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Empirical Examinations of the Information Sets of Economic Agents

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EMPIRICAL EXAMINATIONS OF THE INFORMATION SETS OF ECONOMIC AGENTS

by

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Nils Gottfries and Torsten Persson

Abstract

We show theoretically how one can derive coefficients that measure, in a natural way, the information advantadge of decision-makers with rational expectations over an information set formulated by the econometrician. We discuss econometric estimation of the information advantadge coefficients, and show how to use the estimates to test the hypothesis that agents have no better information than the econometrician or the hypothesis that agents have perfect information. Finally, we present results from an empirical application of the methodology, where estimates of information advantadge coefficients are used to test for significant lags in portfolio revision and associated buffer stock behavior in money demand.

[0] We are grateful for comments by an anonymous referee and by seminar participants at the Institute for International Economic Studies and at the University of Rochester.

I. Introduction

There is growing consensus that rational expectations is the most appealing assumption about how agents form their expectations. According to the rational expectations assumption agents use their available information efficiently. Theory offers little guidance as to what information agents rely on when forming their expectations, however, above vague references to the costs and benefits of gathering information. Empirical applications of rational expectations models therefore tend to rely on fairly arbitrary assumptions about agents' information sets. In some applications the econometrician postulates an information set for the economic agents whose behavior is being modeled and assumes that this is their true information set; see Pagan [1984] and references therein. But much research explicitely assumes that the agents typically have more information than the econometrician; see Mishkin [1983] and the references therein.[1]

This paper suggests a simple way of testing hypotheses regarding the information sets of decision-makers with rational expectations. Specifically, we show how one can test the hypothesis that agents have no information advantadge over the econometrician, as well as the hypothesis that agents have perfect information. Such tests may be of interest in themselves as a diagnostic on the informational assumption in an empirical model. The tests may also be of interest as a means of investigating other economic phenomena. In particular, if agents make decisions at intervals that are finer than the intervals at which the econometrician samples data, a test for perfect information may be equivalent to a test for whether there exist (significant) decision and information lags.

In Section II we demonstrate theoretically how to derive a coefficient that measures rational expectation agents' information advantadge over the econometrician in a natural way. We show how to estimate the information advantadge coefficient empirically and how to test the hypothesis that agents have no better information than the econometrician, as well as the hypothesis that agents have perfect information. Section III reports on an application of the suggested methodology. We present empirical estimates of information advantadge coefficients from a Swedish money demand function which is estimated jointly with relevant forecasting equations. The estimates can be used to test for significant decision lags in the private sector's portfolio revisions. Such lags may give rise to buffer stock effects in money demand. Section IV concludes.

II. Derivation and Estimation of Information Advantadge Coefficients

Consider some agents who attempt to forecast the random variable y. These agents have an identical information set that includes x and z, two (row) vectors of random variables. The econometrician has a more limited information set that includes only x. The conventional approach, when forming a guess about agents' true expectations x, would be to approximate $P(y|x,z)$ with the linear projection $P(y|x)$. This is in fact the econometrician's best guess about $P(y|x,z)$ given x, because the law of iterated projections -- see Sargent [1979, p. 208], for example -- says $P[P(y|x,z)|x] = P(y|x)$.

However, relying on the conventional approach, the econometrician disregards information that is typically available to him, namely the ex post outcome of y. Exploiting this information results in an alternative and better guess about $P(y|x,z)$: $P[P(y|x,z)|x,y]$, the properties of which we will exploit in the following. To simplify the subsequent exposition, let us adopt the shorthand notation $y^e \equiv P(y|x,z)$ for agents' true expectations, $\tilde{y}^e \equiv P(y|x)$ for the conventional guess, and $\hat{y}^e \equiv P[P(y|x,z)|x,y]$ for our alternative guess. Define the associated error terms by

