] using parameter estimates derived from a Translog production function. Hunt (1986) extended Berndt and Wood's results to test for the inclusion of linear (non-neutral) technical progress which was rejected for US Manufacturing, whilst conversely finding for the UK [Industrial sector] that linear technical progress was statistically preferred. This study seeks to extend the efforts of these earlier studies, particularly testing the hypothesis that;

H1: Technical progress is not a linear function of time

This is done using the datasets from Berndt and Wood (1975, 1979), Hunt (1984, 1986) and Norsworthy and Harper (1981).

The elasticity of substitution, particularly between energy and capital (□KE) and the prominent role its understanding plays in the development of sustainability conscious policy measures are the precursor to reconsideration of empirical methods for estimating production functions. The most commonly used form for empirically estimating production functions is the Translog specification originally due to Christensen et al (1973), which offers increased flexibility over other forms. Furthermore, the cost (dual) function is implemented most often which after differentiating the production function and applying Sheppard's Lemma is commonly specified (excluding technology), as;

$$S_i = a_i + \Sigma b_{ij} \ln P_j$$

For i=j=(Kapital,Labour,Energy,Materials)1 and where P is a Divisia index of prices, S is the share of factor i. The Translog model is most commonly operationalised by adding a stochastic disturbance term and estimating using the iterative seemingly unrelated regression (ISUR) method.

The hypothesis **H1** is tested, in the context of the Translog model, firstly in a purely static modeling framework using an Almon lag representation in which technological progress is an n^{th} $(0<n<\infty)$ order polynomial function i.e.

$$T = \Sigma(t^1 + t^2 + \ldots + t^n)$$

and the polynomial order is determined using standard model selection criteria.

Following this a dynamic econometric specification using Harvey's (1989) seemingly unrelated structural time series model (SUSTSM) is applied, where the state space representation and unique properties of the Kalman filter within the transition equation allow technical progress to take a stochastic and nonlinear form, previously only known to have been applied for this purpose by Harvey and Marshall (1991). The advantage of this approach is the parsimonious nature of the estimation method, which in the presence of highly non-linear technical progress will prove to be advantageous over the Almon lag structure which will consume more degrees of freedom.

The elasticity of substitution is then empirically derived from each of the model results and compared. The Allen-Uzawa elasticity has been predominantly used in empirical research, though this has been shown not to be an actual measure of the curvature of the production iso-surface whereas the Morishima (1967) elasticity is, see Blackorby and Russell (1981). As a result of this, the Allen elasticities will be evaluated (for consistency with the earlier studies, and further compared with the empirical value of the Morishima elasticity of substitution between capital and energy and hence further elucidate the resulting policy implications of incorrectly specifying the underlying technical progress.

The results would imply that technical progress shows evidence of non-linearities and subsequently empirical treatment of technology in production functions (i.e. linear deterministic trends) is likely to result in biased parameter estimates. This means that capital-energy substitutability may be incorrectly specified for any given sector, whereby the omitted variable bias causes the models parameter estimates to be wrong in magnitude and potentially signage. Arguably the SUSTSM provides a more econometrically efficient estimation method than the alternatives considered, largely because it allows for non-linear technical progress without adding excess variables/parameters to the model as an Almon lag structure might. Similarly, factor augmenting linear deterministic trends are a restricted form of the SUSTSM and can be easily tested and chosen if econometrically preferred.

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[1] Hunt's (1984, 1986) data for the UK contains no information on materials, though this is not the only empirical work in this area of literature which estimates a KLE rather than KLEM function