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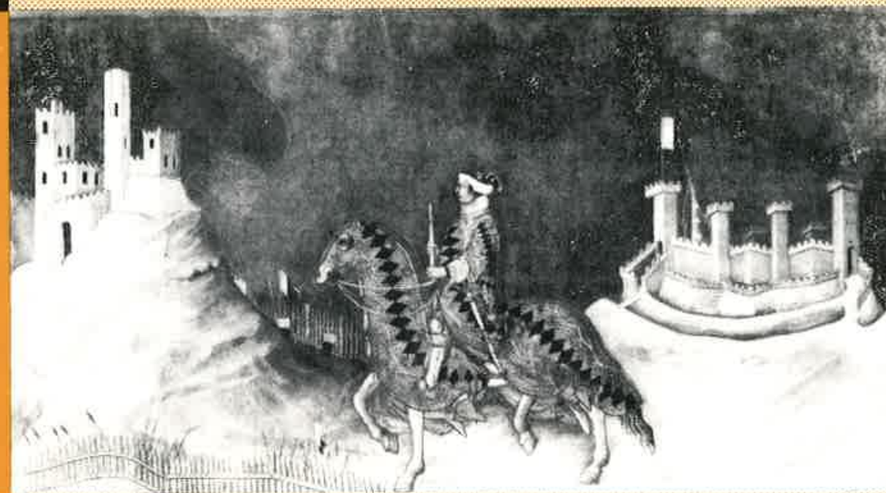
QUADERNI DEL DIPARTIMENTO
DI ECONOMIA POLITICA

Marco P. Tucci

TIME - VARYING PARAMETERS : A CRITICAL INTRODUCTION



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TIME-VARYING PARAMETERS: A CRITICAL INTRODUCTION

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Time-Varying Parameters: a Critical Introduction

by

Marco P. Tucci[1]

Abstract: One of the assumptions behind the standard econometric techniques is that coefficients are fixed throughout the whole sample period or over all the cross-sectional units. This implies the hypothesis that the economic structure generating the data does not change. This paper contains an introduction to time-varying parameters, an econometric tool which enables the researcher to take into account both structural changes and fluctuations of the parameters around a certain mean value. Most of the survey papers on this topic are highly technical and this may prevent many economists from making use of, or even considering, this technique to solve their problems. This paper stresses the intuitive aspect of the assumptions, limits and potentialities characterizing the time-varying parameters approach. Moreover, for each model it is indicated the kind of economic applications for which it is best suited. This gives the non-expert a way of knowing what kind of problems can be fruitfully solved by this technique and what to expect from it.

1 Introduction

One of the assumptions behind the standard econometric techniques is that coefficients are fixed throughout the whole sample period or over all the cross-sectional units. This implies the existence not only of one parameter vector relating the dependent and independent variables[2] but also a constant set of error process parameters and a single functional form, i.e. the economic structure generating the data does not change. But the parameters characterizing the micro units along with their aggregate counterparts do change. In cross sectional studies it may be important to take into account the differences among households, and in time series studies the changing economic environment may induce people to react differently, both quantitatively and qualitatively, to certain stimuli. From here the need for more sophisticated econometric tools allowing the economist to better understand and predict the behavior of the different economic units. Two ways have been used to make coefficients vary over time or cross sectional units: a) systematic changes or b) stochastically evolving coefficients. The systematic way was introduced by Quandt (1958) and has been used, among the others, by Quandt (1972), Fair and Jaffe

[1] This work is a revised and enlarged version of a paper presented at a Symposium on "Structural Change" held in Pontignano (Siena) July 1990. The suggestions of the various participants were very useful in improving both the content and the style of the paper. Any remaining errors are sole responsibility of the author.

[2] See Judge et al. (1985, p. 797) for a discussion of this point.

(1972) and Ohtani (1982).[3] The basic idea is that parameters change discontinuosly at certain points in time which can be either known a priori or estimated from the sample data. On the other hand when coefficients are assumed to evolve in a random way, a stochastic process, which can be either stationary or non stationary, with a certain mean and variance is modelled.

This paper stresses the intuitive nature of the assumptions, limits and potentialities associated with the different approaches. Section 2 is devoted to the possible reasons for modelling parameters in a systematic way or in a stochastic way. Then systematically varying parameters in switching regression models are analyzed (Section 3)[4] and the drawbacks associated with their use are discussed in Section 4. The stochastic parameters modelled as realizations of stochastic processes, both stationary and non-stationary, are described in Section 5. Section 6 discusses the problems associated with the use of stochastic parameters. The major conclusions are summarized in Section 7.

