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Predicting the Signs of Forecast Errors

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Predicting the Signs of Forecast Errors

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Abstract: It is possible to predict the signs of forecast errors using the difference between individuals' forecasts and the average of earlier forecasts of the same variable. Two simple methods for deciding which forecasts are far from the lagged average give the same result. Every forecast which is far above the lagged average is too high and every forecast which is far below the lagged average is too low. by combining these methods, it is possible to improve 115 forecasts without worsening any. It is possible to reconcile such forecasts with rationality only with highly implausible assumptions.

I would like to thank Lavan Mahadeva and Tilman Ehrbeck for useful conversations. The usual caveat applies.

I Introduction

In this paper I attempt to determine whether apparent rejection of the rational expectations hyposthesis by analysis of survey data is the result of auxiliary assumptions about loss functions. In empirical work with survey data, it is generally assumed that survey participants have quadratic loss functions or at least that they report the mean of their subjective probability distribution(Pesando [1975], Carlson [1977], Pearce [1979] Figlewski and Wachtel [1981], Ito[1990], and Keane and Runkel [1990]). Without any assumptions about agents' aims it is possible to reconcile any behavior with full rationality, but a quadratic loss function seems restrictive. My results imply that it is possible to recommend revisions to forecasts which lower losses assuming only that losses are reduced if a forecast is changed slightly in the direction of the outcome.

The striking pattern noted in this paper is that whenever forecasts are very far from the average of older forecasts of the same variable, they are too far from this lagged average. That is forecasts far higher (lower) than the lagged average forecast are always higher (lower) than the outcome. This is true whether the lagged average forecast is the average of one month old forecasts or the average of two month old forecasts. This is true for two measures of "far" from the lagged average forecast -- far compared to the root mean forecast error of the lagged average forecast and far from the root mean squared difference of new forecasts from the lagged average.

Even the assumption that forecasters' losses are reduced when forecast errors are reduced is somewhat restrictive and some loss function would reconcile the data with the rational expectations hypothesis. For example, a similar result is rationalized by the assumption that agents wish to overstate their subjective confidence by under-utilizing publicly available information such as the lagged average forecast in Ehrbeck and Waldmann (1993).

Furthermore it is impossible to rule out peso problems -- survey participants' predictions may reflect rational expectations of the probability of rare extreme events which are not observed in the sample.

In my view the results presented here are striking evidence against the rational expectations hypothesis. They are also very difficult to reconcile with the view that forecasters or economic agents in general exhibit herd behavior, that is understate the difference between their opinion and the conventional wisdom. If anything the data support the view that agents overstate this difference if the lagged average is taken to represent the conventional wisdom.

This paper consists of five parts the first of which is this introduction. The second presents the data set. The third presents the main results. The fourth considers peso problems, and the fifth draws conclusions.

II Data

In this paper I use forecasts collected in Ehrbeck [1993] from Economic Forecasts: A Monthly worldwide survey. In this monthly newsletter, a panel of experts provide forecasts of key economic variables for industrialized countries. Forecasters, who are identified by name, predict the value of some economic variable several times for the same target period.

The prediction variable used for this work is the forecast of the annualized discount rate on new issues of 91-day US-Treasury Bills, based on weekly auction average rates. This variable has been chosen because the panel for the U.S. is the richest and because interest rate forecasts predict a quoted price which excludes some ambiguities that could arise when predicting national accounting data.

The panel of experts submits prediction of the interest rate on a monthly basis for the quarters of the calendar year. The forecast data have consequently been split in three, small homogeneous panels of first month, second month, and third month forecasts respectively. For the empirical test, only forecasts of those panel participants who reported at least 15 times over the sample period from January 1985 to June 1990 have been included. The cross-section dimension of the data is N=23. The times-series dimension is T=22. The average number of non-missing observations per participant is 18.

The realization data needed for the error calculations come from the Federal Reserve Bulletin. Quarterly discount rates are calculated as the simple average of the monthly data which, in turn, come from the average weekly auction rates already quoted on the annualized discount basis.

The same data are described in Ehrbeck(1993) and in Ehrbeck and Waldmann (1994).

