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SMART, IRRATIONAL EXPECTATIONS AND THE GERMAN HYPERINFLATION

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ABSTRACT

The literature on the German hyperinflation is reviewed and arguments are presented why expectations were not rational during this episode. To overcome the simplistic assumptions of adaptive expectations, a "smart" form of adaptive expectations is used, in which the public extrapolates a local trend. The model is further augmented with a market adjustment equation. Estimates suggest this model is a more realistic representation of what actually went on than the standard Cagan[1956] model.

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1. INTRODUCTION

Hyperinflation has generated an impressive body of literature over the years. There are some obvious reasons for this : as a phenomenon, it appeals to the imagination, and the fact that hyperinflations recur over and over again naturally stimulates interest in the question what causes them, and, more to the point, how hyperinflation can be stopped.

The first and most famous hyperinflatory episode of this century took place in Germany after the First World War. Although it was only one of 5 severe inflations then wracking the economies of Central European states, it was by far the most spectacular, and the one which has generated the most interest. It was by no means the most serious hyperinflation of all time - that sad record is still held by the post-WW2 Hungarian hyperinflation - but it is certainly in the top five.

Although studies of this episode started appearing almost as soon as the bank notes had stopped fluttering, the first econometric attempt at analysis was made by Cagan[1956]. Now, 35 years later, we can regard this paper in the light of methodological insights gained since 1956, and note several severe weaknesses in the argumentation, but at the time it had an enormous impact, and it became the progenitor of an impressive body of literature Any reexamination must therefore start by reviewing the literature on this subject, and since this literature is so extensive, the whole of section 2 is devoted to this exercise. In section 3 arguments against rational expectations are given and some alternative model forms are suggested, while section 4 contains the empirical implementation of this alternative strategy. Section 5 collects the main points and makes suggestions for further research.

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[1]The author owes a considerable debt of gratitude to Margreet Schuit, who made several helpful suggestions. Responsibility for any errors remains my own.

2. A REVIEW OF THE LITERATURE

Before Cagan's classic paper on the subject, opinions on the German hyperinflation were roughly divided into two camps. The first school of thought, popular among German economists in particular, held that the hyperinflation was an imported phenomenon : it was actually the external value of the Mark which deteriorated so spectacularly, and - through imports - this leaked into the German economy. The inflation was exacerbated by the German government's limited ability to fight it : most of its financial energy was drained by the Reparations payments. Oddly enough, nobody appears to have suggested that the Soviet Hyperinflation of 1920-1923 acts as an exception to this proposed rule : the rudimentary trade between post-Civil-War Russia and the rest of the world and virtually meaningless ruble exchange rate did not stop hyperinflation in Soviet Russia, so the Soviet Hyperinflation must have been fueled by internal causes.

The second theory placed the blame for the hyperinflation firmly with the German government. In this view, the government's policy of printing money to make up its deficits inflated the money stock to such a degree that the value of money plummeted. Here, it is the internal value of the Mark which is the first to collapse. Since the two theories are so closely intertwined with the matter of Reparations and the (perceived) German sabotage of the Reparations payment scheme, the question of whether the hyperinflation started inside or outside Germany is not without a historical and political significance, and tempers occasionally flared during this discussion. For good reviews, see Angell[1929], Bresciani-Turroni[1937], Ringer[1969] and Horseman[1988].

The first econometrically significant paper is Cagan[1956]. Since it served as the cornerstone of so many subsequent papers, the main features will be summarised here.

Cagan postulates a time-invariant money demand function, of the form :

$$(1) \qquad \log(M_t/P_t) = \alpha + \beta E_t \qquad (\beta < 0)$$

where M_t is nominal money stock, P_t is a price index and E_t is the expected inflation for the next time period. Inflation expectations are adaptive :

$$(2) \qquad E_t = E_{t-1} + \gamma(\pi_t - E_{t-1}) \qquad (0 \leq \gamma < 1)$$

where π_t is the actual inflation. The case $\gamma=1$ was excluded by Cagan : he derived (2) from a continuous-time model with a positive parameter δ, which is related to γ : $1 - e^{-\delta} = \gamma$, so that $\gamma=1$ corresponds to $\delta=\infty$. This is a subtle point, which is occasionally missed (see e.g. Webb[1983] p.437).