2 Why time-varying parameters?

As every economist knows many, if not all, important economic variables such as output, consumption, employment, and trade balance present a seasonal pattern, or some seasonal component. "It is important in this case to identify and estimate seasonal variations in the parameters in the intertemporal relationship" (Judge (1985, p. 800)).[5] This is done using switching regimes models or dummy variables.[6] However seasons are by no means the exclusive cause of systematically varying parameters. A long period of high inflation, or a rate of inflation above a certain threshold for instance, may cause a structural change in the way firms and consumers form their expectations. The same effect may be produced by some policy changes viewed as definitive by the economic agents. For these reasons long data series are likely affected by the occurrence of one, or more, structural change(s). The Italian "hot autumn" in 1969 and the oil shock in 1973 are events with a "known" date. Sometimes however the origin of the structural changes is not known a priori. In many instances it is not known exactly when the change occurred, or what is the value of the threshold of a certain variable affecting the economic behavior or even if the change was due to the simple passing of time or to some other variable. In this kind of the situations, it

[3] For a more comprehensive list of works using this approach see Judge et al. (1985, p. 800 and the References to Ch. 19) and Tucci (1988).
[4] See Judge et al. (1985, pp. 798-800) for a discussion of a general systematically varying parameter model.
[5] See Zellner (1979) for a discussion of some deseasonalizing procedures.
[6] See Havenner and Swamy (1981) for a random coefficient solution to the seasonality problem.

may be appropriate and useful the use of "switching regimes" to improve the understanding and predictability of the phenomenon under consideration.

The need for using stochastic parameters in a cross sectional study was discussed for the first time by Klein (1953). "Individuals differ greatly in behavior and it may not be possible to obtain observations on a sufficiently large numbers of variables so that each unit may be considered to behave according to the same structural equation" (Klein (1953, p. 216). So when considering "a cross section sample of households ... apart from purely economic factors, there are various demographic, sociological psychological and environmental factors ... (affecting individual behavior, that is impossible to specify correctly. Therefore) it may be desirable to specify that each individual has his own intercept and slope coefficients with regard to the (few) included variables" (Swamy (1971, p. 8)). Zellner (1966) furthermore has shown that under certain conditions there would be no aggregation bias in estimating the coefficients of the macro equation obtained by aggregating the micro equations relative to the different micro units.[7]

When considering a time series, coefficients may change stochastically as the underlying micro units react to certain modifications of the environment viewed as transitory or ambiguous. Some of these modifications may be due to policy changes of the economic authorities (Lucas (1976)). Another possible reason for coefficients changing over time in a stochastic way is the use of proxy variables in place of the unobservable ones, or the presence of omitted variables uncorrelated with the correctly included variables.

An often cited justification for the use of stochastic coefficients is the fact that incorrect functional forms, namely estimating linear regressions when the true ones are nonlinear, give rise to parameter variation (Sarris (1973, p. 502)). In this case however it is worthwhile to note that "the distinction between stochastic and systematic variation is important because in most models, stochastic parameter variation is assumed to be uncorrelated with the explanatory variables (included in the regression equation). Hence these models are not intended to account for parameter variation resulting from misspecification in a nonlinear model" (Rosenberg (1973, p. 382)).[8] Shifts in the aggregation weights, when dealing with data series which are aggregates, among the micro units may cause some form of autocorrelated behavior to appear in the macro regression equation parameters" (Belsley and Kuh (1973, p. 376)). The best reason however may

[7] See Swamy (1971, p. 13-14) for a further discussion of this point.
[8] See Tucci (1988, p. 114) for a further discussion of this point.

well be that when "econometricians ... are not lucky or ingenious enough to specify a stable relationship" (Chow (1984, p. 1214)) they use a model with time-varying parameters.

