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Are Investment Expectations Rational?

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Abstract

There is much debate over whether agents form rational expectations of variables or whether, they suffer from systematic errors in judgment. This paper estimates models for plant-level survey data in order to test rationality for those manufacturing plants that report expectations of capital expenditures. An advantage of using such data is that rationality is tested in markets where agents may not have knowledge of each others' expectations so strategic motives behind purposefully irrational forecasts are minimized. Statistical estimates and test results suggest that expectations may indeed be rational depending on size. That is, the larger a plant, the more resources it can expend on forecasting its' future needs. Thus, the statistical results in this paper validate, for the first time, a class of assumptions in the macroeconomic literature.

Keywords: Rational expectations, Adaptive expectations, Dynamic panel estimation

JEL: D21, D84, C51

1. Introduction

Rational expectations as a solution method for dynamic stochastic general equilibrium models is a frequently contested behavioural assumption of modern macroeconomics[1]. As both a solution method and fundamental opinion of the model builder, the rational expectations hypothesis (REH) is also a difficult assumption to evaluate econometrically. To this end researchers have looked to publicly available data from financial markets to test not only the validity of the REH[2], but also to investigate whether forecast biases may be rationalized by appeals to theories of strategic interactions, or the psychological evidence on cognitive biases[3]. As expected, it is hard to draw definitive conclusions as to whether forecast biases exist, and if their significance is such that modern policy models that rely on the REH are to be fundamentally challenged. Keane and Runkle (1998) have found strong evidence supporting the REH as applied to professional earnings per share forecasters, and they cite previous literature that had suggested otherwise (e.g. Abarbanell (1991), Abarbanell and Bernard (1992) and DeBondt and Thaler (1985)).

In financial markets it seems reasonable to assume that agents do follow the dictates of rational expectations in that they do not make predictable forecast errors without due cause. Public observability of the decisions of market participants such as professional forecasters can further induce a lack of observed forecastable errors. However, it is difficult to imagine the same pressures bearing on agents in industries that do not necessarily sell forecasts in a competitive market, but still produce expectations for internal management purposes. Given the econometric literature on testing financial market forecast rationality, it would be prudent to investigate whether or not participants in 'real-side' activities make systematic expectational errors; this paper conducts such an investigation for plants falling within the Canadian Total Manufacturing sector.

Theories of expectations formation have been at the heart of macroeconomic literature for almost as long as the field has been attempting to generate business cycles in stochastic environments. Assuming that expectations formation assumptions are testable hypotheses, there have been several extensive empirical analyses employing both aggregate time series and panel data. It is important to specify what is exactly meant by the REH since it plays different roles in the solution of dynamic stochastic economic models. The majority of the literature tests the REH in the form of *forecast rationality* as distinct from the implicit Bayesian updating procedure that generates such behaviour. In particular, a large literature in behavioural finance[4] had noted that financial analysts' may over (under) react to information in a pattern inconsistent with the predictions of the REH. Such results were largely based on least squares regressions of forecasts on realizations of a variety of variables. However, these studies had neglected to model the information sets of professional forecasters implying that the least squares techniques were biased towards rejecting the REH or falsely accepting it. Keane and Runkle (1990, 1998) recognized the nature of the cross-correlations inherent in forecast errors arising from plausible

1. See Lovell (1986) and Keane and Runkle (1990) for a review of the arguments and issues in this literature.
2 . Here the REH is taken to mean forecast rationality following Muth (1961).
3. See Ehrbeck and Waldmann (1996) for a discussion on agency versus behavioural explanations for forecast biases in financial markets.
4. An analysis and a review of the behavioural heuristics that may be at work in financial markets is provided by Barberis et. al. (1998).

assumptions on the information shared by forecasters, the timeline of the data and other data properties. Using generalized method of moments techniques Keane and Runkle (1990, 1998) incorporated these data properties and then tested the REH, with the not so surprising result that forecast rationality held.

In a recent analysis, Bonham and Cohen (2001) further investigate the econometric foundations of the tests conducted by Keane and Runkle (1990). In particular their concern is the extent to which pooled estimation procedures (with appropriately defined covariance structures) are applicable in testing rationality in the professional forecaster data. They argue that *microhomogeneity* as defined by Zellner (1962) is an important consideration in testing rationality, especially given the integrated nature of the aggregate time series being forecasted in the Survey of Professional Forecasters. Their test results indicate that microhomogeneity is not necessarily tenable and they conclude,

> Since individual rational expectations imply microhomogeneity in the panel, rejection of microhomogeneity implies some degree of bias in panel forecasts.

Further, tests on individual forecasters indicate rejection of rationality across a wide spectrum of specifications. Therefore even the results of Keane and Runkle (1998) are suspect given that tests of the microhomogeneity are not provided. It is important to note that this entire line of work, from Zarnowitz (1985) to Bonham and Cohen (2001), is based on testing the rationality of agents who together forecast the same *public* variable. The panel data employed in this paper are fundamentally different from those employed in such studies in that they are for agents who report expectations of *private* variables. Also, whereas these and other financial market studies concentrated on agents whose forecasts and realizations were clearly observable to one another, the data collected on manufacturing plants in this paper are not of that form. Therefore cross-correlations in forecast errors implied by what each forecaster knows about another are not necessarily relevant for the data used below which provides some justification for the use of standard econometric techniques. However, these expectations are 'real' in the sense that the agent has an economic incentive to form and report them. The data are for manufacturing plants from the Capital Expenditures Survey (Actual and Forecast)[5] that requests information businesses already have on hand for internal decision making processes. Therefore the derivation of the relevant estimating equations is different from that currently present in the literature. In particular these data are not 'off the cuff' forecasts, but well thought out business plans which is the object modeled by the REH. In the remainder of this section the relevance of manufacturers' expectations is defended on investment and outline the main econometric issue that provides an ideal test of rationality, adaptive expectations or any other expectations formation mapping.[6]

5. This survey is conducted by the Investment and Capital Stock Division of Statistics Canada in order to produce aggregate time series such as investment and capital stocks.
6. In the reduced form analyses that follow it is important to note that a weak test of the REH is conducted as it is without a structural model.