(1a) $\epsilon \equiv y - y^e$,

(1b) $\tilde{\epsilon} \equiv y^e - \tilde{y}^e$,

(1c) $\hat{\epsilon} \equiv y^e - \hat{y}^e$,

where $E(y^e\epsilon) = E(\tilde{y}^e\tilde{\epsilon}) = E(\hat{y}^e\hat{\epsilon}) = E(\epsilon\tilde{\epsilon}) = 0$ by the orthogonality properties of linear projections. We can think of $\tilde{\epsilon}$ and $\hat{\epsilon}$ as "measurement errors" for two different measures, $\tilde{y}^e$ and $\hat{y}^e$, of agents' true expectations. Agents' true forecast error ϵ, would also be a measurement error if we measured their expectations by y. The properties of our proposed guess about agents' expectations can then be summarized in the following proposition:

<u>Proposition</u> The linear projection of y^e on x and y satisfies

(P1) $\hat{y}^e = (1-m)\tilde{y}^e + my$,

where the weight m is given by

(P2) $m = \text{Var}\,\tilde{\epsilon} \,/\, (\text{Var}\,\epsilon + \text{Var}\,\tilde{\epsilon})$.

We first prove (P1). Project y^e recursively on x and z -- see Sargent [1979, pp. 206-208] -- to get

(2) $\hat{y}^e = P(y^e|x) + P[y^e - P(y^e|x)|y - P(y|x)]$.

Because of the law of iterated projections $P(y^e|x) = P(y|x) = \tilde{y}^e$. But then we may rewrite (2) as

(3) $\hat{y}^e = \tilde{y}^e + P(y^e - \tilde{y}^e|y - \tilde{y}^e) = \tilde{y}^e + m(y - \tilde{y}^e)$,

which is the desired result. To verify (P2), we need to determine the unknown projection coefficient in (3). From (1) it follows that

$P(y^e - \tilde{y}^e | y - \tilde{y}^e) = P(\tilde{\epsilon} | \epsilon + \tilde{\epsilon})$, so that $m = Cov(\tilde{\epsilon}, \epsilon + \tilde{\epsilon}) / Var(\epsilon + \tilde{\epsilon})$, but since $E(\epsilon\tilde{\epsilon}) = 0$, (P2) follows.

The formula (P2) bears out the close analogy between our approach and the standard signal-extraction problem. We have two noisy "signals", y and $\tilde{y}^e$, from which we are trying to forecast y^e optimally by forming a weighted average of the two signals. In that sense, our approach combines the conventional approach with the approach -- suggested by McCallum [1976], for example -- of using the realization of a variable as a measure of the rational expectation of that variable.[2]

The m-coefficient measures the agents' information advantadge over the econometrician in a natural way. To see this clearer, use (1) to rewrite (P2) as

$$(4) \qquad m = Var(y^e - \tilde{y}^e) / Var(y - \tilde{y}^e).$$

Thus, m measures the fraction of the variation in y which is unpredictable to the econometrician but predictable to the agents. Notice that the value of m rises from zero when $Var\ \tilde{\epsilon} = 0$ -- that is, when knowing z does not improve the forecast of y given x -- to unity when $Var\ \epsilon = 0$ -- that is, when knowing z allows agents to forecast y perfectly.

Let us next discuss estimation. When y^e is unobservable, we cannot estimate the m-coefficients directly. Suppose, however, that we have a behavioral relation in the form of a simple decision rule:

$$(5) \qquad v = \beta y^e + \eta,$$

where η is a shock to tastes or technology. We assume that η is white noise and that $Cov(\epsilon, \eta) = 0$. Next, we substitute $\hat{y}^e + \hat{\epsilon} = (1 - m)\tilde{y}^e + my + \hat{\epsilon}$ for y^e in (5), and express $\tilde{y}^e$ as $\tilde{y}^e = x\tilde{a}$, where $\tilde{a}$ is a (column) vector of projection coefficients. This yields the system