3) Systematically varying parameters

This approach, as indicated in Section 2, is used when parameters vary across subsets of observations within the sample but they are not stochastic. Examples are: a) seasonality models; b) other switching regimes with known joint point and c) switching regimes with unknown joint point. In this situation, the applied economist uses dummy variables or Seemingly Unrelated Regression procedures.[9] For a general time series, this situation is described in Fig. 1. In this case the value of the parameter is b_1 up to time t^*

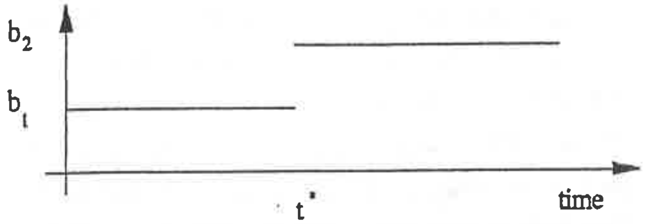

Figure 1. Dynamics of a parameter switching regime at time t^*.

and b_2 afterward. Alternatively, in a cross sectional study the horizontal axis represents a certain variable and t^* its threshold value. For instance, in analyzing the behavior of a group of households it may be assumed that units with a level of wealth below t^* have a marginal propensity to consume equal to b_1 whereas those with a level of wealth above t^* have a propensity equal to b_2. Both in time series and cross-sectional studies, the parameters b_1, b_2 and t^* can be assumed unknown and estimated from the sample.

3.a) Seasonality models

To estimate the seasonality component of a quarterly data series, the observations are rearranged in the following way

$$y_1=X_1\ \beta_1+\varepsilon_1 \qquad (1)$$
$$y_2=X_2\ \beta_2+\varepsilon_2 \qquad (2)$$

[9] See Judge et al. (1985, p. 802), Kmenta (1971, p.422-423) and Johnston (1984, p. 234-239) for a discussion of the advantages and disavantages of using one or the other procedure.

$$y_3=X_3\ \beta_3+\varepsilon_3 \qquad (3)$$
$$y_4=X_4\ \beta_4+\varepsilon_4 \qquad (4)$$

with y_i and X_i the observations on the dependent and independent variables and β_i the parameter vector characterizing each quarter. Moreover it can be assumed that the error term of each period has its own variance, i.e. $\varepsilon_i \sim \mathcal{N}(0, \sigma_i^2)$. More compactly, the seasonality model can be rewritten as

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} X_1 & & & 0 \\ & X_2 & & \\ & & X_3 & \\ 0 & & & X_4 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \end{bmatrix}$$

or

$$y= X\beta + \varepsilon \qquad (5).$$

3.b) Other switching regimes with known joint point

To model a data series reflecting structural changes, the data are divided into separate groups similarly to the previous model. In the presence of one structural change two regressions are run, i.e.

$$y_t=X_t\ \beta_t+\varepsilon_t \qquad t \in T_1 \qquad (6)$$
$$y_t=X_t\ \beta_t+\varepsilon_t \qquad t \in T_2 \qquad (7)$$

which can be put in the format of Eq. (5). However these groupings do not have to contain observations that are sequential in time. For instance, in the first regression can be put all the data relative to war-time periods and in the second one those belonging to peace-time periods. Alternatively, Eq. (6) may model expansionary periods and Eq. (7) recessionary periods. In this respect the present formulation is a generalization of the seasonality model .

It is important to stress that, as indicated by the title of this section, this class of models assumes an a priori knowledge of the "joint points" characterizing the data series.[10]

3.c) Switching regimes with unknown joint point.

Most of the times, the point where there is a switch in the regime is unknown and it has to be estimated. Two cases are discussed in the literature: 1) the deterministic case ; 2) the stochastic case.

3.c.1) Deterministic switching

In the deterministic case the switch between the regimes, two or more, depends upon the fact that the value of some observed value is above a certain unknown threshold. In other words it is assumed that Regime 1 holds when $t \leq t_o$, or more generally $z_t \gamma \leq 0$ with z_t a vector of observed values and γ a vector of unknown coefficients, and Regime 2 when $t > t_o$, or more generally $z_t \gamma > 0$. The estimate of t_o, or γ in the general case, is the value that maximizes the following likelihood function

$$\ell(\beta_1, \beta_2, \sigma_1, \sigma_2 \mid t_o) \propto \sigma_1^{-t_o} \sigma_2^{-(T - t_o)}$$

$$\times \exp\left\{-(1/2\sigma_1^2)\sum_{t=1}^{t_o}(y_t - x'_t\beta_1)^2 - (1/2\sigma_2^2)\sum_{t=t_o+1}^{T}(y_t - x'_t\beta_2)^2\right\}. \quad (8)$$

