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Abstract

This paper explores whether professional macroeconomic forecasters manipulate their forecasts to influence voting outcomes. We model a referendum in which a voter chooses between two policies. The voter relies on a forecaster to learn about the macroeconomic consequences of the policies. The forecaster favours one of the policies and faces a choice between lying to influence the vote and maintaining a reputation for honesty. The model yields three predictions. First, the forecaster is more likely to bias the forecast associated with the policy that is (i) less likely to be selected in the referendum and (ii) associated with greater macroeconomic uncertainty. Second, as the influence of the forecast on the voter's decision increases, so does the likelihood that the forecaster lies. Third, the forecaster sticks to her biased forecasts even after the referendum, at least for some time. We show that these predictions are empirically supported in the context of the Brexit referendum.

JEL-Codes: D720, D820, E270, H300.

Keywords: Brexit, interest groups, forecaster behaviour, voting.

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1 Introduction

Referendums often address issues of great economic relevance. Recent examples include the European Union (EU) membership referendum held in the United Kingdom (UK), the referendum in Greece on the measures to tackle the debt crisis, and the independence referendum in Catalonia. The public debates in the weeks leading to these consultations often focus on the economic consequences of the vote. Estimates published by professional macroeconomic forecasters play a key role in these debates. Even though forecasts require a high degree of expertise, they can be easily communicated to, and understood by, voters. Voters, in turn, can use forecasts to make up their minds before casting their ballots. In many public debates, economic forecasts are taken as given, and not much thought is given to the interests of the institutions publishing these forecasts. We question this approach and explore whether macroeconomic forecasters bias their forecasts to influence voting outcomes.

We build a model of a forecaster's behaviour at the time of a referendum. The referendum asks a voter to choose between the status quo and a new policy. The forecaster publishes macroeconomic forecasts associated with the two policies, and the voter relies on this information to assess the alternatives. The forecaster has an interest in the outcome of the referendum and can bias forecasts to influence the voter and steer the referendum outcome. In the tradition of Kreps and Wilson (1982) and Milgrom and Roberts (1982), deviating from honest behaviour, i.e., biasing the forecast, brings a short-term gain but may result in a long-term damage to the forecaster's reputation.

The model yields three sets of testable predictions. First, a strategic forecaster is more likely to bias forecasts associated with a policy that is (i) less likely to be selected in the referendum and (ii) associated with greater macroeconomic uncertainty. Second, as the influence of the forecast on the voter's decision increases, so does the likelihood that the forecast is strategically manipulated. Third, a strategic forecaster sticks to her biased forecasts in the short term (e.g., days) after the referendum, whereas her forecasts gradually become unbiased in the medium term (e.g., months).

We test the model's predictions in the context of the 2016 EU membership referendum, also known as the Brexit referendum. The referendum asked voters to choose between the status quo (Remain) and a new policy (Leave). The Brexit referendum is a fitting application for a variety of reasons. First, before the vote, the potential impact of the Leave option on the economy was a major issue of discussion. Second, the consequences of the Leave option were difficult to predict for voters since no country had ever previously left the EU. Third, some, but not all, forecasters had their interests threatened by the Leave option. Fourth, and importantly for our empirical strategy, the outcome of the referendum was unexpected. Our data cover a sample of forecasters that publish short-term GDP growth forecasts in the United Kingdom on a monthly basis.

We observe forecasts published before the announcement of the referendum, between the announcement and the vote, and after the vote. For the period before the vote, we observe individual forecasts associated with Remain, whereas forecasts associated with Leave are available only at an aggregate level. To obviate this limitation, we rely on individual forecasts published a few days after the vote as proxies for those published right before. Our theoretical model supports this way of proceeding, as it predicts that estimates produced by a strategic forecaster are sticky in the short term.[1]

We compare forecasts released by partisan forecasters, that is, institutions exposed to financial loss in the event of Brexit, and forecasts released by nonpartisan forecasters, that is, institutions arguably indifferent to the two alternatives. We rely on four proxies of partisanship: (i) being a financial institution – our preferred measure, (ii) being in the City of London's financial district, (iii) being exposed to stock market declines in connection with the referendum results, and (iv) having a large fraction of capital held by UK-based shareholders. The idea underlying the empirical strategy is straightforward: forecasts produced by nonpartisan forecasters should reflect those that partisan forecasters would have released without the incentive to influence voters.