(6a) $\quad v = \beta(1 - m)x\tilde{a} + \beta my + (\beta\hat{\epsilon} + \eta),$

(6b) $\quad y = x\tilde{a} + (\tilde{\epsilon} + \epsilon).$

This system can be estimated by, for example, non-linear multivariate least squares, with the restriction imposed that the $\tilde{a}$-coefficients be equal across the equations. Since $\hat{y}^e$ is an imperfect measure of the true value of y^e, one might suspect to get biased estimates due to an errors-in-variables problem. This is not the case, however, because the measurement error, $\hat{\epsilon}$, is uncorrelated with the measure, $(1 - m)\tilde{y}^e + my$, by construction. In fact, $\hat{\epsilon}$ is orthogonal to the whole vector (x,y). Also, the error term in (6b) is correlated with y, which enters as an explanatory variable in (6a). But since $E[\hat{\epsilon}(y - x\tilde{a})] = 0$ by construction, the error terms in the two equations are uncorrelated. Therefore, estimation of (6) by multivariate least squares will produce consintent estimates of m, β, and $\tilde{a}$.

While our information advantadge coefficient can be estimated easily if the underlying model is (5), other models may be less favorable for identifying information advantadge coefficients. Suppose that we have a "surprise model" like

(7) $\quad u = \gamma(y - y^e) + \mu;$

a formulation common in the efficient markets literature as well as in the neutrality literature. Substitute $y^e = \hat{y}^e + \hat{\epsilon}$ into (7) to get

(8) $\quad u = \gamma(1 - m)(y - \tilde{y}^e) + (\mu + \gamma\hat{\epsilon}).$

Here, m cannot be identified unless we are willing to make an a priori assumption about γ. Observe, however, that the converse is also true. Therefore the estimates of behavioral coefficients in conventionally estimated surprise models will be downward biased unless m = 0; that is, unless agents have no better information than the econometrician.

Let us finally mention a couple of generalizations of the methodology. First, suppose that agents try to forecast not a scalar but a vector $y = (y_i)$ of random variables. It is easy to extend our Proposition to this case by deriving a corresponding vector of information advantadge coefficients, $m = (m_i)$. But for consistent estimation of these coefficients, we have to assume that the measurement error for each expected variable, $\hat{\epsilon}_i = y_i^e - \hat{y}_i^e$, is uncorrelated with the realizations of the other expected variables, y_j for all $j \neq i$. Second, we have only covered the case when the variable forecasted by agents is stricly exogenous in the behavioral equation. We believe that one may be able to estimate information coefficients even when the model is simultaneous, although the interpretation of these coefficients would be slightly different. The information coefficients would then measure how good information agents have relative to a set of instruments specified by the econometrician. Such a measure of information availability may be of interest in a time-series context, when one may choose some of the instruments to be contemporaneous with the variable that agents attempted to forecast and thus unknown to agents at the time they make their forecast.[3]

III. An Application

In this section we report on an empirical application of our methodology, which shows how one can estimate information advantadge coefficients in order to test whether there exist significant lags between agents decisions. Specifically, we try to identify significant lags in the portfolio revisions by private agents in Sweden that give rise to buffer stock effects in money demand. Our estimates are based on quarterly data from 1970 to 1982.[4]

To motivate the specification to follow, assume that time can be measured in elementary time periods of fixed length θ, where θ measures the interval between the representative agent's decisions as well as the interval between the arrival of new information in his information set.[5] Assume also that there are n elementary time periods in a quarter, where n is an integer. In each elementary time period agents decide how to split their financial wealth between planned holdings of money, M^p, and holdings of other assets, K. M includes currency and ordinary (demand and time) bank deposits, while K is an aggregate of other financial assets. Agents' financial portfolio is given by their net financial assets, W, plus their bank loans, L; we assume that agents are rationed in the loan market.