1.1 The Relevance of Manufacturing Expectations

The REH as a behavioural assumption has been vigorously defended by the learning literature as both a 'reasonable' method via which to choose between multiple equilibria, and the limiting behaviour of agents who learn[7]. As such, aggregate models that do not assume the REH in some form or the other are rare in modern macroeconomics. It seems that alternate expectational assumptions that have been put forth in the Behavioural Economics literature[8] have not been incorporated into standard models. Much of that lack of attention is a consequence of the surprisingly robust aggregate empirical results such as those of Kydland and Prescott (1982) and the difficulty in formalizing psychological precepts for use in economic models. However, if it is possible to reject rationality in panel data on manufacturing plants, who comprise a larger class of economic agents than professional forecasters, then there is strong empirical support for reformulating the fundamental assumptions of macroeconomic models The relevance of manufacturing expectations is therefore clear: the data are for agents who have incentive to form and report non-qualitative response expectations, the data are drawn from a much larger class of agents than professionals who sell forecasts, and manufacturing plants are often the central modeling objects of modern business cycle theories.

1.2 Econometric Issues Related to Manufacturing Data

Given the relevance of manufacturers' expectations of capital expenditures, the exact nature of the survey data guides the extent to which rationality may be tested. The main econometric issues relate to the extent to which estimates of 'reduced form' equations that relate expectations to realizations may be considered useful in testing rationality.

Presumably, capital expenditures are incurred in order to achieve some optimal level of capital stocks, given adjustment costs. In formulating say, a partial adjustment model of capital stock, a test of rationality becomes a joint test of the economic model as well as the expectations formation mechanism. The data are annual and so did not exhibit large jumps in capital expenditures vis-a-vis output at the plant level therefore a threshold switching model implied by fixed costs of adjustment is not relevant [9]. However, capital stock data were not available at the plant level further complicating the extent to which rationality may be tested[10]. In studies that examined financial market forecast rationality, this tension between whether the expectations formation assumption is being tested or the economic model was not a consideration. In the data used in this paper this tension is also irrelevant even given partial adjustment for two main

7. See Lucas (1986) for a particularly strong defence of rationality in economic models.

8. See Rabin (1998) for a survey and Thaler (2000) for an opinion on alternate expectations formation assumptions arising from behavioural economics.

9. Whereas one can imagine such threshold effects as examined by Hamermesh (1989, 1992) holding in high frequency micro data on capital expenditures, the data used in this paper are not of that form. Plots for each plant across time of shipments and realized capital expenditures showed that capital expenditures fluctuated with output. Were the level of such expenditures relatively constant across time except in episodes of large changes in shipments, threshold effects of capital expenditure plans changes would be relevant. Presumably such threshold effects are of relevance in high frequency micro data, but since the data used in these paper are annual and an aggregate across investment projects for each plant, and are abstracted away from threshold considerations.

10. Capital stock estimates could be computed at the plant level given plant data on initial book value of physical assets, however the surveys considered in this paper do not record such information.

reasons. First, a defense of the reduced form analysis conducted on manufacturing panel data is the literal interpretation of the following statement by Lovell (1986),

> 'My own view is that the appropriate realm for empirical research should not be demarcated in terms of the dichotomy between assumptions and predictions-I think that direct testing of the rational expectations hypothesis is an appropriate and worthwhile activity. In order to be able to claim that a theory is based on firm micro foundations requires more than the derivation of propositions from the assumption that economic agents maximize, however esthetically pleasing such derivations may be; a theory that is said to be based on micro foundations should survive empirical testing at the level of the individual decision making unit. To the extent that the survey evidence supports the hypothesis of rational expectations, results derived under that assumption, policy impossibility theorems, and so forth, will be more interesting and more demanding of serious attention.'

Second, there is the very relevant issue of econometric identification. To put it simply, if the true data generating process is being driven by say partial adjustment, then clearly capital expenditures will reflect that fact, however, reported expectations will not since one step ahead expectations of investment will not be related to the level of expenditures in the previous period. Investment is used in dynamic factor demand models to catch up to the desired level of capital stock, in an uncertain environment firms will form expectations for future levels of investment. Any dynamic factor demand analysis will show that investment expectations will be economically unrelated to past investment expectations, therefore the coefficients of regressions of expectations on realizations and past expectations will not be contaminated by economic effects and will be pure informational responses.

Given this motivation for testing the REH outside of financial markets, this paper provides econometric evidence in Section 4 after having discussed the plant level data and their properties in Section 2 and the models in Section 3. Section 5 concludes and summarizes the main results of the analysis conducted in this paper: standard equations that have been estimated in this literature indicate that rationality cannot be inferred. However, accounting for the size variation in the data that makes an error by a small plant fundamentally different from that of a large plant leads to the clear acceptance of rationality and a clear rejection of adaptive expectations.

2. The Data

The Investment and Capital Stock Division of Statistics Canada is responsible for the production of industrial and economy-wide aggregate statistics on physical capital stocks, investment, capacity utilization and associated price indices. For this purpose the division surveys businesses in all industrial categories on actual capital expenditures and expectations; the survey is termed the Capital Expenditures Survey (CES). The focus in this paper is on the manufacturing classification and as a result only records matching this industry were chosen for analysis.

As part of its mandate, the Manufacturing, Construction and Energy Division of Statistics Canada is responsible for the production of industrial and economy-wide aggregate statistics on all other input expenditures other than capital. Once again, only records falling within the total manufacturing category were chosen for analysis. The relevant survey, termed the Annual Survey of Manufactures (ASM), provides data on input expenditures and shipments for businesses among other variables.