Define r_t as the average interest rate yield on three month treasury bills in the secondary market in quarter t. Define f_{itj} as forecast of the ith forecaster of the average interest rate in the t'th quarter in the sample based on information available j months before the quarter ended. Define I_{itj} as an indicator variable which indicates non-missing f_{itj}. Define f_{tj} as the average of f_{itj} across forecasters. Note that my data include "forecasts" of the current quarter e.g. f_{it1} -- the forecast of r_t made by the i'th forecaster at the beginning of the third month of the same quarter. This might not seem a very challenging task as the interest rates for the first two months and for the first auction of the third month are already available when the forecast is made.

III Results

I use two extremely simple techniques to test the claim that whenever forecasts are much higher(lower) than the average of lagged forecasts they are higher(lower) than the outcome. The only unclear point in the informal description of my claim is the word "much," which I define in two ways. First I define much higher as significantly higher given the distribution of differences of individual forecasts from lagged average forecasts in previous quarters. Equation 1 defines σ^2_{atjk}

$$1)\quad \sigma^2_{atjk} = \sum_{s=1}^{t-B-1} [\{\sum_{i=1}^{23} I_{isj}(f_{isj} - f_{sk})^2\}/(\sum_{i=1}^{23} I_{isj})]/(t-B-1)$$

where B is the largest integer less than or equal to k/3. Note that σ^2_{atjk} is calculated with information available to all forecasters when the forecast is made. Now define T(t-1-B) as the (two tailed) 5% critical value for a t-statistic with t-1-B degrees of freedom. Given the fact that changes in forecasts contain a common component the use of one degree of freedom per quarter gives a cautious estimate of the confidence interval of "normal" changes in forecasts.

In my sample,

if $[(f_{itj} - f_{tk}) < -T(t-1-B)(\sigma_{atjk})$ then $f_{itj} < r_t$ and
if $[(f_{itj} - f_{tk}) > T(t-1-B)(\sigma_{atjk})$ then $f_{itj} > r_t$.

That is, if a forecast is more than T(t-1-B) standard deviations below the lagged average, then it is too low, and if a forecast is more than T(t-1-B) standard deviations above the lagged average, then it is too high[1].

This is true for all 23 forecasters (i) and for all 22 quarters (t) and for all j and k for which I performed the test. I performed the test for j from 1 to 6, that is, for forecasts of average interest rates in the current quarter and one quarter ahead. I performed the test using average forecasts lagged one, two, and three months, that is, for k = j + 1, for k = j+ 2, and for k = j+2. Using this technique it is possible to reduce 69 forecast errors without increasing any forecast errors. 32 forecasts are judged to be too high using at least one of the lagged averages, and all 32 are indeed higher than the outcome. 37 forecasts are judged to be too low, and all 37 are indeed lower than the outcome. Results are presented in table I.

In cases in which the sign is correctly predicted, the forecast can be improved by changing it by 1 basis point in the direction of the average of lagged forecasts. Since, forecasts and outcomes are recorded in basis points, correctly predicting the sign of a forecast error implies that it is possible to reduce the forecast error.

Needless to say, this approach to improving forecasts never fails because it rarely risks failure. For 1929 of 1998 forecasts the technique neither suggests increasing the forecast nor decreasing the forecast, so it does not risk worsening a forecast. Nonetheless, to improve 69 forecasts without worsening any is an unambiguous improvement. Forecasts are improved in 14 of 21 periods which could be used. Forecasts of

21 of 23 forecasters are improved. Only two forecasters provided forecasts which could not be improved upon using the technique and data available to the forecaster when the forecast was made.

Notice that this result implies that some forecasters have not chosen the forecasting rule which minimizes any function of forecast errors which is reduced as the forecast errors are reduced. For any such function, the modified rule in which forecasters calculate their forecasts then reduce forecasts by the smallest allowed change (0.01%) would give smaller losses. This is true even if the loss function is asymmetric and disturbances are heteroskedastic. This is even true if the loss function is time varying, and if each forecaster has a different loss function.

