# On FIRE, news, and expectations*

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June 8, 2023

**Abstract**

The full-information rational expectations (FIRE) assumption is at the core of modern macroeconomics. We revisit recent evidence which rejects FIRE based on survey data. It relates forecast errors to news at different levels of aggregation. The evidence based on consensus forecasts testifies against the full-information assumption, the evidence based on data for individual forecasters against rational expectations. In contrast to earlier survey evidence that was largely dismissed as irrelevant, the recent evidence is likely to have a lasting impact for two reasons. First, the global financial crisis of 2007/08 has led to a certain uneasiness with the state of macro and a readiness to embrace new ideas. Second, the recent literature has put forward a number of promising alternative models of the expectation-formation process. We review these at the end of the paper.

*Keywords:* Rational expectations, full information, FIRE, crises, survey data, reaction to news, expectations revolution

*JEL-Codes:* B22, E37, E71

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*So long as the tools a paradigm supplies continue to prove capable of solving problems it defines, science moves fast and penetrates most deeply through confident employment of these tools. The reason is clear. As in manufacture so in science—retooling is an extravagance to be reserved for the occasion that demands it. The significance of crises is the indication they provide that the occasion for retooling has arrived.*

Thomas S. Kuhn (The Structure, p. 76)

# 1 Introduction

Rational expectations have dominated mainstream macroeconomics for the last 40 years or so (see, for instance, Taylor 2001; Evans and Honkapohja 2005). This is most likely for three reasons. First, they feature prominently in a compelling narrative of why established models failed to account for the effects of the economic policies in the 1970s. This, in turn, gave rise to the rational-expectations revolution in the first place. Second, rational expectations are a conceptually attractive disciplining device in economic modeling. Under rational expectations, economic agents share the same view of the world as their modelers, eliminating potential degrees of freedom which can otherwise easily be abused to fit the data. Third, for the longest time, there has been a broad consensus that one may not test the rational expectations assumption empirically without additional auxiliary assumptions which, in turn, are unlikely to be satisfied in most data sets. Hence, it seemed impossible to directly reject the assumption on empirical grounds.

This chapter develops the hypothesis that the modeling of expectations in macroeconomics is currently undergoing a paradigm shift. This shift—a second expectations revolution—is centered around a simple idea, namely to take survey measures of economic expectations at face value and to investigate their response to news. This yields a rather straightforward test: Under rational expectations, the forecast errors of survey participants about future developments are not predictable based on how the same participants react to current news. However, by now there is overwhelming evidence that forecast errors are indeed predictable on the basis of news. This evidence is based on many surveys and emerges in various contexts. What's more: rather than simply rejecting rational expectations, testing how forecast errors respond to news provides useful clues as to how rational expectations fail empirically. This, in turn, serves as input for alternative models of the expectation-formation process.

It is perhaps no coincidence that the ongoing, second expectations revolution took off in the decade after the financial crisis which disrupted the world economy during the years 2007/08. Part of the intellectual response to the crisis was to identify rational expectations as

one of the key limitations of existing models which had a hard time accounting for what was going on in real time (see, for instance, Stiglitz 2011). That intellectual shifts in economics take place against the background of disruptive economic events is a familiar pattern. After all, macroeconomics "was born as a distinct field in the 1940s, as a part of the intellectual response to the Great Depression" (Lucas 2003). The (first) rational-expectations revolution is another example. While the concept of rational expectations goes back to Muth (1960, 1961), the rational-expectations revolution took off during the following decade only. And while the work of Lucas (1972, 1973, 1976) is commonly understood to have been pivotal in this regard, so is the macroeconomic crisis of the 1970s. The persistent surge of inflation was partly understood as the failure of Keynesian macroeconomics that had been put into practice during the 1960s and 1970s (Mishkin 1995). As Sheffrin (1996) puts it: "Stagflation and persistent inflation created a receptive environment for new ideas in the field."

With hindsight, it appears plausible that a climate of general uneasiness with the state of macroeconomics that emerged in the wake of the global financial crisis made the profession similarly more open to new ideas and approaches (Krugman 2009). Taking a historical perspective, this chapter is therefore premised on the idea that economic-modeling trends are themselves grounded in the experience of crises—that is, when models are confronted with an unyielding reality, when they inform policies that eventually fail to achieve what they are supposed to deliver, or both.

The chapter is organized as follows. The next section introduces the full-information rational expectations (FIRE) paradigm which has been—and still is—the dominant framework of mainstream macroeconomics. It complements rational expectations with the assumption of full information and yields rather stringent predictions which differ depending on the level of aggregation. This is key to appreciating the recent empirical work which relies on survey data. A first set of studies focuses on the behavior of average expectations and finds that news predicts forecast errors. This is inconsistent with FIRE but may still be consistent with rational expectations, assuming that information is incomplete. Later studies, however, turn to individual forecasts and find likewise that news predicts forecast errors, in contrast to what rational expectations imply. Section 3 provides a historical perspective. In particular, it highlights an earlier strand of the literature which by and large also rejected rational expectations on the basis of survey data. Yet this research, which was published in the 1970s and 1980s, left the profession largely unimpressed. Looking at recent trends in publications, we suggest that this time is different, either because of the sense of failure of macroeconomics during the global financial crisis or because more viable alternatives are becoming available. Section 4 provides a brief overview of these alternatives. A final section offers a short conclusion.