In the weeks leading to the referendum, Leave was considered less likely to win and came with more perceived macroeconomic uncertainty than did Remain. According to our first prediction, partisan forecasters were thus more likely to bias the forecasts associated with Leave than those associated with Remain. We indeed observe that financial institutions released more pessimistic and more incorrect forecasts associated with Leave than did their nonpartisan counterparts; however, we do not find evidence that the two groups were releasing different estimates associated with Remain. The magnitude of the bias associated with Leave was sizable. On average, financial institutions overestimated the negative impact of Brexit on short-term GDP growth by 0.73 percentage point more than did other forecasters. The results are robust to the alternative measures of partisanship specified above.

We next consider the role of the strength of a forecaster's influence on voters. In line with our second prediction, we observe that the bias is significantly heterogeneous across financial institutions that enjoyed different amounts of coverage in UK media outlets. Among financial institutions, forecasters who were historically more likely to be mentioned in newspapers overestimated the negative impact of Brexit on GDP growth by an additional 0.4 percentage point compared to less influential financial institutions. As further evidence, we observe that forecasters often mentioned in newspapers consumed by a relatively large fraction of swing voters overestimated the negative impact of Brexit by 0.5 percentage point more than did forecasters seldom mentioned in such outlets.

Our last prediction concerns the persistence of bias after the referendum. We show

[1] We observe in the data that, at an aggregate level, forecasts right before and right after the referendum are identical. This observation lends additional support to the aforementioned method of proceeding.

that, in line with this prediction, the bias is strong in July 2016, that is, immediately after the referendum. In fact, at the aggregate level and for the subset of forecasters for which we have individual forecasts on Leave before the referendum, the forecasts were the same right before and right after the referendum. Additionally, in line with our prediction, we show that the bias gradually disappeared: by the end of 2016, the bias about vanished.

Thus far, we have discussed evidence in support of the mechanism highlighted in the theoretical model. We also provide evidence that contradicts alternative mechanisms. One might worry, for instance, that forecasters more exposed to Brexit honestly published pessimistic views because the data available, or the statistical models adopted, somehow depended on the stakes in the game. This conjecture requires that whether a forecaster is more or less influential should not correlate with the bias – holding the level of stakes constant – or that more influential forecasters are less likely to release biased estimates. However, the evidence that the most incorrect forecasters are those with a historical record of being most influential to the public is inconsistent with this alternative conjecture. One might also be concerned that influential forecasters published pessimistic views because of market incentives – i.e., because consumers of media outlets in which these forecasters were mentioned *wanted* to read negative news about Brexit. However, our results document the opposite pattern: GDP growth in the event of Brexit was underestimated more by forecasters who were often mentioned in newspapers catering to Leave voters than by forecasters often mentioned in newspapers catering to Remain voters.

We further strengthen the relationship between bias and the incentive to influence the vote by excluding the possibility that similar results could be obtained in periods of high economic uncertainty or economic downturns not connected with a referendum in the UK. We do not find any evidence that financial institutions published estimates significantly different from those of other forecasters at the beginning of the 2008 financial crisis, at the time of the referendum on the EU Constitution that French voters did not approve in 2005 or after the terrorist attack on the World Trade Center in 2001. Moreover, when we look past the period after the referendum, we do not find any evidence that financial institutions and other forecasters published significantly different estimates of the impact of Brexit on GDP.