In the second technique for improving forecasts, the difference between a forecast and the lagged average is compared to the mean squared difference between previous average forecasts and the outcome. This approach has a certain appeal as it implies that I conclude that a forecast is too far from the lagged average if it is unlikely (5% chance) that the truth is that far or farther from the lagged average. The first technique had no such rational. Unfortunately, there is very little information on the mean squared difference between the lagged average forecast and the outcome. For this reason, it makes little sense to use a fixed multiple of the mean squared difference between the lagged average forecast and the outcome, unless one discards early periods[2] . It makes some sense to compare the forecast to the 95% interval for the outcome around the lagged average. To do this I calculate a t-like statistic.

More formally equation 2 defines σ^2_{btk} as

$$2)\ \sigma^2_{btk} = (\sum_{s=1}^{M} (r_s - f_{sk})^2))/(M)$$

Where M is t - 1 - L(k/3), where L(x) is the largest integer less than or equal to x. Note that σ^2_{btk} is calculated with information available when forecast f_{itj} is made so long as j<k.

The absolute difference between the average of forecasts made in December 1984 (the first forecasts in my sample) is 4.24 basis points. This would appear to be a case of beginners luck for Economic Forecasts: A Monthly Worldwide Survey, since over the whole sample the root mean squared error of the average forecasts made in the third month of the preceding quarter is 35.73 basis points. More importantly it far smaller than the absolute difference between the average of forecasts made in January 1985 which is 29.13 basis points. If taken literally, this one observation might convince an agent in the second quarter of 1985 that forecasts worsen with time. Alternatively, the agent might find this implausible and calculate the accuracy of lagged average forecasts using equation 3 which defines σ^2_{ctk}

$$3)\quad \sigma^2_{ctk} = \max(\sigma^2_{btk}, \sigma^2_{btk+1})$$

This is reasonable but chosen (by me) after I noticed that using formula 2 and σ^2_{btk}, many of my predictions of the signs of errors of forecasts of the average interest rate in the second quarter of 1985 made in March 1985 were incorrect.

Recall T(M) is the (two tailed) 5% critical value for a t-statistic with M degrees of freedom.

The second result is that

if $f_{itj} - f_{tk} > (\sigma_{ctk})(T(t-1-L(k/3)))$ then $f_{itj} > r_t$

and

if $f_{itj} - f_{tk} < -(\sigma_{ctk})(T(t-1-L(k/3)))$ then $f_{itj} < r_t$.

that is if one assumes that the outcome is equal to the lagged average forecast plus a disturbance which is a normally distributed innovation and one calculates a 95% interval (with skepticism when one datum suggests that average forecasts worsen with time) for the outcome based on the most recent lagged average forecast one can improve some forecasts without worsening any. In my sample, all 50 forecasts which are above that interval are above the outcome, and all 39 forecasts which are below that interval are below the outcome. This means that the technique improves 89 forecasts without worsening any.
Results are shown in table II.

If forecasts are compared with the confidence interval based on the average of twice lagged forecasts, then many fewer improvements are suggested. The confidence intervals based on the average of twice lagged forecasts are quite large and few forecasts are outside of it. Nonetheless all 15 forecasts which lie above the interval are higher than the outcome, and all 9 forecasts which are below the interval are lower than the outcome. The intervals based on the average of thrice lagged forecasts are still larger and the technique gives only 14 proposed improvements, nonetheless all improvements are correct. In particular 8 of 400 forecasts made in the third month of the quarter being forecast can be improved using data available when the quarter began. This is a small fraction, but remarkable, since "forecasts" of the quarterly average made when over two thirds of the interest rates in the quarterly average are available are corrected using information available before the quarter began. Results are shown in table II.

Some forecasts are corrected more than once, since they lie above or below the intervals based on different lagged average forecasts. This means that a total of 94 out of 1998 forecasts are changed, all in the correct direction.

Predictions of the quarterly average interest rate in 18 of the 21 possible quarters are corrected. The only clear pattern in the corrections, is that few corrections are made in early periods. For early periods, the estimate of the root mean squared forecast errors of lagged average forecasts is imprecise, that is, the t-distribution has few degrees of freedom giving a large confidence interval. No forecasts of the average interest rates in the second and third quarters of 1985 are corrected. These are the first two quarters for which corrections are made, so estimates of the mean squared error of the lagged average are based on one and two data points respectively. Aside from that, for every quarter except the second quarter of 1988, some prediction is corrected. For 15 quarters there is a prediction above the confidence interval and for 14 quarters there is a prediction below the confidence interval, so for 11 of 21 quarters some forecasters make forecasts which are detectably too high and others make forecasts which are detectably to low.