"The justification for using calendar time to 'explain' the variation of β (is that in most cases) it acts as a surrogate for all the unknown time related dynamic forces within the economy. The usefulness of the model (in which the switch in the regime is determined by t) then depends upon the acceptability of that substitution." (Judge et al. (1985, p. 799)). A likelihood ratio test of the form

$$\lambda = \frac{\ell(\beta, \sigma)}{\ell(\beta_1, \beta_2, \sigma_1, \sigma_2 \mid t_o)}$$

[10] See Poirier (1973, 1976) for a piecewise regression function, called the cubic spline function, whose pieces join more smoothly than the usual switching regimes.

with $\ell(\beta, \sigma)$ the likelihood of the restricted model, i.e. with constant parameters, and $\ell(\beta_1, \beta_2, \sigma_1, \sigma_2 | t_0)$ the likelihood of the unrestricted model, i.e. with the structural change, can be used to test the hypothesis of no switching. If the value of $-2\log\lambda$ is above the appropriate critical value, the constant parameters model is rejected.

3.c.2) Stochastic switching

In the so-called stochastic switching the switch between the two, or more, regimes depends upon some unknown probabilities. When nature chooses Regime 1 or 2 on the basis of unknown probability α and $1-\alpha$, the conditional probability function of y_t given x_t is

$$g(y_t \mid x_t) = \alpha f_1(y_t \mid x_t) + (1-\alpha) f_2(y_t \mid x_t) \quad (9)$$

with $f_1 \sim \mathcal{N}(x'_t\ \beta_1,\ \sigma_1)$ and $f_2 \sim \mathcal{N}(x'_t\ \beta_2,\ \sigma_2)$ and then $\beta_1, \beta_2, \sigma_1^2, \sigma_2^2$ and α are found maximizing the appropriate log-likelihood function.

4) Problems associated with the use of switching regimes

A problem associated with the use of switching regime models is the fact that the same number of observations is used to estimate at least twice as many parameters, in the case of two regimes.[11] This implies a substantial loss of degrees of freedom. For this reason the amount of data needed to obtain reliable estimates of the unknown parameters is higher than using the standard econometric techniques.

Moreover as indicated in various studies, see e.g. Farley et al. (1974), the tests for instability are not powerful, in the sense that they tend to accept the null hypothesis of stable coefficients unless the sample is large or the shift is great. The problem with this method, as pointed out in Swamy and Mehta (1975), is that the likelihood goes to infinity as σ_1^2 (or σ_2^2) goes to zero, both in the case of stochastic and deterministic switching. This can be easily seen, for the case of deterministic switching, writing down the log-likelihood function of (8) which looks like

[11] Indeed if the joint points are unknown and/or the Seemingly Unrelated Regressions procedure is used the number of parameters to estimate is even higher.

$$\ell \propto -(t_0/2)\log\sigma_1^2 - (T-t_0/2)\log\sigma_2^2 - (1/2\sigma_1^2)\sum_{t=1}^{t_0}(y_t - x'_t\,\beta_1)^2$$
$$- (1/2\sigma_2^2)\sum_{t=t_0+1}^{T}(y_t - x'_t\,\beta_2)^2 \qquad (10)$$

and reaches its maximum when one of the variances approaches zero. Therefore smaller values of the variances appear to be more plausible than larger values regardless of the observed data. It is obvious then that the hypothesis of "no-switch", corresponding to that of one zero variance, is usually accepted.

A series of Monte Carlo experiments (Hosmer (1973)) shows that the Maximum Likelihood (ML) estimates are not reliable even in fairly large samples. Furthermore there may be problems with the identifiability of the parameters in the sense that two sets of coefficients may be observationally equivalent, i.e. they provide the same probabilistic descrition of the data (Swamy and Mehta (1975, p. 593)). In this situation additional restrictions are needed to obtain identifiability and exploit the proprties of the ML estimators. Finally, it should be noticed that the probabilistic properties of the estimators produced after preliminary testing for stability are not known in general.[12]

5) Stochastic Parameters

The other way of modelling time-varying parameters is by assuming that they are random variables with a different realization in each time period (or cross sectional unit). Three cases are considered in the literature:[13]

a) the stationary case - in which the parameters are assumed to vary around a certain value, its mean, with a variance constant through time;

b) the non-stationary case - in which the realizations of the parameter vector are not centered around a constant mean, but the variance is generally assumed constant;

c) the "non-stochastic solution".