Cagan tacked an error term onto (1) and tried various values of γ for generating E_t and estimating (1) by OLS. The value of γ which minimised the

sum of squares was then chosen. This procedure was used for data of six hyperinflatory episodes.

A few stylised facts about Cagan's estimation procedures and results should be noted. In the first place, there is a great risk of simultaneity bias, as M and P would seem to be jointly determined. This is a point raised by, among others, Jacobs[1975] and further discussed in Sargent[1976a,b], Jacobs[1976], Cagan & Kincaid[1977] and Jacobs[1977b]. Second, the results are very similar for all datasets : high R^2, moderate value of γ and very strong autocorrelation among the residuals. This latter ailment has spurred Khan[1975] to re-estimate (1) with an AR(1) error term, while Bisignano[1975] also tries an MA(1) term in a Bayesian analysis. Since the symptoms are reminiscent of "spurious regression" (a suspicion also voiced by Jacobs[1975]), we might wonder if the explosive processes of the hyperinflation are just as conducive to spurious regression as nonstationary processes.

Thirdly, the periods with the worst hyperinflation had to be dropped from the regression as they were way off the regression line. Cagan speculated that γ might not be constant, and that an increased value of γ during the final months of the hyperinflation caused the aberrant values. This latter point has been further investigated by Khan[1977], who allowed γ to vary with $|\Delta\pi|$, and Jacobs[1977a], who chose a different adaptive scheme which boils down to a γ proportional to $\sqrt{E}$.

With the advent of the Rational Expectations school of thought, the adaptive expectations assumption (2) came under close scrutiny. In a very influential paper, Sargent & Wallace[1973] investigate the consequences of assuming expectations in (2) are rational. Both this paper and a sequel in Sargent[1977] lose much of their appeal when seen in the light of Salemi[1979], who tests the tenability of assuming both adaptivity and rationality for expectations and finds he has to reject this combination of traits. Salemi & Sargent[1979] drop the adaptive expectations assumption. The Sargent/Wallace/Salemi approach has the big advantage that it eliminates any simultaneity bias by formulating a bivariate model for M and P, but some of the consequences of their model have been questioned, for instance in Friedman[1978] and Buiter[1987]. Both these papers note that the SWS model could also embrace *hyperdeflations*, a phenomenon on which, as Buiter notes, a marked scarcity of data has impeded empirical research!

The Rational Expectations assumption has proved to be very alluring, and many subsequent papers assume RE as a matter of course. Examples can be found in Goodfriend[1982], Burmeister & Wall[1982,87], Huang[1984] and Kiguel[1989].

A different line of attack has been spearheaded by Frenkel[1977], who questions the use of exponentially weighted inflation as an indicator for expected inflation. Via an efficient exchange market argument, he proposes the forward exchange rate as an alternative indicator, while a later paper (Frenkel[1979]) corrects heteroskedasticity in the specification and examines the merit of yet more alternatives to holding Marks. Abel, Dornbusch, Huizinga & Marcus[1979] actually use both (2) and the forward exchange rate as joint indicators of expected inflation. An attack on this approach by Salemi[1980] is parried in Frenkel[1980]'s rejoinder.

Other papers investigate the presence of self-fulfilling price bubbles (Flood & Garber[1980a,1980b,1983], Hamilton[1986], Casella[1989]), the direction of causality between M and P (Hernandez-Iglesias & Hernandez-Iglesias[1981], Protopapadakis[1983]), the possibility that a monetary reform was actually expected, influencing inflation expectations (Flood & Garber, LaHaye[1985]) or the consequences of assuming different mechanisms for the formation of expectations (Evans & Yarrow[1981]).

An interesting footnote to the original Cagan model is provided by Dufour[1986] who investigates the stability of the coefficients by recursive techniques. He finds considerable evidence that the coefficients in Cagan's model are <u>not</u> constant through time, not even in the shortened sample period Cagan used.