Only two of 23 forecasters make no detectable errors. 13

of 23 forecasters make detectable errors of both signs. The perfect record of 94 forecasts improved of 94 changed is not based on extraordinarily poor performance of a few forecasters nor is it based on a few strange periods.

It is possible to combine the two techniques. Combined the two approaches have six chances to improve each forecast, since each is used with three different lagged averages. With this approach a total of 115 forecasts are improved and none is worsened.

Forecasts of interest rates in all but the first two quarters are improved. For 12 of 21 quarterly interest rates forecasted, some forecasts are detected to be too high and some are detected to be too low. All but one forecaster makes a detectable misstake. This forecaster provided only 10 forecasts in the 3rd month of quarters (which forecasts are most likely to be improved) and only 16 of 21 possible forecasts in the first and second months of quarters. The perfect record of the combined approach to improving forecasts is clearly not based on poor performance of a few forecasters or unusual behavior of the interest rate in a few periods.

The two techniques separately and in combination imply small corrections to a small fraction of forecasts. These corrrections lower forecasts errors and do not increase any forecast errors.

IV A Peso Problem ?

In section III it is demonstrated that the forecasts in my sample do not minimize any function of forecast errors which is increased as forecast errors move away from zero. It is not, of course, demonstrated that the forecasts do not minimize the conditional expected value of such a loss function. This is clearly impossible as any finite set of forecasts can minimize the expected value of some loss function for disturbances with some distribution. To test the rational expectations hypothesis it is necessary to impose some restrictions on the loss function, the (conditional) distribution of disturbances or both. In this case, with multiple forecasts of the same variable and a panel of forecasters, it is also important to consider the private information forecasters receive in addition to the lagged average forecast.

With strong assumptions about the structure of information and disturbances, it is possible to reject fairly general classes of loss functions. For example, if the difference between the outcome and the expected value conditional on each forecaster's information is an iid random variable (independent across forecasters) then the chance that a forecast is too high is a constant. This constant can vary by forecaster (and without the strong iid assumption by period). This combination of weak assumptions about the loss function and extremely strong assumptions about disturbances is overwehelmingly rejected. The third month forecasts of one forecaster are suffucient to reject the null at the 5% level (results not shown).

In general, however, it is not possible to reject the null hypothesis that forecasters are minimizing the expected value of a given loss function, even if it is assumed that all minimize the expected value of the same time invariant function of forecast errors. The reason is the well known peso problem; rare events can have arbitrarily large effects on expected losses. If the derivative of the loss function is unbounded two events which occur with time varying probabilities, which are known to the forecasters, can cause the expected loss minimizing forecast to take arbitrary values. This is true if the probabilities of the rare events are bounded above by an arbitrarily low positive number. This in turn implies that an arbitrarily large data set in which extreme events are not observed, can not rule out such a possibility.

I will consider only loss functions with bounded derivatives, which implies that rare events can not make the loss minimizing forecast take arbitrary values. In fact, the only loss function which I will consider explicitely is the absolute value of the forecast error, which has a derivative with constant absolute value. The reason I focus on this loss function is that even this case suggests that my results could, in theory, be caused by a peso problem.

Consider the following very simple model. y is a random variable which takes 3 values -1, 0 and 1 as follows.

$$3)\ y \sim \begin{array}{rl} -1 & \text{with probability } p_l \\ 0 & \text{with probability } 1-p_l - p_h \\ 1 & \text{with probability } p_h \end{array}$$

with $p_h + p_l < 1/2$.

There are a number of forecasters who attempt to forecast y on two occasions. In the first period, they have no information and use the unconditional expected value. Then the outcome is determined but not revealed. Instead, in the second period the forecasters observe one of three signals. s_h, s_l and s_0 distributed as follows. If y will equal 1 the forecasters observe s_h. If y will equal -1, the forecasters observe s_l. If y will equal 0, then each forecaster independently observes s_h with probability slightly less than $p_h/(1-p_h-p_l)$, observes s_l with probability slightly less than $p_l/(1-p_h-p_l)$ and otherwise observes s_0. In this case the signals are independent and the forecasters do not communicate. Given the assumptions, forecasters predict 1, if they observe s_h, -1 if they observe s_l and 0 if they observe s_0.