We extend two strands of the literature. The first strand includes studies showing that special interest groups (see, e.g., Baron, 1994; Grossman and Helpman, 1996; Besley and Coate, 2001) and the media (see, e.g., Enikolopov et al., 2011; DellaVigna et al., 2014; Qin et al., 2018) are active political economy players and may release biased information to affect individual beliefs and, in turn, voting behaviour (Martin and Yurukoglu, 2017; Durante et al., 2019). Our theoretical and empirical results also suggest that macroeconomic forecasters exploit their information oligopoly to influence voter beliefs. The second is the strategic literature on the behaviour of forecasters. Laster et al. (1999)

develops a theoretical model in which forecaster payoffs are based on two criteria: the accuracy and the ability to generate publicity for the forecasts. A trade-off exists between the two, as efforts to increase publicity compromise accuracy (see also Croushore, 1997; Ottaviani and Sørensen, 2006; Marinovic et al., 2013, for more on strategic trade-off for forecasters). Our theoretical model proposes an alternative trade-off and shows that macroeconomic forecasters' strategic behaviour can also depend on a political bias arising from an attempt to influence voters.

2 Theoretical Framework

We model macroeconomic forecasting immediately before a referendum as a game with three players: a macroeconomic forecaster (she), a voter (he) and the market.

Policies and Forecasting: We consider two policies, called Leave (ℓ) and Remain (r). Each policy $p \in \{\ell, r\}$ is associated with a distribution $G(\cdot|p)$ over macroeconomic outcomes. Each distribution $G(\cdot|p)$ is uniform and has support $\{\overline{p}, \underline{p}\}$, where $\overline{p} > \underline{p}$. The two distributions are independent of each other.

At the onset, Nature draws a pair of outcomes (y_ℓ, y_r) according to the distributions $G(\cdot|\ell)$ and $G(\cdot|r)$. The forecaster then observes (a signal perfectly correlated with) the outcomes and publishes a pair of forecasts $(f_\ell, f_r) \in \left\{\overline{\ell}, \underline{\ell}\right\} \times \{\overline{r}, \underline{r}\}$.[2] This is the only strategic choice of the forecaster; hence, the strategy of the forecaster, denoted π, is a set of probability distributions $\pi(\cdot|\cdot)$ over forecasts conditional on the outcomes observed.

Referendum: After the forecaster has published her forecasts, the voter selects a policy. Let p° denote the policy selected and y_{p° denote the outcome associated with p°. The voter's payoff is:

$$y_{p^\circ} + \sigma_{p^\circ},$$

where the second term captures the voter's ideological bias and depends on the policy selected. We normalize $\sigma_\ell = 0$ and refer to σ_r as σ: the voter is thus biased in favour of Remain if $\sigma > 0$ and in favour of Leave if $\sigma < 0$. The bias is drawn according to a distribution with cumulative density function $F(\cdot)$ with full support on an interval $[\underline{\sigma}, \overline{\sigma}]$ and median 0.[3] The bias is private information of the voter.

The voter thus favours Remain if:

$$\mathbb{E}(y_r|(f_\ell, f_r)) + \sigma \geq \mathbb{E}(y_\ell|(f_\ell, f_r)),$$

[2] The uniform distribution of outcomes and the perfect observability of outcomes for the forecaster simplify the analysis without – in our view – a significant loss in generality.

[3] Fixing the median at 0 is just a normalization.

and favours Leave otherwise.[4] The voter is naive in that he takes forecasts at face value: he believes $\mathbb{E}(y_p|(f_\ell, f_r)) = f_p$ for each policy p.[5] In line with this belief, we assume that the voter selects Remain if

$$f_r + \sigma \geq f_\ell,$$

and selects Leave otherwise. Once a policy p° is selected, the outcome y_{p° is publicly observed, and the game ends.

Reputation: At the onset, the market believes the forecaster to be honest with some probability $\mu_0 \in (0, 1)$ and strategic otherwise. The market expects the forecaster, if honest, to publish forecasts equal to the outcomes observed and, if strategic, to follow some strategy π^e. After observing forecasts (f_ℓ, f_r) and outcome y_{p°, the market updates the probability assigned to the forecaster being honest to $\mu((f_\ell, f_r), y_{p^\circ}, \pi^e)$, according to Bayes rule. We refer to μ as the reputation of the forecaster.