Finally, several authors have applied Caganite models to other data sets. Interest in the post-WW2 Chinese and Taiwanese hyperinflations is still growing, while episodes of high inflation in Israel, Yugoslavia, Poland, Brazil, Argentina and Bolivia have also been subjected to Caganite scrutiny.

It is worth mentioning that, in all this literature, there is no formal definition of hyperinflation to be found. Cagan formulates a rule-of-thumb : hyperinflation is everything over 50% per month, but his sample periods contain many months in which inflation was lower, to "increase the number of degrees of freedom", so this definition should apparently be taken with a grain of salt.

Summarising, the Cagan model has been the foundation of a large number of papers. These papers examine variants of Cagan's model, said variants usually originating in the following areas :

1. The specification of the demand function (1). Alternative measures of expected inflation, different functional form, different error structure.
2. The formation of expectations. Adaptive, adaptive-rational, rational.

We might also wonder if there are points in Cagan's paper which have not yet been investigated in depth. One question which appears to have received little or no attention is whether the basic specification of the model (or indeed of any of the alternative models mentioned above) is tenable. Misspecification tests are almost completely absent from the entire literature on this subject,[2] with the occasional exception of a Durbin-Watson test statistic. The assumptions of normal disturbances, homoskedasticity and constant parameters, to name a few examples, have never been rigorously tested. Another assumption worth investigating further is the assumption that the "market for money" clears immediately through price adjustments. Only a money demand function is specified, and it really serves to explain price movements only : whatever the actual money stock, the price changes to ensure that (1) is satisfied. Only Hu[1971] and Kiguel[1989] introduce a market adjustment equation, and the latter only in a continuous-time, deterministic context. Dufour[1986]'s indications that certain coefficients might not be constant also gives food for thought. Finally, the fact that the most spectacular period of hyperinflation (August-November 1923) had to be excluded from the estimation as those observations were way off the regression line is cause for concern. Flood & Garber have developed models in which this is explained by assuming that people allowed an expected money reform to influence their behaviour, but since this is the *only* possible explanation in their models it should not come as a surprise that they arrive at this conclusion.

The lone dissenter in the literature is Barro[1970], who formulates a wholly different model. However, the assumptions he needs to make to be able to implement his model empirically are rather severe, and, maybe as a result, his example has inspired virtually no other investigators.

> *How could I have guessed the irony? I was sublimely ignorant of my personal future.*
>
> Michael Moorcock, "The Laughter of Carthage"

3. IN DEFENSE OF IRRATIONALITY

From the above, it is clear that many authors have applied the Rational Expectations paradigm to this particular problem, but very few have actually

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[2] Notable exceptions being Christiano[87], who rigorously examines the Cagan model under Rational Expectations, and Schult[1990], who applies a Caganite model to various modern data sets

wondered if this assumption is tenable *a priori*. We recall that assuming expectations are formed rationally implies that the populace forms unbiased predictions of next period's inflation. We might therefore ask ourselves if this is realistic.

There are in fact some very strong arguments *against* Rational Expectations during hyperinflations. The first argument is based on a simple act of imagination : imagine the situation of the average German consumer during this monetary merry-go-round. The German hyperinflation was the first episode of explosive inflation in history. The only remotely similar experiences were the devaluation of the French *assignat* currency after the 1789 Revolution and the collapse of the Confederate Dollar in the later stages of the American Civil War. In other words, the German people had no precedents on which to base their responses. This is a stronger argument against RE than the oft-quoted observation that it's unlikely the man in the street was able to generate unbiased forecasts if, after 70 years of introspection, econometricians still are not able to formulate a model which manages to do so : in this case, there are objective reasons to suspect the "man in the street" had no consistent idea what was going to happen next. While we might therefore assume that agents in later hyperinflations had learned sufficiently from the German example to form their expectations rationally, assuming rationality for the Germans during this episode is asking a bit much.