In the cases of forecasts of 1 and -1 a slight change in the forecast has no effect on the expected loss.

However, if p_h and p_l are low, the probability that only y = 0 is observed in a given sample can be high. In this case all forecasts far (approximately 1) above the lagged average forecast are too high and all forecasts far below the lagged average forecast are too low. This is the qualitative pattern found in my data set.

However if p_h and p_l are low then the probability that forecasters will observe s_h or s_l are low as well. The probability P of observing y = 0 and a of N forecasters forecasting 1 and b forecasters forecasting -1 is given by equation 4)

$$4)\ P = (1-p_h - p_l)p_h^a p_l^b (1-p_h-p_l)^{(N-a-b)}\ N!/(a!b!(N-a-b)!)$$

Where the first term is the probability that y = 0 and the other terms are the probability of observing a forecasters who predict 1 and b forecasters who predict -1.

If the model is repeated, and it is assumed that y is iid, then it is possible to assign a probability to the results reported in tables 1 and 2. Given the choice to focus only on signs the assumption that y is constant in the absence of rare events is not restrictive. The assumptions of constant p_h and p_l and of independent signals are highly restrictive.

It is possible to test a slightly less trivial model using the number of forecasters whose forecasts are corrected up and those whose forecasts are corrected down. The argument above is not changed if, rather than y = 0 with probability $1-p_h - p_l$, y is distributed with support $-\Theta$ to Θ, and if rather than y = 1 with probability p_h y, is distributed with support $> \Theta$ and if rather than y = -1 with probability p_l, y is distributed with support $< -\Theta$ with probability p_l. Further assume that if $|y| > \Theta$, the forecaster gets a signal which indicates y exactly. The arguments above can be repeated to show that in a data set of T periods with any number of forecasters with probability $(1-p_h-p_l)^T$ all forecasts more than Θ above the lagged average are above the outcome and all forecasts more than Θ below the lagged average are below the outcome. For low p_h and p_l the qualitative results reported in tables 1 and 2 are consistent with this model.

To test this model with the data as summarized in tables 1 and 2, it is necessary to calculate how likely is it that so many forecasts would be improved if p_h and p_l are low. A simple test is a test on the number of forecasts improved given that none are worsened. The test rejects at the α level if inequality 5 holds where T is the number of periods of data and N is the number of forecasts (N would be nT where n is the number of forecasters if no forecasts were missing), p is $p_h + p_l$, and M is the number of improved forecasts.

$$5)\ \max_{p}\ (1-p)^T\sum_{i=M}^{N}\left[(p)^i(1-p)^{(NT-i)}\ N!/((N-M)!M!)\right] \leq \alpha$$

For large M and N the left hand side of equation 5 is approximately equal to the left hand side of inequality 6

$$6)\ \max_{p}\ (1-p)^T\ \Phi((M-pN)(pN(1-p))^{-0.5}) \leq \alpha$$

where Φ is a standard cumulative normal.

When implementing this test it is possible to combine different techniques for deciding which forecasts are to be corrected, but not to combine forecasts made a different number of months before the outcome is realized. Recall that the test tests a very particular loss function -- absolute forecast errors. Assumptions about information and disturbances are also specific. I suspect but have not proven that these assumptions minimize the chance of rejecting the null of rationality and the absolute error loss function. To implement the test it is necessary to find optimal p. I optimized to the nearest 0.0001. The results of the test are reported in table III. The null is rejected at the 5% level only for third month forecasts.

The weak rejection of this specific null suggests that a more general null will not be rejected. If the derivative of the loss function is not constant, the power of tests of this type can be much reduced. If the maximum ratio of the absolute value of the derivative at different points is A then the term (1-p) in equations 4 and 5 must be replaced with (1-p/(1+A)) reducing the power of the test. Furthermore, the assumption of constant p_h and p_l increases the power of the test. The test loses still more power when p_h and p_l are chosen as functions of time to minimize the power of the test. That is p_h is set to zero in periods in which no forecasts are far above the lagged average.