5.a) The Stationary Case

This approach has been thoroughly analyzed by Harvey and Phillips (1982) and Swamy and Tinsley (1980). Formally the model is composed of two equations

[12] See Judge et al. (1985, p. 805).
[13] See Harvey (1981, Ch. 7) for an application of the Kalman Filter to the estimation of stochastic parameters in the three cases discussed below.

$$y_t = x'_t\,\beta_t \qquad (11)$$
$$\beta_t - b = \Phi\,(\beta_{t-1} - b) + \varepsilon_t\ . \qquad (12)$$

Eq. (11), known as the measurement equation, relates the dependent and independent variables. The time subscript of the parameter vector indicates that it is different in each time period or for each cross sectional unit. Eq. (12), the transition equation, describes the way in which parameters vary with Φ having eigenvalues less than one to ensure non explosiveness, b the mean value of the parameter and ε white noise. Namely, it says that the discrepancy between the present value and its mean is a function of yesterday's discrepancy plus an error term. In other words todays' realization is the sum of three components: the mean constant through time, a function of yesterday's discrepancy and an error term with zero mean and a constant variance. This situation is depicted in Fig. 2.

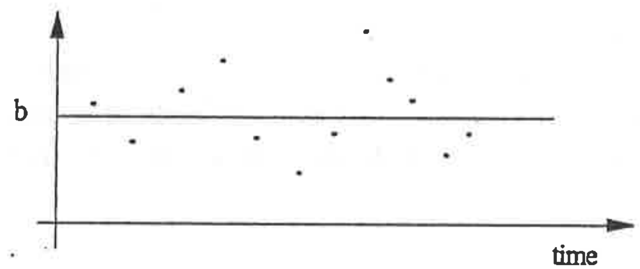

Figure 2. Dynamics of a parameter following a return to normality model.

When $\Phi = 0$, Eqs. (11)-(12) reduce to a Random Coefficient Model (Hildreth and Houck (1968)). In this case today's value of the parameter is given by its mean and and error term and the dynamic behavior of the stochastic parameter is similar to that shown in Fig. 3.

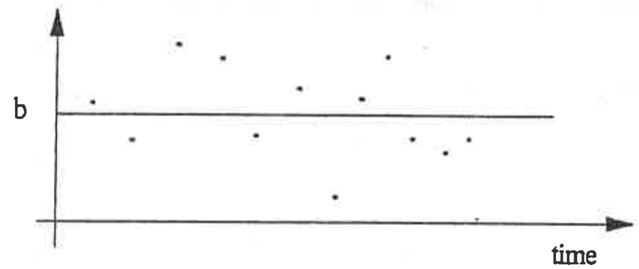

Figure 3. Dynamics of a parameter following a random coefficient model.

Two procedures have been proposed in the literature to estimate the parameters of a "Return to Normality Model". Harvey and Phillips (1982) estimate this model, i.e. Φ, b, the variance of the error term and compute the realization of the parameter vector in each period, using Kalman Filter (KF). They present both a two-step algorithm and a "Maximum Likelihood" one. Swamy and Tinsley (1980), on the other hand, use their own approach claiming that it is superior to the ML approach because it is able to give consistent estimates of some of the parameters even when the latter cannot be applied for the lack of identification. A prelimininary Monte Carlo study (Tucci (1990), shows that Harvey and Phillips (1982) two-step procedure is faster than Swamy and Tinsley (1980) iterative procedure and yields estimators performing at least equally well in many cases.

The assumptions characterizing the "Return to Normality" seem to indicate that this model is best suited to model cyclical fluctuations of the parameters.

5.b) The Non-stationary Case

When the parameters are not centered around a constant mean or, less frequently, or when the variance of their error term is not constant they should be modelled as non-stationary processes. This case is represented in Fig. 4. Assuming that the non-stationarity

Figure 4. Dynamics of a parameter following a non stationary stochastic process.

is due to a non-constant mean, the transition equation becomes

$$\beta_t = \Phi\, \beta_{t-1} + \varepsilon_t \tag{13}$$

with Φ, the transition matrix, unconstrained and ε_t white noise. When $\Phi = 1$, Eq. (13) reduces to a Random Walk Model (Cooley and Prescott (1976)). The ML procedure cannot be applied directly to this model. Therefore all the β_ts have to be rewritten in terms of a

specific parameter vector (β_0 or β_{T+1} generally) which is regarded as unknown but fixed and the likelihood function can be constructed to estimate β_0 (or β_{T+1}), Φ and the variance of the error term.

