

**Barten A P.** Maximum likelihood estimation of a complete system of demand equations. *Eur. Econ. Rev.* 1:7-73, 1969. [Katholieke Universiteit te Leuven, Belgium]

A complete system of demand equations describes how total consumer resources are being allocated over various uses. The allocation is modified in response to changes in the structure of prices. Optimizing behavior by the consumer implies a set of restrictions on the coefficients of the system. The exogenous nature of total resources makes the equation for one use redundant. In the context of maximum likelihood estimation (and also other types of regression), it is irrelevant which equation is deleted. Applying the likelihood ratio test, several fundamental properties of consumer demand theory are being rejected as too restrictive on the data (Netherlands 1922-1962). [The SSC<sup>®</sup> and the SC<sup>®</sup> indicate that this paper has been cited in more than 210 publications, making it the most-cited paper published in this journal.]

## The Vicissitudes of a Research Project

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Henri Theil, my PhD supervisor at the Rotterdam School of Economics, had put me on the trail of the formulation and estimation of complete demand systems.<sup>1,2</sup> After leaving Rotterdam for Leuven, I attempted to refine estimation methodology by using multivariate maximum likelihood and to extend the size of the system from the earlier 4 alternative uses to 16. Intuition suggested the redundancy of one equation. Experimenting with alternatives for the equation being deleted showed invariance for the estimated coefficients of the rest of the system. At that time, Luigi Solari from Genève was working on the maximum likelihood estimation of the then well-known linear expenditure system. When he reported that it made a difference which equation was deleted, I expressed my doubts. To convince him, I set down to prove the invariance property. Solari answered that he had found the bug in his program and that he had also reproduced invariance. I have the impression that the proof of the invariance property, included in the final version of the paper, is the main reason for the high citation frequency.

This paper was also pioneering in another direction. Most systems until then had a rather small set of alternative uses—three, four, five.

Sixteen uses required the inversion of a matrix of 120 by 120, which was more than the available computer could handle in its internal memory. Reading off to tape and disk took immense amounts of computer time, which at that time was still without charge.

Invariance and large size are basically technicalities. The feature of the paper which was for me most interesting was that the choice of functional form (Theil's Rotterdam system<sup>3</sup>) made it possible to test some fundamental properties of the theory of consumer demand, like homogeneity and Slutsky symmetry, which had not been attempted before on such a scale. The tests rejected the propositions. One authority told me not to publish the results. If they were true, he said, the profession would be shocked: and if it all amounted to some calculation error, I would look foolish. The negative results were confirmed by other researchers working with the same and with other data. Several explanations were advanced to explain the contradiction of theory and fact. At the time it was not realized, however, that the statistical distribution used for the test statistic was of a large sample nature while one was dealing with a small sample set-up. As Monte Carlo experiments and theoretical studies demonstrated later, the small sample bias increased with the size of the system. Corrections for this bias indicate that the rejection of theoretical propositions is far less frequent and could be due to other factors than the invalidity of the theory.

The paper was submitted for publication to a reputable journal. The referee report was humiliatingly negative. Nevertheless, the editor was willing to accept a shortened version. At that time, Jean Waelbroeck was starting the *European Economic Review (EER)* and looking for manuscripts. I showed him the referee report and the editor's letter and offered him my paper on the condition of minimal revision. He accepted, and so it appeared as the first article in the first issue of the *EER*. The publisher had absolutely no experience in printing mathematics and tables and made a thorough mess of it. Proofreading tables by telephone is not to be advised. Anyway, this article is apparently the most cited one of the *EER*, which has attracted quite a number of papers in the area.

In the meantime the formal structure of the consumer allocation model has also been applied to empirical studies of production, investment portfolio composition, international trade, acreage allotment, and so on. This has increased the interest in, say, the invariance property and has presumably contributed to the citation frequency.

1. **Barten A P.** Consumer demand functions under conditions of almost additive preferences. *Econometrica* 32:1-38, 1964. (Cited 65 times.)
2. ----- Estimating demand equations. *Econometrica* 36:213-51, 1968. (Cited 40 times.)
3. **Theil H.** The information approach to demand analysis. *Econometrica* 33:67-87, 1965. (Cited 60 times.)  
Received July 24, 1992