# 2 FIRE under fire

For the largest part, macroeconomics today relies on the full-information rational expectations (FIRE) assumption in order to model the expectation-formation process. Under FIRE, one obtains stringent predictions for how expectations respond to news.[1] During the last couple of years, a rich empirical literature has developed which uses survey data to assess these predictions. It turns out that FIRE can be rejected at different levels. In what follows, we first clarify basic concepts and provide an illustrative example before discussing the evidence.

## 2.1 Rational expectations and the reaction to news

The empirical literature which we discuss below is centered around the notion of overreaction and underreaction of expectations to news. Rational expectations yield different predictions depending on whether a) one assumes full information or b) one considers aggregate or individual expectations. We discuss these aspects in what follows. Table 1 offers a summary. Column (1) shows the predictions of the FIRE benchmark, Column (2) relaxes the full-information assumption, while the last column departs from rational expectations altogether. In the following, we explain how predictions vary across columns and across aggregate and individual expectations (top v bottom row).

The theory of rational expectations imposes restrictions at the level of *individual* actors, notably that they make the best possible forecast given the available information. In addition, rational expectations stipulate that both the forecaster and the econometrician know the data-generating process (see, for instance, Sargent 2008).[2] Still, forecasts will not necessarily come true, as future disturbances are generally not foreseen. Put differently, rational expectations differ from perfect foresight, an assumption that is sometimes imposed for pedagogical purposes. Under rational expectations, agents (and econometricians alike) will make expectation errors by over- or underestimating the variable of interest at different points in time. Such prediction errors are consistent with rational expectations as long as forecast errors themselves are not predictable based on the information set that is available to agents in real time. Clearly, these information sets may be very limited. What matters for rational expectations is that forecast errors are not *systematically* related to individual information available at the time the forecast is made: Over time, errors in one direction are

[1] We use the terms news and information interchangeably in this context, both defined as previously unknown information that is relevant for the prediction of a specific variable, where this information does not have to be correct. This is important to note as, in similar contexts, news sometimes refers to the correct part of information.

[2] Further, we assume that survey responses reflect actual expectations (possibly subject to measurement error) and are not deliberately biased because of, say, strategic considerations due to asymmetric payoff functions (see Gemmi and Valchev 2022 for a discussion of this case).

Table 1: Predicted reactions to news at different levels of aggregation

| Level of aggregation | (1) FI & RE | (2) ∼FI & RE | (3) ∼FI & ∼RE |
|---|---|---|---|
| Aggregate | Correct reaction | Underreaction | Underreaction |
| Individual | Correct reaction | Correct reaction | Under-/Overreaction |

*Notes:* Reaction of aggregate (upper row) and individual (lower row) expectations to news as predicted by combinations of full information (FI) and rational expectations (RE). Entries in the second and third columns are not universally valid but refer to the specific predictions discussed in this section.

offset by errors in the other direction. Instead, we speak of over- and underreactions to news only if such a systematic link exists and forecast errors are indeed predictable by current information.

If all actors possess the same (even if incomplete) information and form expectations in the same way, aggregating expectations does not make any difference as individual and average expectations coincide. In this case, rational expectations imply that neither individual nor aggregate expectation errors can be predicted ex-ante: see Column (1) of Table 1. Expectations no longer coincide once agents have access to different information. Information is then also necessarily incomplete for some agents. Such an environment of 'dispersed information' represents a specific deviation from the assumption of full information (where 'full' does not include realizations of future disturbances, as would be the case under perfect foresight) and leads to heterogeneous expectations, even if agents form expectations in the same way. Crucially, an individual might receive less information than what is available in the aggregate. This is the case if the correlation of information across agents (or the number of agents receiving similar information) helps to predict the future. Individual expectations are nevertheless formed independently of this correlation, as the information available to others is unknown to the individual.

The information structure in a rational-expectations model of 'noisy (and dispersed) information', as developed in Lorenzoni (2009), generates a specific correlation of the average forecast revision with the aggregate forecast error (Column (2) of Table 1). In the model, agents adjust their expectations only partially in reaction to new information, as this information might be incorrect. By doing so, the expectation will be too pessimistic in case positive news turns out to be correct and too optimistic in case it doesn't (and vice versa for negative news) but will be correct on average. The additional (quite natural)

model assumption that correct news is correlated across agents while incorrect news is not implies that the average information picks up the informative news, while the so-called 'noise' averages out. As agents (rationally) underreact to correct information due to their inability to identify their information as informative, aggregate expectations will hence underreact to the aggregate, and therefore informative, news.

Predictable forecast errors at the aggregate level despite rational expectations at the individual level do not only emerge under noisy information. Models of rational inattention (e.g., Sims 2003; Mackowiak and Wiederholt 2009) assume a different information structure but deliver the same outcome. Here, agents do not pay full attention to relevant information because of information-processing costs. This limited attention renders information, as processed by the agents, noisy, which again leads to an underreaction at the aggregate level (see Fuster et al. 2022 for a demonstration of this equivalence). Individual forecast revisions, however, are still not systematically linked to future forecast errors. This would violate the rational-expectations assumption as individual forecast revisions are observable at no cost.