This section describes the sampling methods employed by the surveys, the variables collected for analysis, how the data were cleaned and finally the results of matching the surveys across time; the objective was to obtain a panel that tracked *manufacturing plants in operation* over time.

2.1 Sampling Methods and Survey Timing

The CES has distinct phases for each yearly sample. First is the 'Actual Survey' that requests information on capital and repair (including maintenance costs) expenditures on construction and machinery and equipment for the fiscal year ended. The next phase is the 'Preliminary Survey' that requests the same information as the Actual Survey except that it also has an expectation component; that is, businesses are asked to report their expectations for capital expenditures for the upcoming year. The timing of the phases is important in that it will reflect what sort of information businesses have when making their expectations. Figure 1 in the Appendix presents the stages of the CES and as can be seen by the timing represented, there is some overlap between the two phases. However, by the time businesses report expectations for the upcoming period, their fiscal year is well over, implying that the two phases are rough approximations to one step ahead expectations.

For the available data, for every calendar year, samples of businesses are drawn from a stratified concept of a population which represents the universe for inclusion in the CES and ASM. Each survey draws a sample (based on industries and geographic regions) independently based on the income statement variable of gross business income. The ASM is conducted once a year and requests information on input expenditures and output shipments for the fiscal year just ended. In addition this general sampling method relies on certain identifiers that correspond to different concepts of a measurement unit. The ASM uses an identifier termed the Record Serial Number (RSN), and the CES uses the Universal Identifier (UID). The RSN is a finer identifier in that it considers industries[11] and a finer level of geographic classification, in contrast the UID is broader. Consequently, several RSN's match to a single UID and since the only identifier that was available across surveys was the UID, it was the one used to match the cross sections across time.

An important consideration in the panel data creation is temporal constancy of the sampling methods. The CES samples were generally static (except for occasional correction for births and deaths) until 1992, they became dynamic with heavy rotation of businesses in later years. This was witnessed by dramatic decreases in match rates starting in 1993, and since the loss of units was not due to business failure but a change in the nature of the survey methods (both in terms of sampling and the concept of an observational unit), the panel was created having cleaned the cross sections using categorical variables from both surveys for the years 1986-1992.

11. Please note that the exact classification system was not specified (the 1970 or 1980 Standard Industrial Classification (SIC) or North American Classification System (NAICS)) as those systems varied throughout the years considered.

2.2 Cleaning the Data

The CES provided data on new purchases of capital machinery and repairs expenditures (y_{it}) and expected purchases of capital machinery and repairs expenditures (y_{it}^{e}) for $j \in J$ plants. Construction expenditures were not considered since what was required was a variable on which one step ahead expectations are reasonable. Given the lumpy nature of aggregate construction investment, construction capital expenditures would not fit that category all that well. The CES also provided categorical variables which were used to clean the data. These categorical variables pertained to whether the unit was deemed to be in business or not, if it had been amalgamated into another identifier etc. In effect units that matched the concept of a manufacturing plant were kept as long as they remained operational as defined by Statistics Canada. The ASM provided data on the value of manufacturing shipments (Z_{it}), an output measure used to compute gross domestic product at factor cost, and categorical variables used to adhere as closely as possible to the concept of a manufacturing establishment or plant. In summary three variables (in addition to categorical variables) were taken from the CES, and one from the ASM once the cleaning was completed. Further, tabulation of the number of units falling under various two digit industry classes indicated that these categories were well represented.

2.3 The Survey Question and Data Properties

It is important to note the exact question units are answering when responding to the surveys. In the Actual CES they are asked to report their expenditures on new capital machinery and repairs (financial statement variables), in the expectations phase they are asked to, "...report the [capital expenditures on new machinery and repairs] expected to be put in place during the year."

The data exhibited significant size variation which may very well reflect varied resources devoted to expectations formation activities, therefore rationality is conditional on whether a plant had the resources to forecast budgets properly. More problematic was that the data are rounded to the thousandth dollar, that is, values below a thousand are recorded as zero, therefore the distribution of the variable is censored at one thousand. There were also plants who reported zero expectations and positive realizations and vice-versa throughout the time period[12], and the identity of the plants changed from year to year; these plants could not be distinguished from those who may be reporting zero values due to the censoring of variables and were therefore dropped.

2.4 Are Sample Correlations Enough?

The sample correlations between variables considered would at first pass indicate strong reasons for assuming that rationality is predominant in the plant and industry panels. For example the

12. The number of plants exhibiting such behaviour was quite small in each cross section. Further, these plants were located towards the tails of the distribution of Z_{it}. Therefore their inclusion or exc lusion did not change regression estimates significantly. This problem was further compounded by the fact that in some years small units do not report due to response burden yet remain active. Whereas the number of such units is relatively small it cannot be discerned whether the data were truly zero-valued or suffered from censoring or response burden issues.

overall correlation between realized and expected values of capital expenditures in the Plant Panel is approximately 0.92. This high correlation signals a strong linear relationship that is confirmed by Figure 2 which plots expectations vs. realizations for each cross section as well as the 45 degree line. At this point the case for rationality seems to be very strong especially as the computed expectational error ($e_{it} = y_{it}^{e} - y_{it}$) seems to be centered on zero and dispersed uniformly through zero as see in Figure 3. There are however two items of interest, the first is that Figure 2 indicates some shift in the relationship in each period, that is, an individual invariant time specific effect might be required. Second, as witnessed by Figure 2 and 3, there is a relatively high density of individuals towards the lower end of the distribution. This possible size effect might also influence regression results for which reasons the lower end of the distribution was examined for any qualitatively different characteristics. There was no real qualitative difference in behaviour between the low and higher ends of the distribution except that there was more dispersion around the 45 degree line at the lower end. Given that the panel is formed of plants that have been in operation for a relatively long period of time, this dispersion may simply be due to the possibility that fewer resources are expended on expectations formation activities by smaller units. Therefore, it does seem apparent that rationality may hold conditional on size variation.

