

# INDIRECT ESTIMATION OF A SIMULTANEOUS LIMITED DEPENDENT VARIABLE MODEL FOR PATIENT COSTS AND OUTCOME

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This paper proposes applying indirect inference (II) (Gourieroux, Monfort and Renault, 1993) to estimate simultaneous equation limited dependent variable models. II estimators have been shown to be highly useful in many different situations when the likelihood is difficult to deal with, but the model is simple to simulate. Its primary advantage is its generality: unlike other methods that may require optimizing of a complicated criterion function, as is the case with maximum likelihood estimation in many econometric models, the indirect inference technique applies a simplified approximate model, and basically updates its estimates via simulations from the more complicated underlying structural model to obtain consistent estimates. Consequently, II is applicable in a broad range of model specifications including nonlinear models, making it very suitable for the kind of models considered in this paper.

We consider a simultaneous equation system,

$$\begin{aligned} \ln y_i &= \begin{cases} \ln y_i^* & \text{if } \ln y_i^* < \ln 365 \\ \ln 356 & \text{if } \ln y_i^* \geq \ln 365, \end{cases} \\ \ln c_i &= \theta \ln y_i + z_i' \beta_2 + \varepsilon_i, \end{aligned}$$

where

$$\ln y_i^* = x_i' \beta_1 + \eta_i,$$

with the error terms  $\eta_i$  and  $\varepsilon_i$  following a bivariate normal distribution. The endogenous variable  $y$  is observed via a nonlinear transformation of a latent structural continuous variable  $y^*$ . This transformation consists of a censoring mechanism in which we observe the structural continuous variable if it is below some known threshold, and observe the value of the threshold if above. An obvious problem of this model is the endogeneity as a consequence of the simultaneity of  $c$  and  $y$ . Because of the joint problem of censoring and simultaneity, the likelihood is difficult to deal with. Consequently, alternatives to full information maximum likelihood have been derived and proposed in the literature. For simultaneous equation models with limited dependent variables two step estimators have been suggested (Nelson and Olsen, 1978;

Heckman, 1978; Amemiya, 1979; Blundell and Smith, 1989). For the kind of models considered in this paper, with a censored endogenous regressor, Vella (1993) present a simple two-step estimator, in which a generalized residuals approach is employed to adjust for the inconsistency caused by the endogeneity of the censored regressor. Our paper adds to this literature by proposing an indirect inference estimation procedure. In a Monte Carlo study, we show that the II procedure outperforms its competitors in terms of bias and root mean squared error.

Our motivation for looking at this particular simultaneous equation limited dependent variable model is that an important area in health economics is aimed at measuring and estimating patient costs. Achieving high quality of care and containing costs are both important goals for the health care. However, these may be conflicting goals, and there may be a trade-off between them. E.g. longer survival for an acute myocardial infarction patient may imply higher costs. A model of the type we study is one possible approach to the complicated relation between costs and quality in health care. See, for example, Stargardt et al. (2013) for alternative such models.

**Keywords:** Endogeneity, Health economics, Indirect inference, Simultaneous equation system.

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