Second, the German government certainly showed little ability to forecast consistently. A good review of German government policy can be found in Bresciani-Turroni[1937] and Merkin[1983], and the story is one of consistent underestimation of the problems involved and the actions necessary to solve them. To name one example which will assume extra significance later on, the quantity of banknotes produced consistently fell short of the needed quantities, while the inept fiscal policy is another example. In a different context, Schneidman[1970] has offered convincing evidence the Russian government also had little idea of what it was doing during its bout with hyperinflation. If the government - a very important player in the economic arena, was unable to act rationally or forecast unbiasedly, there is little reason to assume the consumers and/or producers were.

Third, we must realise that we are in a very fortunate position. After half a century the worst errors have been removed from the data, and most of the important macroeconomic series are now available to us at the press of a key on the PC. However, the German agent was not so fortunate. The German government had a very imperfect knowledge of the various variables, and the same holds *a fortiori* for the German consumers and producers. Knowledge of

the model therefore isn't enough, we must also demand that the agents in the German economy knew the exact value of the various variables in the model *even though the German government did not!*

Finally, there is another reason for not attaching too much weight to rationality in expectation formation. The demand that forecasts are unbiased limits itself to the first moment of the predictive density, but what of the higher moments ? Any restriction on the mean of the prediction becomes meaningless if the variance of that prediction is large enough, and I can think of fewer economic scenarios in which the uncertainty of the agents was larger than the German hyperinflation. Any "expected inflation" must have been accompanied by an uncertainty margin that grew rapidly as time went by. And if the uncertainty about next period's inflation is large enough, any restriction placed on the expected inflation becomes meaningless.

In this paper I will therefore refrain from demanding rationality of the German people during their hyperinflationary delirium. On the other hand, assuming adaptive expectations may be doing the predictive abilities of the agents an injustice. The predictive properties of adaptive expectations as in (2) are well-known : if inflation becomes constant, expected inflation will converge to that same constant over time. If, however, inflation grows linearly in time, expected inflation will never catch up and will always, pun not intended, fall short of the mark. While I am willing to allow for irrationality among the agents in the German economy, I find it hard to defend these agents being so dense. If monthly inflation continues to grow, from 5% to 10% to 15% to 20% and so on, won't the German consumer/producer catch on and extrapolate a local trend to form his prediction for next month's inflation ? This would imply a Holt-Winters-type prediction mechanism:

(3a) $$E_t = E_{t-1} + e_{t-1} + \gamma_1(\pi_t - E_{t-1} - e_{t-1})$$

(3b) $$e_t = e_{t-1} + \gamma_2(\pi_t - E_{t-1} - e_{t-1})$$

where e_t is the perceived change in inflation, the perceived slope of the inflation curve at time t. We may also consider the use of dummies to introduce specific events into the formation of expectations. The Ultimatum of London (June 1921) was generally recognised to be the death-blow to German public finances, and inflation shows a clear jump in June 1921, a jump which is otherwise inexplicable. In the above framework, we might postulate a dummy in (3a)-(3b) to catch this (apparently nontransient) jump in inflation and expected inflation. The murder of foreign secretary Walther Rathenau in July 1922 was likewise followed by a notable increase in the speed of inflation. Stability of the parameters is also a point of concern.

4. A MODEL FOR SMART, IRRATIONAL EXPECTATIONS, AND SOME ESTIMATION RESULTS

The arguments presented in the previous section boil down to the following model :

(4) $\log(M^d_t/P_t) = \alpha + \beta(E_t + e_t) + u_t \qquad u_t \text{ iid } N(0,\sigma^2)$

(5) $E_t = E_{t-1} + \rho e_{t-1} + \gamma_1(\pi_t - E_{t-1} - e_{t-1})$

(6) $e_t = e_{t-1} + \gamma_2(\pi_t - E_{t-1} - e_{t-1})$

Note that we have introduced a parameter ρ to allow for some reluctance in extrapolating trends. We will augment the model further with a market adjustment equation, as in Kiguel[1989][3] :

(7) $\log(M_t/P_t) = \log(M_{t-1}/P_{t-1}) + \delta\{\log(M^d_{t-1}/P_{t-1}) - \log(M_{t-1}/P_{t-1})\}$

Hu[1971] uses a slightly altered form in a study of the post-WW2 Chinese hyperinflation :

(7a) $\log(M_t/P_t) = \log(M_{t-1}/P_{t-1}) + \delta\{\log(M^d_t/P_t) - \log(M_{t-1}/P_{t-1})\}$

However, this form assumes a more forward-looking money supply policy, and it lacks an advantage which (7) does possess, see below.