However, the correlation matrix indicates that the expectations are correlated with past realizations and the computed expectational errors, a fact deserving of attention since the afore-mentioned correlations need not imply causality. In addition the variation in the data are high as witnessed visually and by the summary statistics reported in Table 1 (data are in thousands of dollars). Therefore it is of importance whether or not regression estimates provide confirmation of the correlations reported in Table 2. This confirmation would follow since the REH derives from suppositions on those very correlations, conditional on data properties.

3. Testing Expectation Formation Mechanisms

In this section some basic tests of various expectations formation mechanisms are provided from regressions of expectations of capital expenditures on realized values. In order to be historically consistent, tests of the AEH are provided first followed by tests of the REH and a general Expectations Efficiency Hypothesis (EEH).

All standard theories of expectations formation postulate some mapping between expectations, realizations and information sets. In a panel context where they may be unobserved individual and/or time specific variation, this relationship is a conditional one, that is, conditional on unobserved variation various theories specify (differing) mappings between expectations, realizations and information sets. Further, given that individuals in any cross section are dispersed as per some unknown rule, it may well be of relevance to condition on heteroscedasticity that stems on behaviour unrelated to expectations formation. Therefore, under these considerations and assuming a degree of linearity, all standard theories may be written in the following form,

$$y_{it}^{e} = a + f(b(L)y_{it}, d(L)\Omega_{it}; q) + u_i + l_t + x_{it} \tag{1}$$

where y_{it}^{e} denotes the expectation of a random variable y (in our case investment) at time t-1 for time t, y_{it} denotes the realization, Ω_{it} denotes the information set, (u_i, l_t) are the unobserved individual and time variation respectively and x_{it} is the regression error. The only assumption common to all of the theories is the regression error be unsystematic, the definition of which is left to the econometric specification.

3.1 The Adaptive Expectations Hypothesis

The general theory of extrapolative expectations provides the following specification for $f(\bullet)$,

$$f(\bullet) = \sum_{j=0}^{\infty} w_j y_{it-1-j} \qquad (2)$$

The theory of Adaptive Expectations as stated by Keynes (1936) and interpreted by Hicks (1939) adds the following to (2),

$$w_j = b(1-b)^j, \qquad b \in [0,1] \qquad (3)$$

In which case,

$$y_{it}{}^e - y_{it-1}{}^e = b(y_{it-1} - y_{it-1}{}^e) \qquad (4)$$

The model in (4) is a restricted specification, and therefore the unrestricted version is estimated and the restriction tested. To do so, we can rewrite (4) in the panel context as follows,

$$y_{it}{}^e = a + b_1 y_{it-1}{}^e + b_2 y_{it-1} + u_i + l_t + x_{it} \qquad (5)$$

with the test for Adaptive Expectations being whether the following restriction holds,

$$H_0: \quad b_1 + b_2 = 1 \qquad (6)$$

Next, the nature of the unobserved variation and regression error needs to be specified. Time specific variation can be incorporated by the use of time dummies, and given the many facets of capital expenditure decisions it is assumed that u_i is distributed i.i.d with mean zero and finite variance. If the adaptive expectations mapping is correct then the regression error should also follow a zero mean finite variance i.i.d process, further it is assume d that the joint expectation of the regression error and unobserved individual effect is zero and that the unobserved individual effect is correlated with the right hand side variates, so that the random effect could have some relation with last periods capital expenditure. Finally, under the assumption that the adaptive mechanism holds it should be the case that the joint expectations of the regression error with y_{it-1} is always zero.

3.2 The Rational Expectations Hypothesis and Expections Efficiency Hypothesis

Rational expectations in the sense of Muth (1961) has lead to two methods prevalent in macroeconomic model building. The first, termed the REH, replaces one step ahead expectations of variables with realizations and an error. The second, termed the EEH, treats expectational errors as being orthogonal to past information; the two hypotheses are clearly related and therefore two tests of rationality are provided. The first test is the standard in the literature where the Muth (1961) condition is directly estimated and tested to hold or not. The second test postulates a dynamic model of computed expectational errors and tests for any persistence.

3.2.1 The Rational Expectations Hypothesis

The theory of Rational Expectations as stated by Muth (1961) entails specifying $f(\bullet)$ as,

$$f(\bullet) = E(y_{it} \mid \Omega_{it-1}) \tag{7}$$

which translates into the following linear panel model,

$$y_{it}^{e} = a + b_1 y_{it-1}^{e} + b_2 y_{it} + b_3 y_{it-1} + b_4 Z_{it-1} + u_i + l_t + x_{it} \tag{8}$$

The test for fully rational expectations (Lovell (1986)) is,

$$H_0: \quad b_1 = b_3 = b_4 = 0 \quad \cap \quad b_2 = 1 \tag{9}$$

As in the adaptive case, if expectations are rational and unobserved individual variation is random then the regression errors are i.i.d and the joint expectation of the error with the right hand side variates is always zero.

3.2.2 The Expectation Efficiency Hypothesis and Size Variation

Next the REH implies that expectational errors are unsystematic and orthogonal to lagged information, denoted the EEH. In order to test this version of the hypothesis define,

$$e_{it} = y_{it}^{e} - y_{it} \tag{10}$$

Then rationality requires,

$$E(e_{it} \mid \Omega_{it-1}) = 0 \tag{11}$$

which suggests the following panel model,

$$e_{it} = a + b_1 e_{it-1} + b_2 Z_{it-1} + u_i + l_t + x_{it} \tag{12}$$

and a test of the EEH hypothesis is,

$$H_0: \quad b_1 = b_2 = 0 \tag{13}$$

Given random variation, the assumptions appended regarding the regression error are the same as before. However, given that there is significant dispersion in the data the model in (12) must be conditioned on the fact that an error made by a small plant is fundamentally different than that by a large plant. For example, if a large plant makes an error of $1 million but has revenues and investment expenditures in the hundreds of millions the error is of less consequence than if a small plant who might make an error of $10,000 and have investment expenditures of $100,000. In order to incorporate this feature (12) may be rewritten by redefining the error as,

$$e'_{it} = \frac{y_{it}^{e} - y_{it}}{y_{it}^{e}}$$

and similarly writing $z_{it} = \dfrac{Z_{it}}{y_{it}^{e}}$ yielding the following model,

$$e'_{it} = a + b_1 e'_{it-1} + b_2 z_{it-1} + u'_i + l'_t + x'_{it} \tag{14}$$

Now the test of rationality is whether there is any persistence in errors as fraction of expectations. This specification also assumes random effects along with the afore mentioned assumptions on regression errors.