Given the above, evidence of under- (or over-) reaction to news at the aggregate level does not pinpoint the specific deviation from FIRE, as this observation can be rationalized by two broader categories of explanations. The first one relaxes the full-information assumption and focuses on the predictability of forecast errors that arises due to the aggregation of heterogeneous expectations.[3] An underreaction at the aggregate level can, as explained above, be squared with rational expectations if coupled with, e.g., dispersed information.[4] The second type of explanation assumes that the predictability of forecast errors is already present at the individual level. Yet an over- or underreaction at the individual level implies a departure from rational expectations, as agents could improve their average forecast (that is, reduce forecast errors) based on their forecast revisions.[5] This rejection of rational expectations at the individual level can exist alongside the discussed dispersed-information structure, giving rise to potentially opposite over- and underreactions at the individual and the aggregate level (Column (3) of Table 1).

[3]Note in this context that under certain conditions incomplete-information models and behavioral models featuring myopia (extra discounting of the future) or anchoring of current to past behavior (such as habit persistence) give equivalent predictions regarding the reaction of average expectations and equilibrium dynamics (see Angeletos and Huo 2021).

[4]There is no easy explanation for an overreaction at the aggregate level that still features rational expectations. Empirical studies, however, typically find an under- instead of an overreaction at this level of aggregation, see Section 2.3.

[5]Hence, predictable forecast errors at this level allow us to reject rational expectations. But this does not imply a rejection of rationality *per se*: Predictable forecast errors may also emerge because of forecasters' asymmetric loss function, specific constraints on information processing, or in a learning environment with parameter uncertainty (e.g., Elliott et al. 2008; Farmer et al. 2023; Kohlhas and Robertson 2022; Bachmann et al. 2023).

## 2.2 An illustrative example

To provide further intuition for under- and overreaction at the individual and aggregate levels, we provide a simple example with noisy and dispersed information. Suppose that at a certain point in time, every individual in a population expected no change in a specific variable, say, GDP. One individual then receives idiosyncratic news that GDP will increase by 2%. Assume furthermore that this information is noisy in the sense that it has a 50% probability of being correct. With the remaining 50% probability, GDP will not change. The rational forecast is a prediction of a 1% rise: If the news turns out to be correct, the individual has underestimated GDP growth by 1 percentage point (p.p.), while she has overpredicted GDP by 1 p.p. in case of incorrect news. Since both events are equally likely, the prediction is correct on average, that is, the expected forecast error (realization minus expectation) is zero: $.5 * 1 + .5 * (-1) = 0$. If, for whatever reason, the agent overestimates the likelihood that the information is correct, she would increase her forecast by more than 1 p.p., leading to a negative forecast error on average (average realizations are below average forecasts). A negative correlation with the positive forecast revision (from zero to above one upon receiving the news) obtains.

To see how an overreaction at the individual level can be squared with an underreaction at the aggregate level, assume now that if GDP will increase by 2%, *each* agent receives the same (correct) news about a 2% increase.[6] If agents hold rational expectations and predict a 1% growth rate, the average forecast revision will also be 1%, but this will underestimate actual GDP growth. The forecast error is $2 - 1 = 1$ p.p. and therefore positively correlated with the forecast revision, representing an underreaction at the aggregate level despite the rational-expectations forecasts at the individual level. However, also if agents predict GDP growth of 1.5%—representing an overreaction according to the discussion above—the average forecast revision of 1.5% will underestimate GDP growth with a forecast error of $2 - 1.5 = 0.5$ p.p. We therefore still have an underreaction at the aggregate level. In other words, because information sets are assumed to be correlated in the case of correct news but uncorrelated for incorrect news, we can obtain overreaction at the individual level simultaneously with underreaction at the aggregate level. The observation that overreaction may be observed alongside underreaction, *both* at the individual level, as documented in the next section, requires different explanations, though.

[6]For completeness, the remaining probabilities of this example are as follows: if growth is nil (50% probability), half of the population receives news of a 2% increase, the other half of a 2% decrease. The average forecast revision is therefore zero in this case. If growth is plus or minus 2% (25% probability for each case), all agents receive the correct news.

## 2.3 The evidence

The FIRE benchmark discussed above provides the benchmark for a number of recent empirical studies which bring survey data to bear on the issue. This is noteworthy because, as we discuss in Section 3 below, the assessment of economic theory based on survey data has been frequently debated on methodological grounds.