Substituting this into (4) gives :

(4') $\log(M_t/P_t) = (1-\delta)\log(M_{t-1}/P_{t-1}) + \alpha\delta + \beta\delta(E_{t-1} + e_{t-1}) + \delta u_{t-1}$

Without further complications we can redefine parameters and write :

(4'') $\log(M_t/P_t) = \alpha^* + \beta^*(E_{t-1} + e_{t-1}) + \delta^*\log(M_{t-1}/P_{t-1}) + u_t$

The instantaneous market adjustment postulated by Cagan and most of his successors is approximated (but only approximated!) by the case $\delta^*=0$, a testable assumption. Note that the delay in the money supply equation has caused the irksome simultaneity in the reduced form of the model to disappear. This means that at least one shortcoming of the Cagan is avoided. However, in view of the criticisms listed in the previous section, we will have to examine this model carefully for misspecification after estimation.

The reduced form (4'') obscures the interpretation of the model somewhat. Basically, there are three processes at work here :

1. The stable money demand function (4)

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[3] A similar adjustment function is actually suggested by Cagan[56], who simply assumes δ is large enough to guarantee almost instantaneous adjustment. However, as the changes in real cash balances were quite large, we may question this assumption, hence the more cautious formulation used here.

2. The "smart" inflation expectation formation (5)-(6)

3. The adaptive money supply process.

The latter can be seen as the government's expectation of next period's money demand. Making this expectation adaptive may be doing the government an injustice : here, too, we could postulate a Holt-Winters mechanism, allowing the government to learn from its mistakes. However, the anecdotal evidence supplied by Bresciani-Turroni[1937] strongly suggests that even the use of simple adaptive expectations may be overestimating the government's adaptability.

The end result is a model in which both the private and the public sector are allowed to make biased predictions, a "tragedy of errors".

During estimation we run into one further problem : the need to initialise the expectations with values E_o and e_o. While various ad hoc strategies suggest themselves, we will initially regard these two quantities as extra parameters to be estimated, giving us 9 parameters in all. (ρ, γ_1, γ_2, σ^2, α^*, β^*, δ^*, E_o and e_o)

Estimation was by numerical maximum likelihood. Data used were monthly observations over the period 1919.01 - 1923.11, taken from Cagan[1956], giving us 58 observations. The last month of 1923 was deleted as the stabilisation took hold in that month, leading us into a situation in which a model for hyperinflation is not designed to function. During initial estimation runs it was found that the two initial expectation parameters are poorly identified by the data at hand. Substituting actual inflation in 1918.12 and inflation growth between 1918.11 and 1918.12 gave results not noticably different in terms of other parameter estimates, likelihood, etc. to results obtained by leaving them as free parameters, so those two parameters were replaced by these ad hoc initialisations, leaving us with 7 parameters. See Table 1 for estimation results.

TABLE 1

coefficient	ρ	γ_1	γ_2	α^*	β^*	δ^*
estimate (final)	0.81	0.20	0.08	-0.09	-0.08	0.70
st.error (asymp.)	0.21	0.06	0.016	0.06	0.01	0.29

R^2 = 0.89 S.E. of regression = 0.30 Log(lik) = -7.15

Some indication of the stability of the parameters can be gained by, if not *recursive* estimates, then *sequential* estimates. Three sample plots are shown as figs.1-3 (with 95% intervals). Both γ_1 and γ_2 show some jumpiness around the historically significant months of June 1921 and July 1922, but adding

dummies to (5)-(6) for those two months does not lead to coefficients significantly different from 0 (χ^2_4 LR-test value of 2.87). All other parameters appear to converge to their final estimates quite well, and the tracking plot of β in fig.3 is fairly typical of the other parameters. We may conclude tentatively that the parameters in model (4'')-(6) are stable over the sample period, although the informal nature of this test gives it little weight. The dog did not bark during the night, but whether this constitutes a curious incident is not clear.