Forecaster Payoff and Optimal Strategies: If the forecaster publishes forecasts (f_ℓ, f_r) and the voter selects policy p°, the forecaster obtains a payoff equal to

$$\mu((f_\ell, f_r), y_{p^\circ}, \pi^e) + \rho_{p^\circ},$$

where the second term captures the forecaster's bias. We normalize $\rho_\ell = 0$ and refer to ρ_r simply as ρ. The value of ρ is a parameter of the game. For a pair of outcomes (y_ℓ, y_r), the forecaster's expected reputation associated with forecasts (f_ℓ, f_r) is

$$M((f_\ell, f_r), (y_\ell, y_r), \pi^e) \equiv (1 - F(f_\ell - f_r))\, \mu((f_\ell, f_r), y_r, \pi^e) + F(f_\ell - f_r)\mu((f_\ell, f_r), y_\ell, \pi^e),$$

and her expected payoff is thus:

$$u((f_\ell, f_r), (y_\ell, y_r), \pi^e) \equiv M((f_\ell, f_r), (y_\ell, y_r), \pi^e) + (1 - F(f_\ell - f_r))\, \rho.$$

We say that a strategy π^* is *optimal* if, for every outcome realization, the strategy maximizes the forecaster's expected payoff conditional on the market expecting $\pi^e = \pi^*$.

Parameter Restrictions: To match the setting of the Brexit referendum, we restrict our attention to parameter values that satisfy:

(i) $\overline{\ell} - \underline{\ell} \geq \overline{r} - \underline{r}$;

[4] We make an arbitrary assumption regarding the voter's preference in the zero-probability event $\sigma = \mathbb{E}(y_\ell|(f_\ell, f_r)) - \mathbb{E}(y_r|(f_\ell, f_r))$.

[5] The naive-voter assumption simplifies the analysis. In Section 2.3, we show that, in the context of a numerical example, all of our predictions also hold with a fully rational voter.

(ii) $\underline{r} > \overline{\ell}$;

(iii) $\overline{\sigma} > \overline{r} - \underline{\ell} > \underline{r} - \overline{\ell} > \underline{\sigma}$.

In other words, Leave is associated with at least as much macroeconomic uncertainty as Remain is (Assumption (i)). Whereas Remain enjoys better odds (Assumption (ii)), the referendum outcome is uncertain (Assumption (iii)). To fit our empirical exercise, we also assume that the forecaster favours Remain:

(iv) $\rho > 0$.

Assuming a strong initial reputation for honesty of the forecaster simplifies the analysis at no cost to generality:

(v) $\mu_0 > \frac{2(1-F(\overline{\ell}-\overline{r}))}{2-F(\overline{\ell}-\overline{r})}$.

2.1 Analysis

Here, we characterize the forecaster's optimal strategy and present the first two model predictions. We first establish that the forecaster never lies in a way that hurts the odds of Remain. This is intuitive: the forecaster prefers Remain (Assumption (iv)) and lying hurts the reputation of the forecaster. All of the proofs for the results in this and the next subsection are in Appendix A.

Lemma 1. *Every optimal strategy is such that if the forecaster observes $y_\ell = \underline{\ell}$, then she publishes $f_\ell = \underline{\ell}$; if instead she observes $y_r = \overline{r}$, then she publishes $f_r = \overline{r}$.*

Lemma 1 restricts the set of candidate optimal strategies and ensures a relatively straightforward proof for the following lemma.

Lemma 2. *An optimal strategy exists and is unique.*

A complete characterization of the optimal strategy for all parameter values is lengthy, as the optimal strategy can involve one or more of five different "lies": after observing outcomes $(\overline{\ell}, \overline{r})$ and/or outcomes $(\underline{\ell}, \underline{r})$, the strategy could call for forecasts $(\underline{\ell}, \overline{r})$; after observing $(\overline{\ell}, \underline{r})$, the strategy could require forecasts $(\underline{\ell}, \underline{r})$, $(\overline{\ell}, \overline{r})$, or even $(\underline{\ell}, \overline{r})$. Here, we only present the optimal strategy for a numerical example.