In an influential study, Coibion and Gorodnichenko (2015) propose a simple diagnostic in order to shed light on the expectation-formation process. Their study has given rise to an intensive debate about this process and has motivated new explorations, both empirically and in terms of theory. Specifically, using the Survey of Professional Forecasters (SPF), Coibion and Gorodnichenko (2015) regress the upcoming forecast error on the current forecast revision. As discussed in Section 2.1 above, forecast errors should not be predictable based on information that is available to the forecaster in real time under rational expectations. If one assumes full information in addition to rational expectations, the average forecast error across forecasters should also not be predictable based on average news. Therefore, Coibion and Gorodnichenko (2015) test the full-information rational expectations (FIRE) assumption based on the following specification:

$$x_{t+h,t} - F_t(x_{t+h,t}) = \beta_0 + \beta_1 \cdot \text{news}_t + \varepsilon_t \ . \tag{1}$$

Here, $x_{t+h,t} - F_t(x_{t+h,t})$ is the *average* forecast error and $\text{news}_t$ is some surprise, typically proxied by the *average* forecast revisions across forecasters. Under FIRE, we have $\beta_1 = 0$. Based on the median (consensus) professional forecast for inflation, Coibion and Gorodnichenko (2015) obtain positive regression coefficients. That is, forecast revisions predict forecast errors in the same direction. An upward revision, for example, is followed by an underprediction of the same variable—forecasters seem to underreact to news. While Coibion and Gorodnichenko (2015) focus primarily on professional inflation forecasts from the SPF, they show that their finding also holds for (i) other macroeconomic variables such as real GDP, (ii) different surveys, e.g., the University of Michigan Survey of Consumers and the Livingston Survey, (iii) different forecast horizons, and (iv) different countries.[7] Using a similar setup as Specification (1), Kohlhas and Walther (2021) confirm the underreaction to average new information.[8] Shintani and Ueda (2023) aim to disentangle sticky information

[7]The Livingston Survey was started already in 1946 by the columnist Joseph Livingston. It is now run semi-annually by the Federal Reserve Bank of Philadelphia and includes individual inflation forecasts from, e.g., academic institutions, commercial banks, and non-financial firms. Another survey that has been regularly used is the Blue Chip Survey based on professional forecasters at financial firms (see, e.g., Angeletos et al. 2020).

[8]Interestingly, Kohlhas and Walther (2021) also show that aggregate forecast errors are positively correlated with the actual levels of output and inflation, i.e., forecasters extrapolate from recent events.

from noisy information in the same framework and find some evidence for a noisy-information model in which agents can quickly learn the underlying state.[9]

It is important to reemphasize that underreaction at the aggregate level is consistent with rational expectations: It may simply reflect a failure of the full-information assumption. However, and this point is stressed by Coibion and Gorodnichenko (2015), once Specification (1) is estimated at the level of individual forecasters, it yields a more stringent test: $H_0: \beta_1 = 0$ is now a test of rational expectations instead of a test of FIRE. As explained above, rational-inattention or noisy-information models would predict that expectations underreact to the (unobserved) fundamental shock but respond on average correctly to the combination of shock and noise, that is, to news. The key point, therefore, is to employ $news_{it}$, which are the observations made by forecasters in real time (where $i$ is an index for the individual forecaster). Fuhrer (2018), Bordalo et al. (2020), and Angeletos et al. (2021) estimate versions of Specification (1) based on *individual forecasts* and find negative coefficients, that is, they find overreaction to news. Bouchaud et al. (2019) also show this for financial analysts' forecasts. Overall, the recent evidence based on individual-level regressions points toward a rejection of rational expectations and, as discussed in Section 4, has provided important inputs for the development of theoretical alternatives to the rational expectations paradigm.

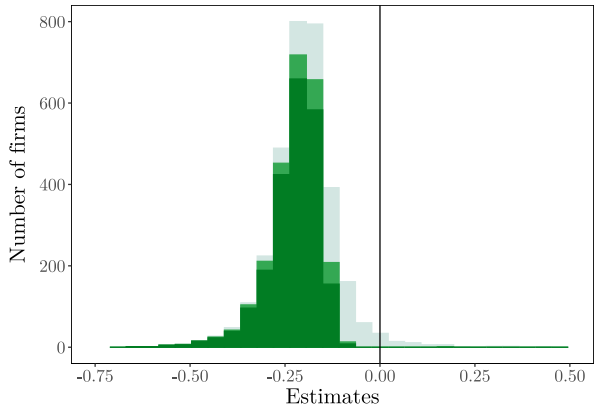
Before turning to theoretical developments, we stress that news does not always lead to overreaction at the level of individual forecasters, as recent work by Broer and Kohlhas (2023) and Born et al. (2022a) show. On the one hand, Broer and Kohlhas (2023) confirm that the forecast error of individual forecasters, especially regarding inflation forecasts, is negatively correlated with their own forecast revision, pointing to overreactions. On the other hand, forecast errors overreact to some public signals (like the consensus inflation forecast from the SPF) but underreact to other public signals (like the unemployment rate or the year-on-year change in the exchange rate). Born et al. (2022a) put forward new evidence to the debate along three dimensions. First, they consider firms instead of professional forecasters or households.[10] Second, they focus on firm-level variables, notably production (and prices), rather than macro-level variables (such as aggregate inflation). Third, they distinguish between (private) micro and (public) macro news regarding firm performance. In the tradition of the above literature, Born et al. (2022a) approximate what is news to

[9]Cautioning against overinterpreting the results of Coibion and Gorodnichenko (2015)-type regressions, however, Bianchi et al. (2022) show by using machine-learning tools that forecast revisions are not reliable *out-of-sample* predictors of mean forecast errors in this type of setup.