There is, however, a notable rising tendency in the estimate of ρ. This might indicate that the public became more and more willing to fully extrapolate a local linear trend. At no time is 0 within the confidence band around the estimate, which may be taken as an indication that the simple adaptive expectations assumed by Cagan are rejected for this more general alternative. The Cagan assumption of instantaneous market adjustment (δ=0) is also rejected.

Surprisingly - in the light of the persistent autocorrelation found in Caganite models - the residuals of this model show virtually no temporal structure. Tests for autocorrelation (up to lag 6), ARCH (up to lag 4) are nonsignificant at the 5% level, while an LM-test on heteroskedasticity is nonsignificant at the 1% level. A Bera-Jarque test on normality of the residuals gave a value of 3.99, also nonsignificant. This increases confidence that the expectation formation mechanism used here avoids the persistent underestimation of inflation which occurs when the simple adaptive mechanism is used.

An interesting feature of the model is that it allows us to compare actual money stock and desired money stock (both in real terms). It turns out that in 32 of the 58 observations - virtually all during 1921-1923 - the actual money stock is less than the desired money stock. While a shortage of money seems paradoxical during a hyperinflation, this does tally with anecdotal evidence given by Bresciani-Turroni, who notes that the Reichsbank could not keep up with the demand for banknotes. No less than 30 paper mills were engaged in producing paper for bank notes during 1923, and even so, the model given here suggests the demand for money could not be met. The substantial drop in real money balances therefore has *two* causes in this model : lower demand because of expected inflation, and the government's inability or unwillingness to produce enough banknotes.

5. Conclusions

This exercise is intended to make the following points :

1. The assumption of Rational Expectations is highly dubious in the German context. On the other hand, the assumption of simple adaptive expectations does not do credit to the German public's ability to catch on to trends.
2. The model presented here assumes smart adaptive expectations, which are not necessarily rational. The model fits the data satisfactorily and survives the usual misspecification tests quite well. In particular, little or no temporal structure remains in the disturbance term.
3. There is some evidence the Ultimatum of London (June 1921) and the Rathenau Murder (July 1922) caused increased pessimism among the German public. However, a formal test procedure is unable to reject the hypothesis that these events did not cause significantly increased inflation expectations.
4. There were considerable periods when the actual money real money stock was actually *less* than the desired money stock. This tallies with anecdotal evidence and supplies a second explanation for the observed drop in real money balances.

There are several questions which need further research. The "smart" adaptive expectations mechanism chosen here is a very plausible one, but it is certainly not the only conceivable choice. Alternative mechanisms certainly need to be explored. Evans & Yarrow[1981] suggest three alternative mechanisms in a continuous time context, of which the third corresponds to (5)-(6) with ρ=1. We might think of a Markov-type model in which the public switches between different mechanisms.

Second, is the Caganite demand schedule used here really all there is ? Although virtually all authors ignore non-monetary events, there were very definite events taking place outside the "monetary windtunnel" as well, the occupation of the Ruhr and the subsequent mass unemployment being just one example. Is there a way to fit the real sector into this model ?

Third, can we dismiss exchange rates as a source of information altogether ? Why do they consistently *lead* inflation in 1920-1922, while inflation catches up to the movements in the exchange rate druing the 1923 climax ? One explanation is that the German economy virtually became a dollar economy in 1923, so that the exchange rate and the Mark price index were the same series during that year. These considerations may not be very useful as a source of information, or they may be very useful : the model used here certainly ignores any information in exchange rates.