Further, in all of the specifications to be estimated [(5), (8), (12) and (14)] it is important that the estimated residuals not exhibit any autocovariance, in the case of (12) and (14) such behaviour along with a failure of the respective nulls would indicate some adaptive mechanism at work. Arellano and Bond (1991) provide tests of first and second order autocovariance and therefore are used in determining model fit, as explained below. Finally, it is a point of departure from the standard expectations hypothesis tests (Keane and Runkle (1998) and others) that nowhere is the constant expected to test to equal zero. The reason is that if the unobserved variation is viewed as being composed of individual specific, time specific and a constant then it need not equal zero.

4. Estimation and Results

In this a description of the estimation technique used is described and then the estimation results of equation (5), (8), (12) and (14) are discussed. The chosen technique was the Arellano and Bond (1991) GMM estimator and the results indicated that rationality held if size variation was accounted for as in specification (14).

4.1 Estimating Dynamic Panel Models

All of the models to be estimated are of the form,

$$Y_{it} = dY_{it-1} + X'_{it} b + m_{it} \quad (15)$$

where X_{it} is K by 1 and m_{it} follows a one way error component of the form,

$$m_{it} = h_i + z_{it} \quad (16)$$

with the assumption that the random effect and error are i.i.d and are independent individually and of each other. The specification in (15) presents several estimation problems if standard estimators are used. For example, OLS has been shown to be biased given the inclusion of the lagged dependant variable and inconsistent even if the errors are serially uncorrelated. Further, under the random effects assumption GLS is also biased leading Anderson and Hsiao (1981) to suggest that first differences of Y or two period lagged values be used in an instrumental variables formulation. However, their estimator has been shown to be inefficient (although consistent) prompting Arellano and Bond (1991) to derive a generalized method of moments estimator that uses more of the available moment conditions. This GMM estimator requires little of initial conditions or the distributions of the random effects and errors and the 'one step' version of the estimator outperforms the Anderson and Hsiao (1981) technique. However, their 'two step' estimator suffers from downward biased coefficient standard errors and so was not used in this paper. Arellano and Bond (1991) also derive tests of first and second order autocovariance in the estimated residuals which are important for the models estimated in this paper as theory dictates that errors not suffer from such covariance. In fact, in equations (12) and (14) the presence of autocovariance would indicate some adaptive mechanism at work.

The exact form of the optimal instrument matrix in the Arellano and Bond (1991) approach depends crucially on the behaviour of the independent variables with respect to the error given that the correlation of the variates with the random effect is non-zero. Specifically, all of the above models assume that the independent variables are exogenous in the sense that their joint expectation with the regression error are always zero. Several estimators have been proposed for dynamic panel models and all of them require that the relationship of the covariates and errors be specified, recent estimators exploit further moment restrictions and assumptions on the initial conditions to derive GMM estimators. Since the information to expectations and realizations mappings above correspond directly to the requirements of Arellano and Bond (1991).

4.2 Estimation Results

Table 3 in the appendix provides the estimation results. For each equation estimated the Arellano and Bond (1991) estimates are provided alongside the OLS results for comparison; all estimation was carried out with White corrected errors and time dummies. The first two columns provide the estimates for equation (5), the Adaptive Expectations mechanism. The OLS results clearly indicate that the null hypothesis is accepted, however, the Arellano and Bond (1991) estimates reject the null. Given the dispersion in the data the Arellano and Bond (1991) estimates seem to be of relevance as OLS is biased under random effects and a dynamic structure. Clearly the standard method via which Adaptive Expectations are tested indicates a rejection of the hypothesis.

The next two columns on Table 3 provide the estimation results of equation (8), the Rational Expectations hypothesis. OLS clearly rejects the null of rationality as do the Arellano and Bond (1991) estimates. It seems from these results that the estimated residuals exhibit first order autocovariance and that expectations are below realizations throughout this time period. The specification were run with time dummies so that the aggregate shocks that would have hit the manufacturing sector in 1986-1992 should be picked up by the year dummies. Despite dummy inclusion, expectations are below realizations which would not be entirely out of the realm of rationality given the recession in the early 1990's and the fact that the data have a low time frequency. However, the estimated residuals do exhibit some persistence which cannot be easily reconciled. The estimates of equation (12) further exhibit this persistence, they are presented in the fifth and sixth columns of Table 3. Whereas the constants seem to be zero in both the OLS and Arellano and Bond (1991) estimates, lagged errors are significant around 0.2 along with persistence in the estimated residuals. In combination with the estimates of equation (8) it would seem that rationality is clearly not holding in the sense outlined above.

However, size variation might be driving this result. The last two columns of Table 3 provide the estimates of equation (14), and they indicate a clear acceptance of the rational expectations hypothesis as formulated by the EEH. The OLS results continue to admit a rejection of the rationality hypothesis, however the more appropriate Arellano and Bond (1991) estimates strongly accept the null. In addition, the estimated residuals do not exhibit any autocovariance of the first or second order, which would have been implied by the adaptive expectations hypothesis.