This model is able to accommodate fairly fundamental structural changes. Moreover it is appropriate to describe those transitory periods in which the parameters move from a certain equilibrium level, which prevailed in a certain period, to a new level.[14]

5.c) The "non-stochastic" solutions

Recently some "non stochastic" solutions have been proposed to estimate stochastic parameters. The objective is to find a technique able to produce time-varying estimates of the parameters using as few probabilistic assumptions as possible. The most popular of these attempts is the one by Kalaba and Tesfatsion (1986,1988)[15] who develop the so-called Flexible Least Squares (FLS) approach. They assume that the noisy observations have been generated in accordance with a linear regression model whose coefficients evolve slowly through time, if at all, and do not assign specific probabilistic properties to residuals, i.e.

$$y_t - x'_t\, \beta_t \sim 0 \tag{14}$$

$$\beta_t - \beta_{t-1} \sim 0\ . \tag{15}$$

Even though intuitively appealing, this "non-stochastic" solution present serious shortfalls. It has been found (Tucci (1990)) that the FLS approach produces the same estimator as a KF which assumes that Φ=1, that is the parameters follow a random walk, all the parameters are independent of each other and are characterized by an identical variance. These assumptions are much stricter than those usually accepted by the researcher. Usually Φ, the variance of the parameters and their reciprocal independence are estimated and, eventually, tested. In other words the investigator using FLS ends up with estimators much worse than those obtained using the usual stochastic approach and the usual numerical technique, i.e. KF.

14 Cooley and Prescott (1976) model $\beta_t = \beta^p_t + u_t$ with $\beta^p_t = \beta^p_{t-1} + v_t$ and assume that σ_u and σ_v are known up to a scale factor.

15 See also Nachame and Rao (1990) which use a similar approach.

6) Problems associated with the use of stochastic parameters

The use of stochastic parameters, analogously to the case of systematically varying parameters, greatly increases the number of coefficients to estimate. Assuming that an equation with two coefficients has to be estimated, e.g.

$$y_t = \alpha + \beta x_t + \varepsilon_t \quad , \qquad (16)$$

in the standard case there are only three unknown parameters (α, β, and the error term variance σ^2) whereas in the case of stochastic parameters they are 9, i.e.[16]

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix} \quad \begin{bmatrix} \phi_1 & \phi_2 \\ \phi_3 & \phi_4 \end{bmatrix} \quad \begin{bmatrix} \sigma_1 & \sigma_2 \\ \sigma_2 & \sigma_3 \end{bmatrix}$$

For this reason many more observations are needed to have reliable estimates of the parameters. Some preliminary results (Tucci (1990)) show that sometimes estimating a slightly simplified structure of the stochastic parameters, for instance the following with 6 distinct parameters

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix} \quad \begin{bmatrix} \phi_1 & 0 \\ 0 & \phi_4 \end{bmatrix} \quad \begin{bmatrix} \sigma_1 & 0 \\ 0 & \sigma_3 \end{bmatrix}$$

in place of the correct one, the one with 9, may result in better out of sample forecasts. This is due to the fact that the number of observations is not sufficient to produce reliable estimates of all the unknown parameters. The loss in terms of Mean Square Error due to a bad specification of the parameter structure may be lower than the loss associated with poor estimates. Therefore the researcher trying to estimate "everything" may end up with lower

[16] See Pagan (1980) for some results on identification and estimation.

quality estimates which affect the ability of the model to predict correctly the out of sample observations.

Another thing to notice is that all models with random parameters fit perfectly the data. Therefore all the usual measures used to assess the goodness of fit of a certain model, such as the coefficient of determination and the F ratio are no longer appropriate. The relative performance can be measured only checking the out of sample performance. A good specification of an econometric model with stochastic parameters shows a smaller forecasting error than a constant parameter model, in the first few out of sample observations 2-4. As time goes the benefit of using models with stochastic parameters vanishes as shown in Fig. 5. To make out-of-sample forecasts the parameters are projected