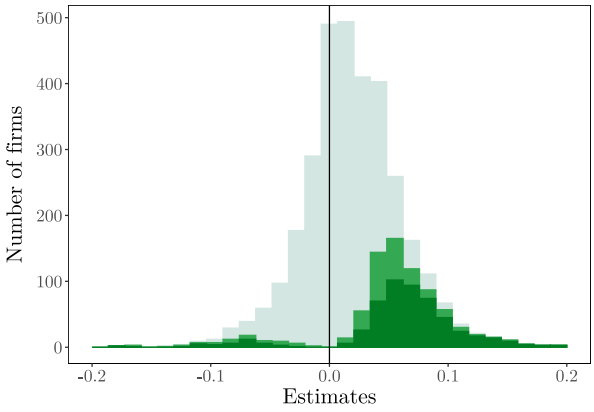
[10]Their analysis is mostly based on data from the ifo survey of German firms, which is a well-known and widely used survey that has been conducted since 1949 and whose design has since then been adopted by surveys around the world (Becker and Wohlrabe 2008; Born et al. 2022b).

Figure 1: Distribution of firm-level responses to news

(a) Production expectations: micro news




(b) Production expectations: macro news




*Notes:* Figure reproduced from Born et al. (2022a); Grey area represents insignificant estimates, light-green area represents estimates significant at the 10% level, dark-green area indicates significance at the 5% level.

firms by a firm's forecast revision, that is, the change in what they report as production expectations. Importantly, these revisions may reflect firm-specific news (micro news) or news about the aggregate economy (macro news).

Formally, their baseline regression equation is given by:

$$x^i_{t+h,t} - F^i_t(x^i_{t+h,t}) = \beta_0 + \beta_1 \cdot \text{micro news}^i_t + \beta_2 \cdot \text{macro news}_t + v^i_t \ . \tag{2}$$

Here, $x^i_{t+h,t} - F^i_t(x^i_{t+h,t})$ is a firm's forecast error for its own production, micro news is the production-forecast revision once one controls for macro news, and macro news is the surprise component in the ifo business climate index of the previous month.[11] As before, under rational expectations, these coefficients should be zero because micro and macro news are part of a firm's information set at the time the forecast is submitted to the survey.

Born et al. (2022a) find that the distinction between micro and macro news is essential: firm expectations overreact to micro news, but simultaneously underreact to macro news. This pattern emerges robustly across a variety of specifications and for all firm types that they consider (e.g., small and large, young and old). It also holds for different measures of expectations and different outcome variables. The key result is displayed in Figure 1. Here, Specification (2) is estimated for each of the 3,000 firms in their sample separately and the

[11]The ifo *business climate index* is an aggregate indicator of the German business cycle compiled on the basis of the ifo survey. This index is widely watched and Bloomberg samples a consensus forecast prior to its release. Macro news is computed as the difference between the current release of the index and the consensus forecast, both available in real time.

figure displays the distribution of estimates for $\beta_1$ and $\beta_2$ which capture the response to micro and macro news, respectively. There is a clear pattern: the mass of the estimates for $\beta_1$ is concentrated to the left of zero, and significantly so (dark green bars). The estimates for $\beta_2$ instead are centered to the right of zero. In this case, however, estimates are not always significantly different from zero (grey bars), but among the significant estimates, the macro coefficient is positive for 92 percent of firms. Overall, the results show that the micro coefficient is generally negative while the macro coefficient tends to be positive. Given our discussion above, the interpretation is straightforward: the expectations of individual firms overreact to micro news and tend to underreact to macro news. As discussed in Section 2.1 above, this pattern testifies against rational expectations. The finding of underreaction to macro news at the level of individual-firm expectations is particularly noteworthy in light of a frequently voiced concern which suggests that overreaction at the level of individual forecasters may simply reflect measurement error rather than a failure of rational expectations (Juodis and Kučinskas 2023). And indeed while in theory measurement error can account for the overreaction of individual expectations to micro news, it cannot explain the underreaction of individual expectations to macro news, nor the overreaction to lagged micro news, both documented by Born et al. (2022a).[12]

# 3 This time is different, maybe

Before turning to current theories which attempt to account for the failure of FIRE, a brief historical digression seems warranted. For at about the same time as the rational-expectations revolution changed macroeconomics for good, a fairly large number of studies had already turned to survey data in order to test the rationality of expectations as reported by survey participants. Sheffrin (1996) reviews this literature which tests survey expectations for unbiasedness, efficiency, and forecast-error non-predictability, properties which one would expect to be satisfied under rational expectations. In an early (perhaps the first) study Pesando (1975) rejected rationality for the Livingston survey and started a debate that was never really settled despite a large research effort spanning almost two decades (see, for instance, Mullineaux 1978; Swidler and Ketcher 1990; Bondt and Bange 1992). What is more, this debate was not limited to evidence from the Livingston survey and the contributions to this debate were, by the standards of the profession, well-published. For instance, in an influential article published in the *American Economic Review*, Lovell (1986) discusses a number of rationality tests conducted on sales-expectations data. He writes:

[12]See Born et al. (2022a) for further discussions. They also run a number of additional robustness tests which suggest that measurement error is unlikely to drive the overreaction to micro news.