Example 1. *Let $\sigma \sim U[-1, 1]$, $\mu_0 = 0.95$, $\overline{r} - \underline{r} = \overline{\ell} - \underline{\ell} = 0.1$, and $\underline{r} = \overline{\ell} + 0.6$. Figure 1 describes the probabilities of different types of "lies" according to the optimal strategy for different values of ρ.[6] If $\rho \leq 1.9$, the forecaster does not lie. For $\rho \in (1.9, 15.4]$, the forecaster lies about Leave but not about Remain. Only for very large biases ($\rho > 15.4$) does the forecaster lie about both policies.*

[6] Lemma 1 ensures that the probabilities shown in the graph fully describe the optimal strategy. The calculations for this and all of the other examples can be found in Appendix B.

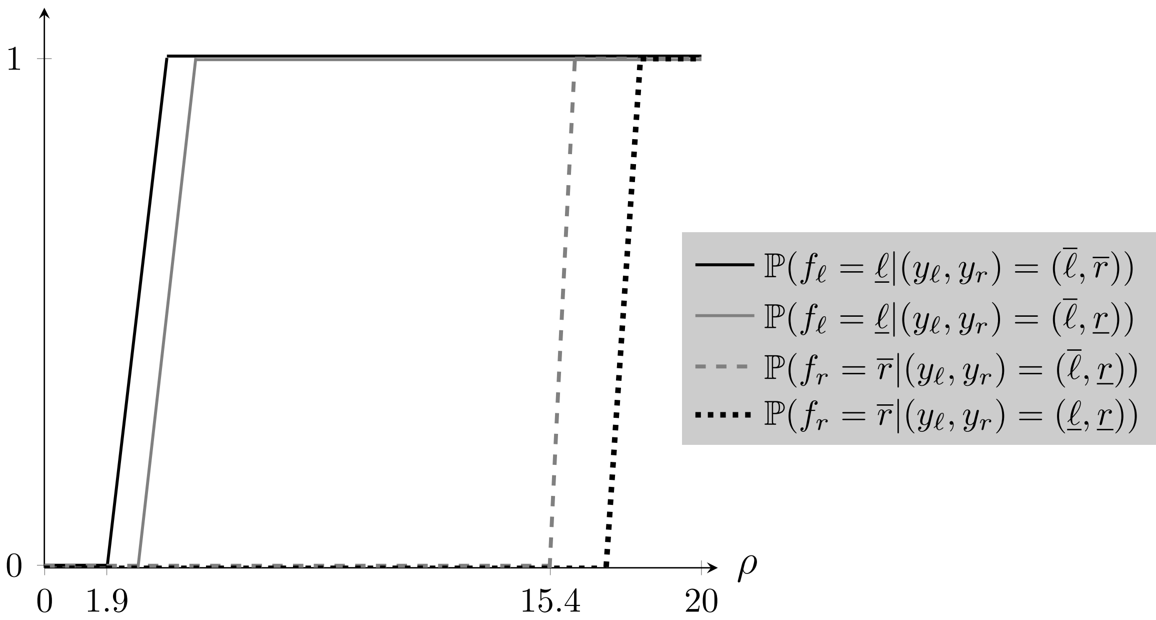


Figure 1

In the example, a strategic forecaster lies *selectively*: for a sizeable interval of parameter values, she lies about Leave but not about Remain, whereas the opposite (lying only about Remain) does not occur for any parameter value. The intuition is clear. The forecaster has two ways to manipulate her forecast in order to favour Remain: exaggerating the demerits of Leave (i.e., publishing $\underline{\ell}$ after observing $\overline{\ell}$) or the merits of Remain (i.e., publishing $\overline{r}$ after observing $\underline{r}$), or both. The former option is more effective and less dangerous than the latter. A lie about Leave is more effective because it is associated with at least as much macroeconomic uncertainty as is Remain (Assumption (i)). To see the point, note that if a policy p is associated with no uncertainty, that is, if $\underline{p} = \overline{p}$, then the macroeconomic forecast does not influence the referendum. A lie about Leave is less dangerous than a lie about Remain because Remain enjoys better odds (Assumption (ii)). After all, the market can determine whether the forecaster lied about y_p only if y_p is observed, that is, only if the referendum selects policy p.