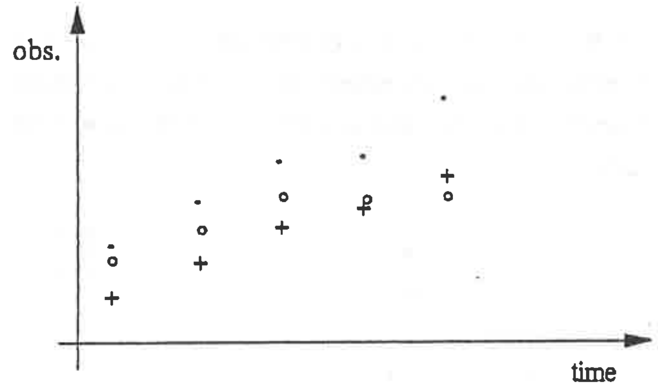

Figure 5. Out of sample behavior of historical data (.), well behaved stochastic parameter estimates (°) and OLS estimates (+).

forward as many periods as needed using the estimated conditional mean of (12) or (13), i.e. $\hat{\beta}_t = \hat{b} + \hat{\Phi}(\hat{\beta}_t - \hat{b})$ and $\hat{\beta}_t = \hat{\Phi}\hat{\beta}_{t-1}$ respectively. Therefore the stochastic parameters behave more and more like constant parameters. Furthermore it is likely that these estimates are less reliable than those generated by the usual OLS procedure, for the reasons described above. For this reason constant parameter models forecast equally well, or even better, after a few periods.

When stochastic parameters are used inappropriately the out of sample forecasts of an econometric model where some of the parameters are stochastic are worse than those generated by the common OLS procedure. A plausible behavior is sketched in Fig. 6.

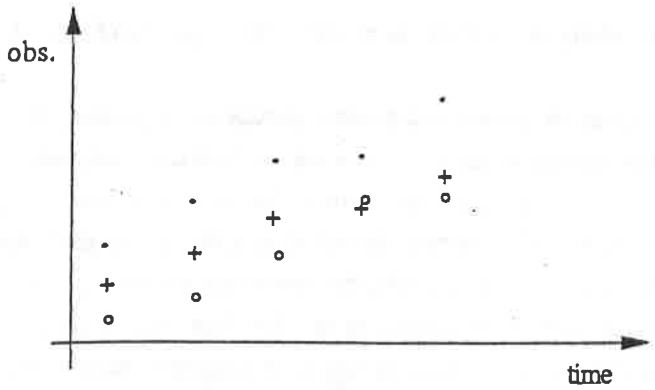

Figure 6. Out of sample behavior of historical data (.), badly behaved stochastic parameter estimates (°) and OLS estimates (+).

Another problem is the fact that "an extension of a random coefficient model to a simultaneous equation system will most likely generate reduced form error terms which are quotients of random variables" (Tsurumi and Shiba (1982, p. 239)). To see this point more clearly, consider the following example[17]

$$C_t=a+b_tY_t+u_t \tag{17}$$
$$Y_t=A_t+C_t \tag{18}$$
$$b_t=b+v_t \tag{19}$$

where C is consumption, Y is GNP and A is autonomous expenditures assumed exogenous. Moreover the parameter b is assumed stochastic with a constant mean and variance; u_t and v_t are white noise. It can be shown that the reduced form is

$$C_t=(\alpha/a)+(\beta/a)A_t+w_t \tag{20}$$
$$Y_t=(\alpha/a)+(1/a)A_t+w_t \tag{21}$$

where $a=1-\beta$, $w_t=(b_t\, v_t+u_t)/(a-v_t)$ and $b_t=(a+A_t)/a$. "The reduced form error term, w_t is the ... quotient of correlated normal variables" (Tsurumi and Shiba (1982, p. 241)), namely u_t and v_t. The probability density function of w_t turns out to be quite complicated and the usual econometric techniques, which assume an error term normally distributed can no

[17] This example is thoroughly worked out in Tsurumi and Shiba (1982).

longer be applied.[18] This problem can be avoided assuming that either only the reduced form parameters are stochastic[19] or that only the coefficients of the exogenous variables vary stochastically.[20] Therefore only when there is evidence that one of these assumptions are plausible the stochastic parameter approach can be applied fruitfully to a system of simultaneous equations.

This problem is likely to characterize also systems of simultaneous equations in which the parameters are assumed to evolve according a non-stationary stochastic process. In addition it should be pointed out that the statistical theory for non stationary processes is not very well developed.[21] For instance, non stationarity prevents the straightforward use of maximum likelihood estimation technique.[22] For this reason all the β_ts, assumed stochastic and unknown, are rewritten in terms of β_{T+1}, assumed constant and unknown.[23] But this introduces a very ad hoc difference among the various parameter vectors. Furthermore the usual notion of consistency can no longer be applied to the estimator of β_{T+1}.