> My survey of a number of empirical studies of expectations is not supportive of the commonly invoked rational expectations hypothesis. Quite the contrary, **if the cumulative evidence is to be believed, we are compelled to conclude that expectations are a rich and varied phenomenon that is not adequately captured by the concept of rational expectations**; while the predictions of some forecasters may be characterized as rational, in other instances the assumption of rationality is clearly violated. (Lovell 1986, p. 120, emphasis added)

This verdict is no exception. Sheffrin concludes his survey of this literature as follows: "On the whole, survey data do not support the rational expectation hypothesis" (Sheffrin 1996, p. 21). Even more striking in the present context, we note that some of the earlier work put forward evidence very similar to that discussed in Section 2.3 above. Nordhaus (1987), Ehrbeck and Waldmann (1996), and Lahiri and Sheng (2008) all estimated variants of Specification (1) and documented "overreaction" and "underreaction" to news in all but name. Yet, while very well published and cited, these results seem to have been largely forgotten over time—at least they are not referenced in the more recent studies discussed above.

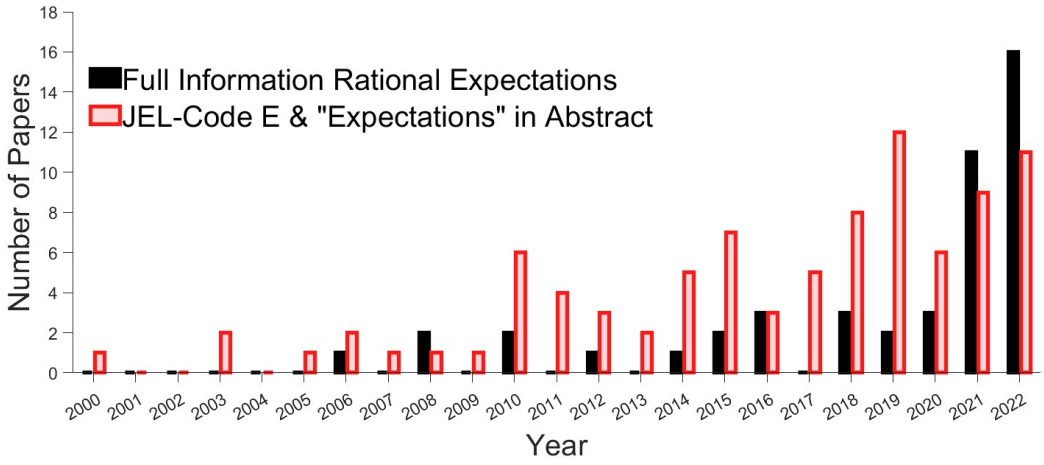
More importantly still, macroeconomics as a whole was unimpressed, carrying on under the rational-expectations banner. The likely reason is a strong tradition in economics to focus on peoples' behavior rather than on what they say. It goes back to the revealed preference theory by Samuelson (1938) and led many economists to dismiss survey evidence outright:

> Like utility, expectations are not observed, and **surveys cannot be used to test the rational expectations hypothesis**. One can only test if some theory, whether it incorporates rational expectations or, for that matter, irrational expectations, is or is not consistent with observations. (Prescott 1977, p. 30, emphasis in original)

Prescott's assertion—arguably widely shared by economists at the time—raises the question of what counts for an observation or, more generally, what science considers a relevant phenomenon. Normal science, as philosopher of science Thomas Kuhn explains in his influential essay on the "Structure of Scientific Revolutions," operates under a paradigm's law and theories, which restricts "the phenomenological field accessible for scientific investigation at any time" (Kuhn 2012). On these grounds, it is possible to dismiss new "evidence" as irrelevant and, in fact, for a good reason:

> By ensuring that the paradigm will not be too easily surrendered, resistance guarantees that scientists will not be lightly distracted and the anomalies that

Figure 2: Research on expectations in macroeconomics




Notes: Solid bars are the number of papers in the Quarterly Journal of Economics, American Economic Review, Journal of Political Economy, Journal of Finance, Review of Economic Studies, Review of Financial Studies, Journal of Financial Economics, Journal of Economic Literature, Review of Economics and Statistics, and Journal of Monetary Economics which contain the term "Full Information Rational Expectations" according to Google Scholar; shaded bars are the number of papers in AEA journals with JEL code E ("Macroeconomics and Monetary Economics") which feature the term "Expectations" in their abstract.

> lead to paradigm change will penetrate existing knowledge to the core. (Kuhn 2012, p. 65)

At the risk of making a premature judgment, it seems to us that this time is different. The evidence discussed in Section 2.3 above and the anomalies which are documented by this line of research may indeed "penetrate existing knowledge to the core." Why should things turn out different this time? According to Kuhn there "is probably no fully general answer" to the question of what "makes an anomaly seem worth concerted scrutiny" and thus eventually leads to a paradigm shift.