We assume that agents' plan at t-θ for money holdings at t is

$$\Delta M_t^p = \beta_0 + \beta_r(\Delta r_{mt}^e - \Delta r_{st}^e)Y_{t-1} + \beta_W \Delta W_t^e + \beta_L \Delta L_t^e + \beta_Y \Delta Y_t^e + \eta_t, \tag{9}$$

where r_m is the own interest rate on money, r_s is the interest rate on "special deposits" (taken to measure the opportunity cost of holding money), Y is national income, f_t^e denotes expectations at t-θ about f at t, and η is a white noise error term.[6] Equation (9) is thus a conventional demand function for broad money on first difference form.[7,8]

At t-θ agents also choose their holdings of other assets at t, K_t to satisfy the (expected) wealth constraint

$$\Delta K_t = \Delta W_t^e + \Delta L_t^e - \Delta M_t^p.$$

Any unexpected changes in W or L during the decision interval (t-θ,t) are temporarily held in the form of money. Thus, actual money holdings, M, at t satisfy

$$\Delta M_t = \Delta M_t^p + (\Delta W_t - \Delta W_t^e) + (\Delta L_t - \Delta L_t^e), \tag{10}$$

where the two last terms bring out the "buffer stock" role of money.

For each expected variable f_t^e in (9), we formulated conventional forecasts $\tilde{f}_t^e$ by projecting f_t on variables in an information set containing variables dated t-1 and earlier.[9] Following the approach in Section II, we then formed guesses about agents true expectations at t-θ, f_t^e, as $\hat{f}_t^e = (1 - m_f)\tilde{f}_t^e + m_f f_t$. Notice that a rejection of perfect information in this model -- that is, a rejection of $m_f = 1$ -- can be interpreted as evidence of significant lags in portfolio revision. With m_f below unity, it is impossible that agents knew f_t when deciding on M_t^p, as they would if the decision interval θ was arbitrarily short.

To obtain the final form of the money demand function, we inserted our guesses $\hat{f}_t^e + \hat{\epsilon}_{ft}$ for f_t^e in (9), substituted the resulting expression into (10) and added seasonal dummies. This money demand function and the forecasting equations were estimated jointly with nonlinear multivariate least squares (using the TSP-package, Version 4.0). Table I reports the estimated information advantdge coefficients -- m_{rm}, m_{rs}, m_W and m_Y -- and the parameters in the money demand function.[10,11] All the m-coefficients except m_{rm} are estimated fairly precisely. Furthermore, all the m-coefficients except m_Y are significantly below unity. This strongly suggests that there is indeed significant decision and information lags in the private sector's portfolio revisions and buffer stock effects in money demand.

IV. Concluding remarks

We have shown how an econometrician can derive and estimate information advantage coefficients. These coefficients measure in a natural way how large an information advantdge agents with rational expectations have over the information set that the econometrician has specified. Our methodology can thus be used to diagnoze how bad the specified information set is.

In Section III we gave an example of an application of our methodology, which went beyond a test of the information set *per se*. The major information advantadge of agents was that they sampled some variables more frequently than the econometrician. In that context, we showed that a test for perfect information could be interpreted as a test for significant lags in portfolio revision.[12] One could easily think of other similar applications; for instance, tests for significant lags between price setting decisions by firms in particular industries. There may also be applications where one would want to test whether agents have access to information that is not known to the econometrician, quite apart from any advantadge arising from more frequent sampling of information.

Finally, we would like to stress that our methodology yields an informed guess ($\hat{y}^e$ above) about agents' true expectations (y^e above), where the resulting forecast error by definition has lower variance than the forecast error generated by the conventional guess ($\tilde{y}^e$ above). If one is simply interested in generating an accurate guess about the representative agent's true expectations, our methodology would thus be preferable to the conventional approach.[13]

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Footnotes

1. Hansen and Sargent [1980] indeed take this information advantadge to be one possible motivation for the presence of an error term in empirical rational expectations models; the other motivation they give is unobservable shocks to tastes or technology. Their work, as well as subsequent work by Hansen and Singleton [1982] among others, discusses econometric issues in the estimation of structural parameters in such models.