Finally, the role of the German government in the model appears somewhat

oblique. A good review of German public finances can be found in Witt[1983], and it is not for the squeamish. Surely these extraordinary fiscal policies must have played a key role in the Hyperinflation ? We might think of a wholly different money supply function to replace (7). There is definite feedback from inflation to the budget deficit, as real expenditures remained constant or even increased (during the 1923 Ruhr occupation), while real expenditures collapsed completely (see e.g. Bresciani-Turroni[1937]). Also, the German government used the Reichsbank as a more or less willing tool to convert these deficits into money : the percentage of the deficit financed by the Reichsbank increased to nearly 100% as the public became less and less interested in buying government bonds. This suggests a causal link :

inflation $\longrightarrow$ increased real deficit *and* less interest in government bonds $\longrightarrow$ rapid increase in money stock

However, this link appears to be highly nonlinear. Attempts to replace (7) by a mechanism as described above foundered on the high number of parameters necessary to fit this process satisfactorily. A more satifactory way to model this is urgently needed.

These questions ensure that the list of references given at the end of this paper will continue to grow, if not exponentially like the German price index, then at least at a healthy pace.

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Figure 1
Sequential estimates of gamma1

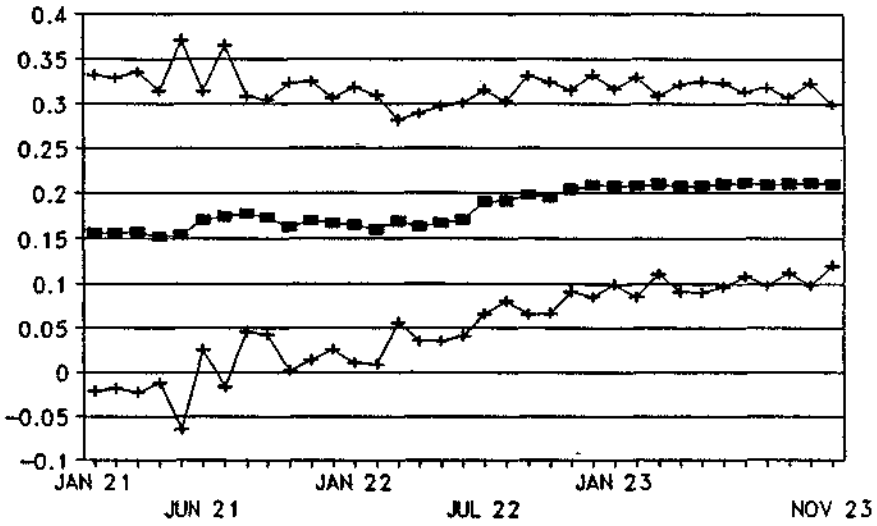

Figure 2
Sequential estimates of gamma2

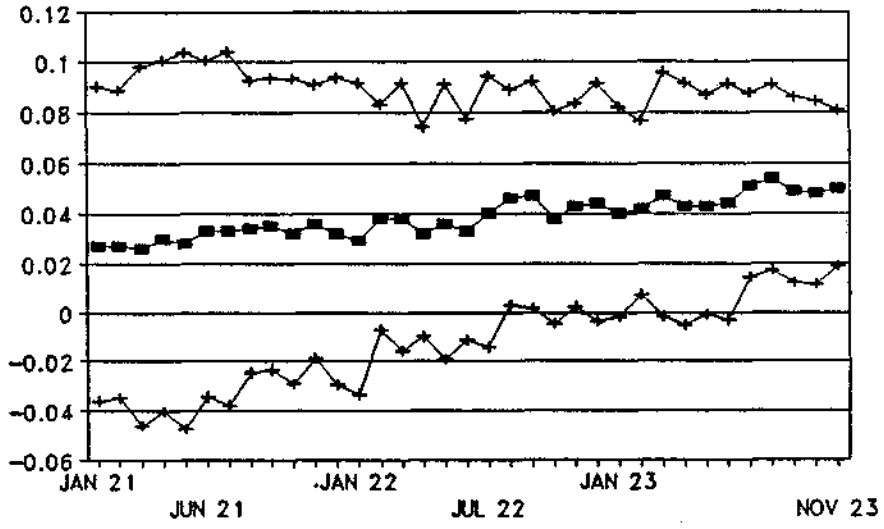

Figure 3

Sequential estimates of beta*