This excercise illustrates the well known point that it is not possible to reject the null that forecasts minimize the expected value of some function of forecast errors without putting restrictions on the loss function and on the distribution of the variable being forecasted and on forecasters private information. In the case of my very small data set strong restrictions are required.

IV Conclusions

The forecasts of quarterly average 91 day t-bill yields in Economic Forecasts: A Monthly Worldwide Survey contain predictable errors. Using two simple natural definitions of "far", I find that all Foreecasts which are far above the average of one month lagged forecasts are too high and that all forecasts which are far below the average of one month forecasts are too low. This means that it is possible to reduce losses using only lagged information for any loss function which increases if forecasts are further from the truth.

It is not possible to rule out a peso problem -- the forecasts could have been made considering the possibility of a rare extreme event which did not occur during the sample period. If all (or very many) forecasters anticipate the rare event, the approaches which always improve forecasts in my sample would worsen all (or very many) forecasts in one period. This implies that even very specific loss functions are rejected with only modest confidence. It is necessary not only that extreme events which did not occur in sample might occur but also that all (or very many) forecasters anticipate such events. I find the idea that there are such extreme and widely anticipated events implausible. Extreme events occur, but are generally not universally (or very widely) anticipated.

I find the perfect record of simple techniques to predict the sign of forecast errors to be very striking evidence against the rational expectations hypothesis.

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End Notes

1) first I used an arbitrary cutoff point of 2 standard errors. Using third month current quarter forecasts and the average of second month current quarter forecasts this gives no incorrect predictions of the sign of the forecast error. Then I proceeded to method 2 as described. When I performed method 1 with other lags, I continued to use the 5% critical value of the t-statistic).

2) In my first implementation of the second method I considered forcasts two standard errors from the lagged average to be far from the lagged average and dropping an arbitrary number of periods (three) a priori. There were 0 incorrect "improvements."

Table I

Forecast	using avg lag	No.	changed	increased	reduced	improved
3rd month same quarter	1	400	12	5	7	12
	2	400	5	0	5	5
	3	400	5	2	3	5
	all	400	14	6	8	14
2nd month same quarter	1	413	11	3	8	11
	2	413	8	5	3	8
	3	391	6	4	2	6
	all	413	16	8	8	16
1st month same quarter	1	410	16	14	2	16
	2	390	9	7	2	9
	3	390	2	0	2	2
	all	410	19	17	2	19
3rd month prev. quarter	1	384	8	3	5	8
	2	384	3	1	2	3
	all	384	9	3	6	9
2nd month prev. quarter	1	391	11	3	8	11

forecasts reduced (increased) 0.01% if (forecast - lagged average) > (<) 5% critical level of a t-statistic with M degrees of freedom times the root mean squared difference forecast - lagged average in previous quarters. Forecasts improved if closer to outcome.

Table II

Forecast	using avg lag	No.	changed	increased	reduced	improved
3rd month same quarter	1	400	49	18	31	49
	2	400	10	1	9	10
	3	400	8	3	5	8
	all	400	51	19	32	51
2nd month same quarter	1	413	20	6	14	20
	2	413	8	5	3	8
	3	391	4	2	2	4
	all	413	23	9	14	23
1st month same quarter	1	410	13	11	2	13
	2	390	4	2	2	4
	3	390	2	0	2	2
	all	410	13	11	2	13
3rd month prev. quarter	1	384	3	1	2	3
	2	384	2	1	1	2
	all	384	3	1	2	3
2nd month prev. quarter	1	391	4	3	1	4

(M+1)th Forecast reduced (increased) if
forecast - lagged average > (<) 5% critical level of a
t-statistic with M degrees of freedom times the root mean
squared value of quarterly average 91 day t-bill yield -
lagged average forecast based on the M previous quarters.

Table III

Forecast	#	# improved[1]	p[2]	significance[3]
3rd month same quarter	400	51	0.139	0.032
2nd month same quarter	413	25	0.072	0.170
1st month same quarter	410	19	0.058	0.241
3rd month prev quarter	384	9	0.034	0.422
2nd month prev quarter	391	11	0.039	0.376

1) Number improved with either method using any of up to three lagged averages.
2) probability of an extreme event which maximizes probability of so many improvements of forecasts with no worsening of a forecast
3) probability that at least this many forecasts are improved and none is worsened given p.

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