Our assessment is merely based on the observation that survey expectations have staged a comeback. By now, it seems fair to say, they are accepted as relevant observations (see, for instance, D'Acunto et al. 2021; Andre et al. 2022; Bachmann et al. 2022; Enders et al. 2022; Weber et al. 2022). At the same time, macroeconomic research has increased focus on the expectation-formation process since the global financial crisis. To illustrate this, Figure 2 shows data for the period 2000–2022. For each year, it displays the number of research papers published in highly regarded journals about "Full Information Rational Expectations" according to Google Scholar. The list of journals is given in the figure notes. The (black) solid bars in the figure show a clear pattern: up until the global financial crisis

there were hardly any papers on the topic. During the last couple of years, the picture changes fundamentally. A very similar pattern emerges if we consider instead the number of papers in the field of "Macroeconomics and Monetary Economics" (JEL code E) which feature the term "Expectations" in their abstract. They are measured by the (red) shaded bars in the figure. Of course, ever since the rational-expectations revolution, almost all papers in macroeconomics assume rational expectations. But to the extent that these papers do not question this assumption but rather take it for granted, the terms "Expectations" or "Full Information Rational Expectations" will generally not feature in the abstract.

Hence, we conclude that there is a strong uptick in macroeconomic research which is in one way or another concerned with the expectation-formation process. What's different this time? It is perhaps no coincidence that the recent trend in research can be traced back in time to the global financial crisis. After all, as discussed in the introduction, economic crises tend to make the profession more open to new ideas, thus preparing the ground for an intellectual response to the crisis. That said, it is clear that a new trend in research must also appear conceptually compelling, or else it would not be as persistent as it is. In the following, we summarize recent and ongoing work in order to make exactly that case.

# 4 Alternative models of expectation formation

The previous section has shown that the recent literature which questions the FIRE paradigm has gained momentum since the global financial crisis. This is particularly noteworthy because the earlier survey-based work of the 1970s and 1980s did little to change the rational-expectations paradigm. We are not in a position to judge whether the recent survey-based evidence is more compelling. But the regressions above—by documenting overreaction and underreaction to different types of news and at different levels of aggregation—guide recent modeling efforts which depart from rational expectations. Such efforts are essential because it "takes a model to beat a model", as it is often said in economics; or because of the way in which scientists respond to crises according to Kuhn:

> Though they may begin to lose faith and then to consider alternatives, they do not renounce the paradigm that has led them into crisis . . . : once it has achieved the status of paradigm, a scientific theory is declared invalid only if an alternative candidate is available to take its place. (Kuhn 2012, p. 77)

Against this background, we now briefly discuss current attempts to develop models which may account for the empirical evidence presented in the previous section. As discussed in Section 2.1, the commonly made observation of an underreaction to news at the *aggregate*

level can be reconciled with the theory of rational expectations. In fact, based on their empirical evidence regarding aggregate variables, Coibion and Gorodnichenko (2015) suggest a theoretical explanation featuring noisy and dispersed information, thereby shying away from discarding rational expectations. The effects of noisy and dispersed information, including the role of resulting higher-order expectations, are studied by a large literature (see, e.g., Morris and Shin 2003; Woodford 2003; Angeletos and Lian 2016). Kohlhas and Walther (2021) extend the dispersed-information cum rational-expectations setup by developing a model in which agents rationally allocate costly and hence limited attention mostly to those variables that are particularly important for them. As long as these variables are procyclical, agents become overly optimistic regarding output in booms, as found in the data. At the same time, the model inherits the underreaction of aggregate expectations.

Yet, the evidence of over- or underreaction at the level of *individual* forecasters discussed in Section 2.3 is inconsistent with rational expectations. This insight guides research efforts that account for behavioral 'biases', i.e., deviations from rational expectations, in the individual expectation-formation process. A relatively large group of models introduces various cognitive limitations that induce an underreaction to news. These limitations prevent individuals from grasping the whole effect of economic disturbances or from observing these disturbances fully in the first place. In models of level-k thinking, agents do not consider the entire chain of other agents' reactions to innovations, as each individual believes that all others are less sophisticated than themselves (e.g., Farhi and Werning 2019; García-Schmidt and Woodford 2019). As a result, their expectations underreact to current news.[13] Angeletos and Sastry (2021) disentangle the precision of agents' information and their beliefs about the information of others, which is linked in standard models of dispersed information. Specifically, agents counterfactually assume, akin to level-k thinking, that a fraction of other agents is less informed than themselves. This again leads to an underreaction of individual expectations. Similarly, cognitive discounting introduces a form of myopia that causes an underestimation of the current and future reactions to innovations (Gabaix 2020). Carroll et al. (2020) put forward a model of sticky expectations—imperfect attention to aggregate shocks—to account for evidence of sluggish consumption dynamics. Likewise, Bouchaud et al. (2019) demonstrate that a version of sticky expectations, modeled as partial updating, can generate stock-return predictability. Given the focus on an underappreciation of the effects of current information, however, these models don't speak to the recently observed overreaction to news at an individual level.

[13]Some versions of this framework also feature a possibility of overreacting, which is, however, mostly seen as a 'bug'. See Angeletos and Lian (2022) for an overview.