2. Wickens [1982] labels the conventional approach the "substitution method" and the approach where realizations are used to measure expectations the "errors-in-variables method". His paper compares the statistical properties of the two methods when estimating structural coefficients in a general context.

3. Suppose, to fix ideas, that y and η were correlated in the model given by (5) and that we still wanted to derive an information coefficient and estimate it. Let us choose the vector x to include only exogenous and predetermined variables. Further, suppose that we have another vector of exogenous variables, q, that may or may not be known to agents. In a time series context x may include only predetermined variables, and q may include contemporaneuos exogenous variables. Thus the full set of instruments we want to use is (x,q). Define $\bar{y}^e = P(y^e|x,q)$. It is easy to show that $P(y^e|x,\bar{y}^e) = (1 - m)P(y|x) + m\bar{y}^e = (1 - m)\tilde{y}^e + my - m\bar{\epsilon}$, where $\bar{\epsilon} = y - \bar{y}^e$. Here, m equals zero if agents have no better information than x, and m equals unity if agents' information is equivalent to knowing (x,q). The error term $\bar{\epsilon}$ is orthogonal to (x,q) by construction. But the "measurement errror" $P(y^e|x,\bar{y}^e) - y^e$, which corresponds to $\hat{\epsilon}$ above, is not orthogonal to q in general. However, it is orthogonal to $(x,\bar{y}^e)$ and since $\bar{y}^e$ will be the

instrument for y in 3SLS, say, it seems that the measurement error should not lead to bias in the estimation.

4. The data is described in Gottfries, Palmer and Persson [1986].

5. A more sophisticated model would distinguish between decision and information lags and allow for staggered decision-making across agents.

6. During the estimation period the Swedish credit market was heavily regulated. The interest rate on deposits and many other interest rates were regulated, as well as the quantity of loans. These regulations make the assumption that the error term in (9) is uncorrelated with the explanatory variables less objectionable than in a market clearing model.

7. The model is formulated on first-difference form for data reasons. We believe that the data for changes in the financial portfolio is more reliable than the data for levels.

8. The money demand function is specified in nominal terms. We divided both sides of the equation by the CPI, however, since the variance of the error term is likely to increase with the price level.

9. The variables in the information set at t were specified to be: $r_{m,t-1}$, $r_{s,t-1}$, ΔW_{t-1}, ΔW_{t-4}, L_{t-1}, L_{t-4}, Y_{t-1}, Y_{t-4}, constant, and seasonal dummies.

10. The fact that β_L is close to unity caused problems in the estimation of m_L (m_L is not identified if β_L is unity). We therefore arbitrarily set m_L to unity.

11. The estimates of the forecasting equations are not reported, but available on request from the authors. We had too few degrees of freedom to test the cross-equation restrictions.

12. Gottfries, Palmer and Persson [1986] estimate portfolio models for Sweden and carry out more tests for the presence of decision lags in the portfolio revisions of banks and of the non-bank private sector.

13. In this respect our approach is related to the work, such as that by Hamilton [1985], that tries to uncover expectations from market behavior by help of Kalman Filtering techniques. There is a formal similarity in that our work relies on recursive projection, which is what underlies Kalman Filtering.

TABLE I

Estimates of Information Advantadge Coefficients and

Parameters in Money Demand for Sweden 1969:1 -1982:4

m_{rm}	m_{rs}	m_W	m_Y
0.135 (0.316)	0.302 (0.180)	0.751 (0.126)	0.917 (0.365)
β_r	β_W	β_L	β_Y
0.045 (0.010)	0.369 (0.102)	0.742 (0.131)	0.377 (0.136)

Standard errors in brackets. Durbin-Watson: 2.44

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