For the large part, the estimation results speak for themselves, and the reason why the standard specifications [(8) and (12)] did not accept rationality may be because of the low time dimension. However, if size variation along with unobserved time and individual effects are accounted for then rationality holds and adaptive mechanisms do not, even given this low frequency data. Unobserved variation is certainly a tenable assumption given the many choices plants face in making capital expenditure decisions. Further, despite the fact that the time period considered includes a recessionary period, rationality in the sense of unsystematic forecast errors holds. This result is based upon data drawn from a large class of agents, is continuous in nature and unlike previous analyses clearly accepts rationality and rejects adaptive mechanisms.

5. Conclusion

In this paper evidence has been gathered at the plant level on the validity of the AEH, REH and EEH. The objective of the exercise has been motivated by the widespread use of rationality in business cycle models that have strong prescriptions for both monetary and fiscal ailments. Perhaps a most difficult statistical decision is whether the econometric evidence on some issue is sufficient to draw inference that may have meaningful consequences for contemporary methodology. Whether the evidence provided in this paper is definitive is left to the reader to judge, and the conclusion (conditional on the assumption that the econometric exercises conducted are accurate) is relatively straightforward. Financial market analyses culminate in the work of Keane and Runkle (1998) where rationality is accepted subject to the caveats of Bonham and Cohen (2001). Recognizing the inherent problems with qualitative response surveys as explained by Keane and Runkle (1990), this paper provides a parallel analysis using quantitative data for a much larger class of economic agents. These agents are shown to act in a rational manner with respect to their capital expenditure decisions conditional on the fact that agents with less resources cannot devote as much to the expectations formation activity.

Finally, the results rely on the strength and precision of the Arellano and Bond (1991) estimator. Therefore the results are conditional on their approach, future analyses could consider other estimators that may lead to alternate inferences.

Appendix - Tables and Figures

Table 1 Summary Statistics

Variable	Mean	Standard Deviation
y_{it}^{e}	4303.33	7904.39
y_{it}	3863.61	7167.94
e_{it}	439.72	2895.17
Z_{it}	52707.44	80329.03

Table 2 Correlations

1987	y_i^e	y_i	e_i	$Z_{i,-1}$	**1988**	y_i^e	y_i	e_i	$Z_{i,-1}$
y_i^e	1				y_i^e	1			
y_i	0.92	1			y_i	0.93	1		
e_i	0.23	-0.15	1		e_i	0.29	-0.07	1	
$Z_{i,-1}$	0.65	0.61	0.14	1	$Z_{i,-1}$	0.64	0.59	0.19	1
1989	y_i^e	y_i	e_i	$Z_{i,-1}$	**1990**	y_i^e	y_i	e_i	$Z_{i,-1}$
y_i^e	1				y_i^e	1			
y_i	0.93	1			y_i	0.94	1		
e_i	0.45	0.10	1		e_i	0.59	0.29	1	
$Z_{i,-1}$	0.63	0.62	0.22	1	$Z_{i,-1}$	0.59	0.59	0.26	1
1991	y_i^e	y_i	e_i	$Z_{i,-1}$	**1992**	y_i^e	y_i	e_i	$Z_{i,-1}$
y_i^e	1				y_i^e	1			
y_i	0.93	1			y_i	0.91	1		
e_i	0.51	0.16	1		e_i	0.35	-0.06	1	
$Z_{i,-1}$	0.61	0.59	0.24	1	$Z_{i,-1}$	0.60	0.61	0.08	1

Table 3 Estimation Results

	Equation (5)		Equation (8)		Equation (12)		Equation (14)	
	OLS	Arellano and Bond	OLS	Arellano and Bond	OLS	Arellano and Bond	OLS	Arellano and Bond
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
	$\|t\|$-statistic)	($\|t\|$-statistic)	($\|t\|$-statistic)	($\|t\|$-statistic)	($\|t\|$-statistic)	($\|t\|$-statistic)	($\|t\|$-statistic)	($\|t\|$-statistic)
a	-26.85	-35.47	-209.55	-30.23	-101.39	6.94	-0.08	0.04
	(0.22)	(0.78)	(2.10)	(0.80)	(0.90)	(0.26)	(1.29)	(1.38)
b_1	0.45	0.55	0.30	0.28	0.25	0.22	0.11	0.08
	(8.12)	(2.40)	(6.65)	(1.91)	(5.45)	(3.72)	(1.91)	(0.66)
b_2	0.53	-0.33	0.70	0.64	0.00	0.01	0.00	0.00
	(8.66)	(2.07)	(19.11)	(12.41)	(3.28)	(2.43)	(5.06)	(0.30)
b_3	..	..	0.01	-0.03	..	..	..	..
	..	..	(0.17)	(0.32)	..	..	..	..
b_4	..	..	0.00	0.02	..	..	..	..
	..	..	(2.63)	(2.69)	..	..	..	..
R^2	0.82	..	0.89	..	0.10	..	0.08	..
A(1)?	..	(3.28, 0.00)	..	(3.77, 0.00)	..	(7.65, 0.00)	..	(1.78, 0.07)
A(2)?	..	(0.89, 0.38)	..	(0.21, 0.84)	..	(0.30, 0.76)	..	(0.16, 0.87)
H_0	1.38, 0.24)	(60.15, 0.00)	(34.51,0.00)	(16.49, 0.00)	(25.58, 0.00)	(8.68, 0.00)	(29.87, 0.00)	(0.74, 0.47)

Notes:

1. The A(*)? test is Arellano and Bond (1991)'s test of autocovariance in the residuals of order *.
2. The H_0 test refers to the F-test of the expectations formation mechanism for each of the models.
3. The test results in 1. and 2. above are reported in the form (Test statistic, p>|Test statistic|).