Selective lies are not a special feature of the example. Our main proposition establishes that, in general, the forecaster lies selectively.

Proposition 1. *The optimal strategy π^* requires the forecaster to lie about Leave at least as often as about Remain; that is,*

$$\pi^*((\underline{\ell}, \overline{r})|(\overline{\ell}, \overline{r})) + \pi^*((\underline{\ell}, \underline{r})|(\overline{\ell}, \underline{r})) \geq \pi^*((\overline{\ell}, \underline{r})|(\overline{\ell}, \overline{r})) + \pi^*((\underline{\ell}, \underline{r})|(\underline{\ell}, \overline{r})).$$

Proposition 1 yields the first testable prediction of our model.

Prediction 1. *A partisan forecaster is more likely to lie about Leave than about Remain.*

We next consider how the forecaster's optimal strategy varies with the magnitude of her influence on the vote. The influence is determined by the distribution of the voter's bias, $F(\cdot)$, and by the uncertainty about macroeconomic outcomes: for each policy p, the larger the difference $\overline{p} - \underline{p}$ is, the stronger is the forecaster's influence. It is easy to see that if the influence of the forecaster is weak (because either the distribution $F(\cdot)$ is dispersed or the differences $\overline{\ell} - \underline{\ell}$ and $\overline{r} - \underline{r}$ are small), the forecaster has no reason to risk her reputation. For intermediate degrees of influence, the optimal strategy requires selective lies (see Proposition 1). For a sufficiently strong influence, the optimal strategy requires publishing $(\underline{\ell}, \overline{r})$ regardless of the outcomes observed. We illustrate this with an example.

Example 2. *We consider here the parameter values of Example 1 with two modifications: we fix $\rho = 20$ and let $\sigma \sim U[-\sigma^\dagger, \sigma^\dagger]$ for some $\sigma^\dagger > 0$ to show the effect of a more or less concentrated distribution of the voter's bias. Figure 2 illustrates that the probabilities differ according to the equilibrium strategies for different values of $\sigma^\dagger$. Larger values of $\sigma^\dagger$ are associated with lower odds of a lie: for $\sigma^\dagger \leq 2.2$, the forecaster does not lie; for $\sigma^\dagger \in (2.2, 15.4)$, the forecaster lies only about Leave; and for $\sigma^\dagger > 15.4$, the forecaster lies about both policies.*

The second prediction follows from the discussion above and the example.

Prediction 2. *The stronger the influence of the forecast on the voter's choice is, the more likely a partisan forecaster is to bias her forecast.*

In the next two subsections, we modify the baseline model. In Subsection 2.2, we let the forecaster publish an additional forecast after the referendum. The analysis of this richer model yields our third and last prediction concerning the bias in the forecasts published *after* the referendum. In Subsection 2.3, as a robustness check, we consider a fully rational voter.

2.2 Forecasts Before and After the Referendum

Here, we modify the model to include forecasts published after the referendum. Unless otherwise specified, every aspect is the same as in the baseline model.

Model. Before the referendum, the forecaster observes the signals $(s_\ell, s_r) \in \{\overline{\ell}, \underline{\ell}\} \times \{\overline{r}, \underline{r}\}$.