6) Conclusion

Summarizing time-varying parameters have pros and cons. On one hand, they provide the possibility to forecast the conditional mean of the dependent variable more accurately. On the other hand, the researcher may 'abuse' this powerful tool. Often times the variations in the coefficients across the sample are due to misspecifications of the model rather than to a changing underlying structure (linearity, proxy and omitted variables). For these reasons the present models should be used only when they have advantages in terms of both realism of assumptions and estimation efficiency. Furthermore in some cases the structural change cannot be detected using time-varying parameters because of the insufficient number of observations. In this respect, it is never repeated enough times the warning that "modelling a changing economic structure by allowing response parameters to vary across observations may be a realistic approach but the chances for misspecifications are many" (Judge et al. (1985, p. 815)). As always, inferences about economic processes based on

[18] See Tsurumi and Shiba (1982) for details.
[19] See Zellner (1969) and Swamy (1970).
[20] See Raj et al. (1980).
[21] See, e.g., Priestley (1965) for a discussion on non-stationary stochastic processes.
[22] See Judge et al. (1985, p. 813).
[23] See Pfefferman (1984) for a discussion of this point.

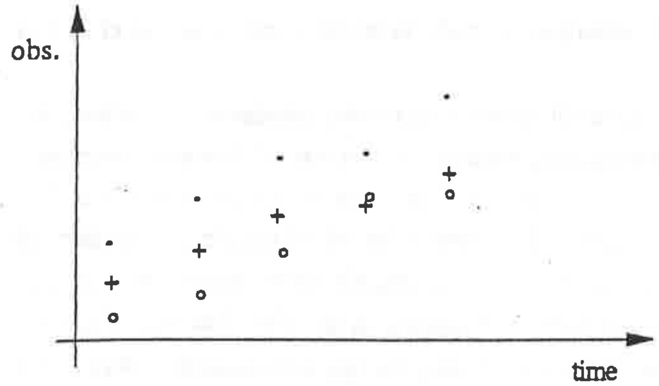

Figure 6. Out of sample behavior of historical data (.), badly behaved stochastic parameter estimates (°) and OLS estimates (+).

Another problem is the fact that "an extension of a random coefficient model to a simultaneous equation system will most likely generate reduced form error terms which are quotients of random variables" (Tsurumi and Shiba (1982, p. 239)). To see this point more clearly, consider the following example[17]

$$C_t=a+b_tY_t+u_t \tag{17}$$
$$Y_t=A_t+C_t \tag{18}$$
$$b_t=b+v_t \tag{19}$$

where C is consumption, Y is GNP and A is autonomous expenditures assumed exogenous. Moreover the parameter b is assumed stochastic with a constant mean and variance; u_t and v_t are white noise. It can be shown that the reduced form is

$$C_t=(\alpha/a)+(\beta/a)A_t+w_t \tag{20}$$
$$Y_t=(\alpha/a)+(1/a)A_t+w_t \tag{21}$$

where $a=1-\beta$, $w_t=(b_t\ v_t+u_t)/(a-v_t)$ and $b_t=(a+A_t)/a$. "The reduced form error term, w_t is the ... quotient of correlated normal variables" (Tsurumi and Shiba (1982, p. 241)), namely u_t and v_t. The probability density function of w_t turns out to be quite complicated and the usual econometric techniques, which assume an error term normally distributed can no

[17] This example is thoroughly worked out in Tsurumi and Shiba (1982).

longer be applied.[18] This problem can be avoided assuming that either only the reduced form parameters are stochastic[19] or that only the coefficients of the exogenous variables vary stochastically.[20] Therefore only when there is evidence that one of these assumptions are plausible the stochastic parameter approach can be applied fruitfully to a system of simultaneous equations.

This problem is likely to characterize also systems of simultaneous equations in which the parameters are assumed to evolve according a non-stationary stochastic process. In addition it should be pointed out that the statistical theory for non stationary processes is not very well developed.[21] For instance, non stationarity prevents the straightforward use of maximum likelihood estimation technique.[22] For this reason all the β_ts, assumed stochastic and unknown, are rewritten in terms of β_{T+1}, assumed constant and unknown.[23] But this introduces a very ad hoc difference among the various parameter vectors. Furthermore the usual notion of consistency can no longer be applied to the estimator of β_{T+1}.

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statistical models are conditioned by the theoretical and institutional knowledge of the economic structure on which the sampling model is based.

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