Figure 1 Survey Phases

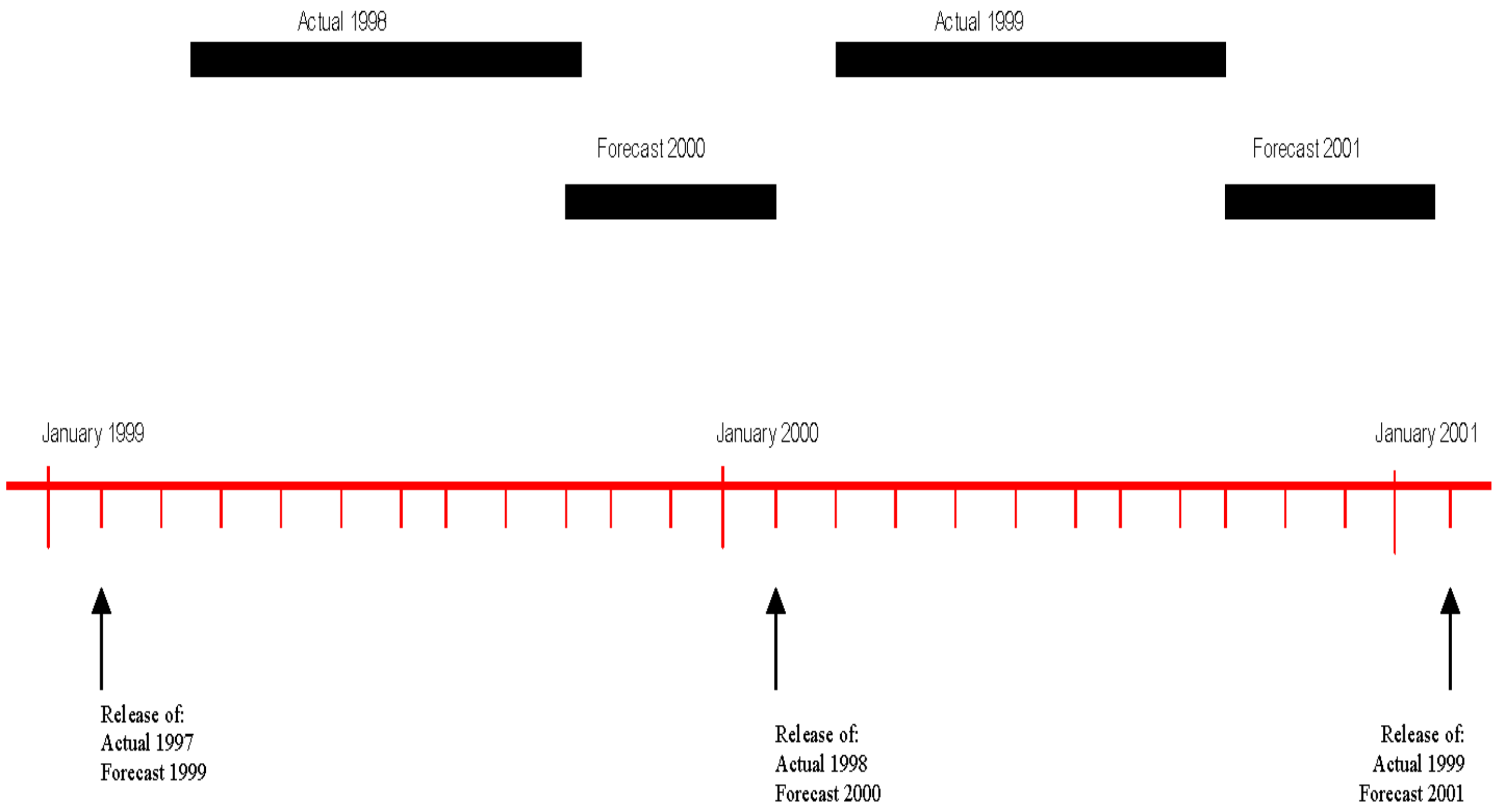


Figure 2 y_{it}^{e} vs. y_{it}

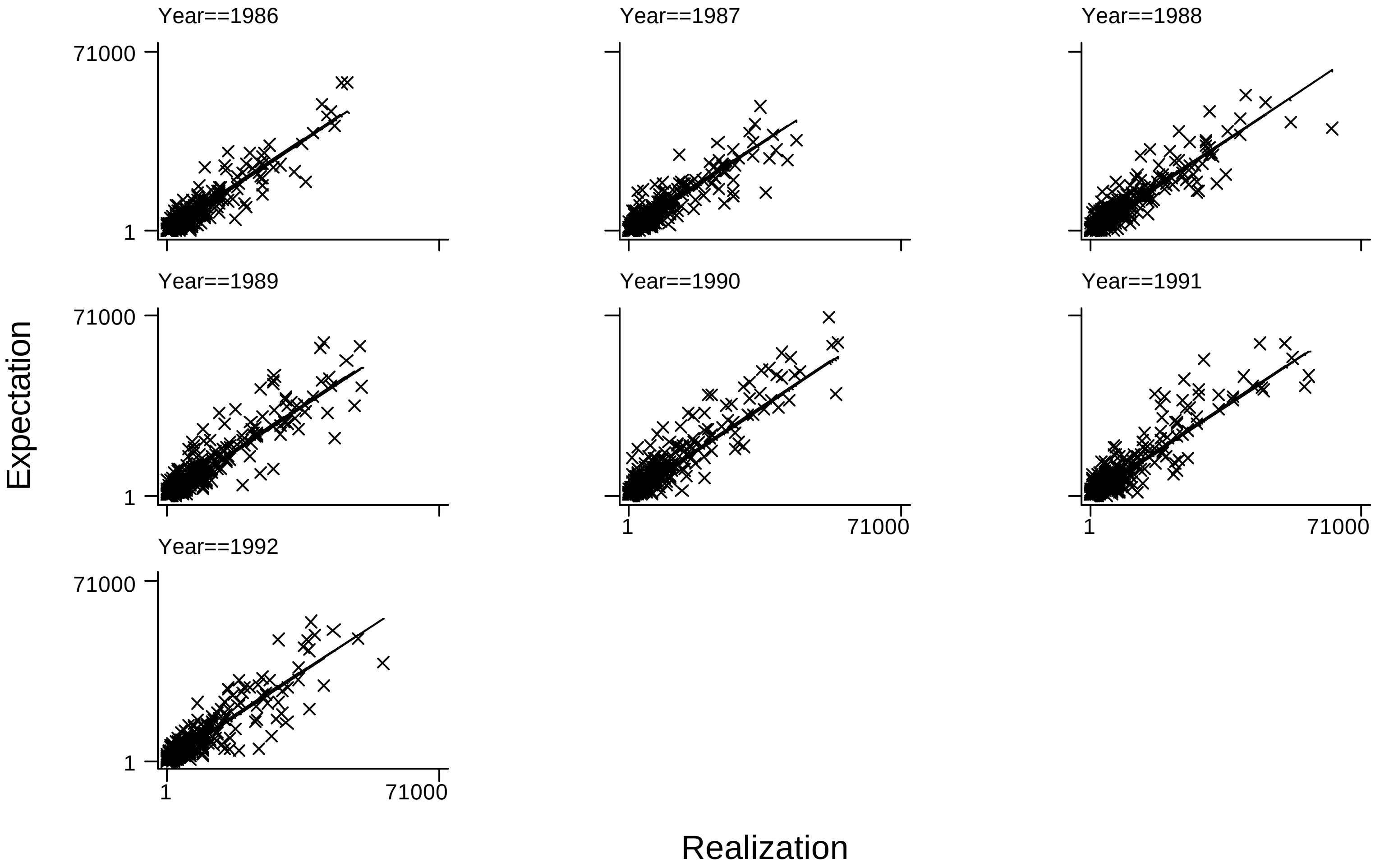