Models that allow for such an overreaction typically introduce a cognitive distortion that lets agents overweight the likelihood of future states of nature that are covered in these news. That is, on receiving information about the development of a certain variable, agents overestimate the probability that this information is indeed correct, the relation of this development to other variables, or its translation into the future. Early proposals include Metzler (1941), who assumed an extrapolation from past observations that can lead to overreactions and thereby contribute to economic fluctuations. In the same spirit, Fuster et al. (2010, 2012) develop a model of "natural expectations" in which agents use only recent realizations of autocorrelated variables to construct forecasts. If future values depend on realizations that have occurred in the longer past, agents tend to overreact to recent realizations. Chahrour et al. (2021) introduce distortions in the expectation-formation process through firms' reliance on potentially unrepresentative media reporting. Shiller (2017) suggests that agents react (too) strongly to narratives. Azeredo da Silveira and Woodford (2019) develop a model of noisy information, arising from a memory constraint. Similar to models of rational inattention, this constraint limits the complexity of stored memory. The authors additionally impose an information constraint concerning the memory of past cognitive states. As a result, recent news is disproportionately weighted, leading to overreactions. Similarly, diagnostic expectations (Bordalo et al. 2019, 2020) let agents overreact to news as it increases their subjectively held probabilities of those states that became more likely in light of recent news, above the objective probabilities. Thus, receiving positive news leads to an overrevision of beliefs. This theory has its psychological foundations in the assumption that news makes certain states of the world more salient to individuals.[14] More generally, Ba et al. (2023) show how bounded rationality can give rise to over- or underreaction depending on the complexity of the state space, the precision of signals, and employed priors. To square findings of an overreaction to news at an individual level with aggregate underreactions, these models can be combined with the dispersed-information structure discussed in Section 2.1. In fact, in light of their empirical evidence, authors such as Bordalo et al. (2020) favor a combination of non-rationality with noisy information. In this way, individual expectations overreact due to behavioral biases but agents' lack of knowledge on the correlation between information sets lets aggregate expectations underreact. However, it remains a challenge for the discussed models to explain the simultaneous presence of over- and underreactions at the individual level, as recently observed by a couple of authors (see Section 2.3).

[14] L'Huillier et al. (2023) incorporate diagnostic expectations into a standard New Keynesian model, representing efforts to introduce new models of expectation formation into mainstream models of the business cycle.

A few papers take up this issue by providing a theoretical framework that is able to predict overreactions to news in some instances and an underreaction in others, both at the individual level. Angeletos et al. (2021) combine absolute overconfidence with dispersed information and over-extrapolation of agents to explain under- and overreactions at different points in time. That is, agents assume that movements in certain variables are more persistent than they actually are. With this combination, the authors are also able to replicate their empirical observation of initially underreacting and then overshooting average forecasts. Broer and Kohlhas (2023) show in a partial-equilibrium model with dispersed information that over-confidence in the precision of private information can lead to over- and underreactions of expectations depending on the type of news. Specifically, agents are overly confident in the precision of their private information (absolute overconfidence), such that, relative to a rational benchmark that considers the noise present in this information, they overrevise their expectations upon receiving news. At the same time, agents are overly confident in the precision of their information relative to that of other agents (relative overconfidence). They, therefore, attach too low a weight to public news that aggregates the expectations and actions of others and hence underreact to these signals. Alternatively, misperceptions about the structure of the economy may lead to under- and overreactions, again depending on the type of news. Developing a general-equilibrium model focusing on firm expectations regarding their own output, Born et al. (2022a) theoretically show that 'island illusion' can account for the observed differential reaction of firms to micro news (private and relating to the individual firm) and macro news (public and about aggregate variables). In particular, firms underestimate the importance of aggregate variables for their own business. Taking the general-equilibrium effects of innovations in supply and demand into account, firms then overreact to micro news and underreact to macro news when forecasting their own sales, as found in the data.

In sum, at the current juncture, a number of alternatives to the expectation-formation process are being put forward. We think that these alternatives appear promising. Yet, the profession still needs to settle on an alternative theory that can, on the one hand, account for the deviations from FIRE discussed above, and is, on the other hand, simple enough to be embedded in a full-fledged model of the macroeconomy.

# 5 Conclusion

Survey evidence testifies against the rational-expectations hypothesis. In the 1970s and 1980s, however, the profession dismissed it as irrelevant observations for judging the validity of the hypothesis. This time may be different. We document a recent trend in research

about expectations in macroeconomics that takes survey data seriously, uses it to test model predictions, and informs new models of the expectation-formation process.

We put forward two potentially complementary factors for why this time the survey evidence may have a lasting impact on macroeconomics. First, as with earlier shifts in macroeconomics, the recent developments may be understood as an intellectual response to crisis times, specifically the global financial crisis. Second, there is a relatively rich body of theoretical work which puts forward specific alternatives of the expectation-formation process. Parts of this work, in turn, build on a rich literature in behavioral economics that has flourished largely outside of macroeconomics during the last few decades.

In conclusion, we flag a caveat. At the time of writing it is too early to tell whether we are actually witnessing a second expectations revolution in macroeconomics. The intellectual appeal of the rational-expectations hypothesis that has captivated generations of researchers is still strong. After all—and despite appearances to the contrary—it reflects a humble attitude of economists: that they know the world no better than the humans that populate it.

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