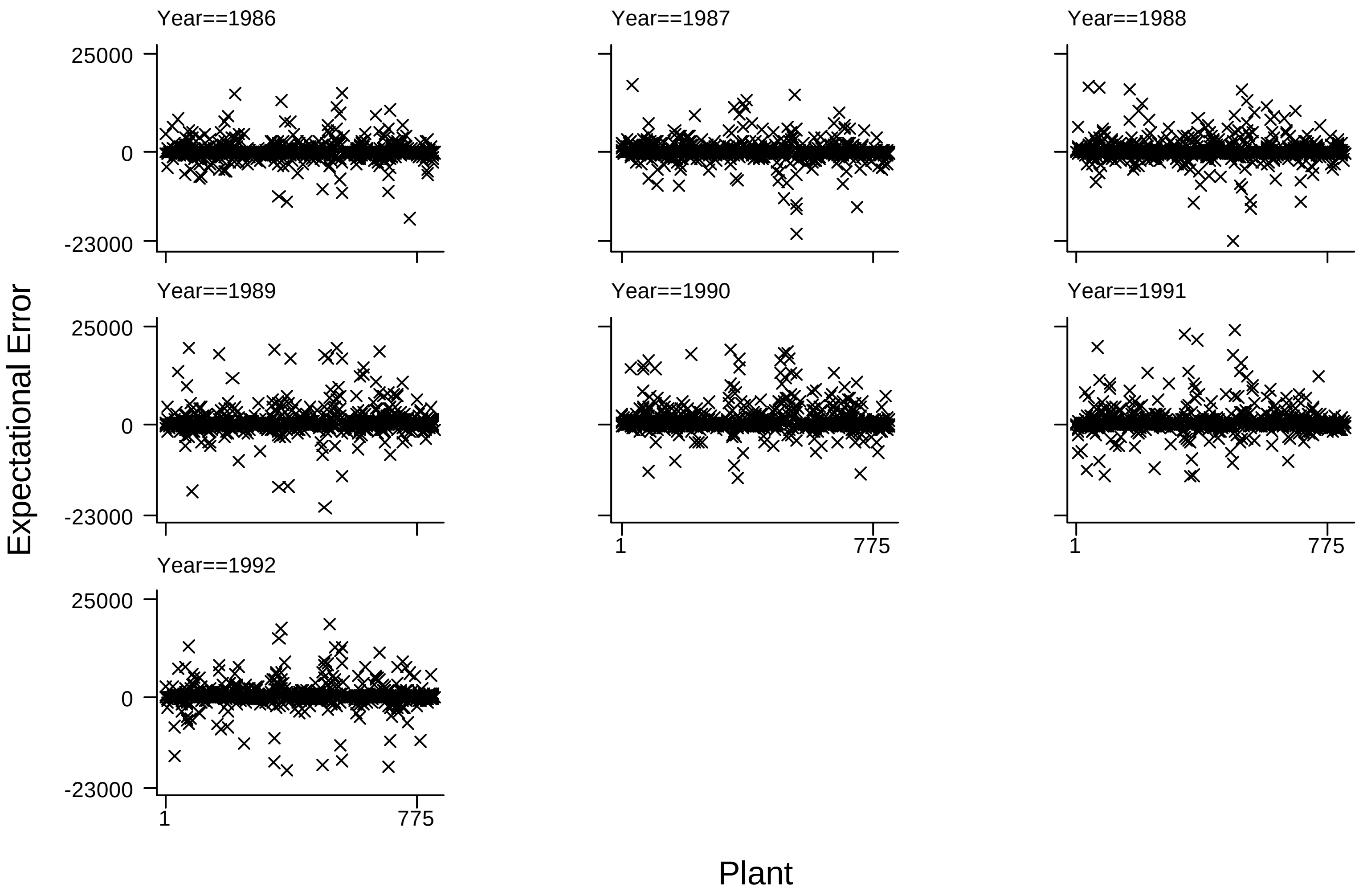


Figure 3 e_{it} vs. i



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