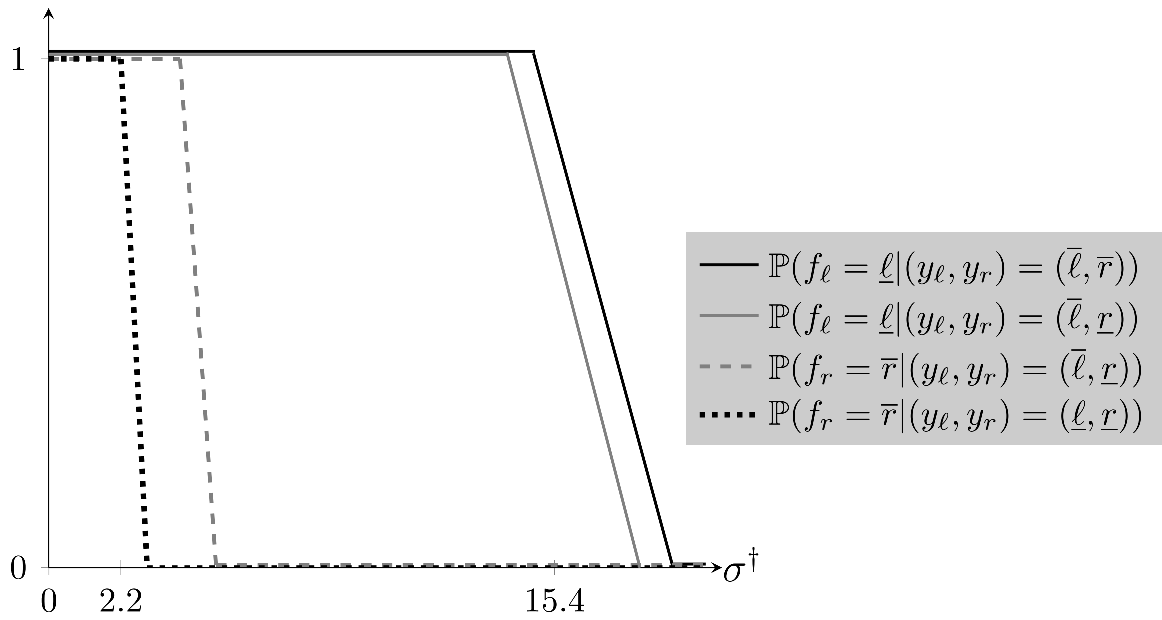


Figure 2

The signals are partially correlated with the outcomes.[7] For each $p \in \{\ell, r\}$,

$$\mathbb{P}(s_p = y_p) = 1 - \epsilon,$$

where $\epsilon \in (0, 1/2)$. As in the baseline model, the forecaster publishes a pair of forecasts (f_ℓ, f_r), and the naive voter selects some policy p°. Afterwards, the forecaster observes an additional signal $s'_{p^\circ} \in \{\overline{p^\circ}, \underline{p^\circ}\}$. For some $\eta \in (\epsilon, 1]$, the distribution of the additional signal satisfies:[8]

$$\mathbb{P}(s'_{p^\circ} = y_{p^\circ}) = 1 - \epsilon; \qquad \mathbb{P}(s'_{p^\circ} = y_{p^\circ}|s' \neq y_{p^\circ}) = 1 - \eta.$$

The additional signal has the same precision as the first signal. The signals s'_{p° and s_{p° could be partially ($\eta \in (\epsilon, 1)$) or perfectly ($\eta = 1$) correlated. The distribution of signals is common knowledge.

After observing the additional signal, the forecaster publishes an additional forecast $f'_{p^\circ} \in \{\overline{p^\circ}, \underline{p^\circ}\}$. The market observes all of the forecasts, as well as the outcome associated with the policy selected by the voter. The market then forms a belief about the type of forecaster.[9] As in the baseline model, the payoff of the forecaster is the sum of her final reputation and, in case Remain is selected, the additional term ρ. The forecaster's strategy is composed of (i) a set of probability distributions $\pi(\cdot|\cdot)$ over pairs of forecasts

[7] Allowing the forecaster observe the outcomes perfectly is an innocuous simplification in the baseline model but not in this version of the model.

[8] These conditions together imply $\mathbb{P}(s'_{p^\circ} = y_{p^\circ}|s_{p^\circ} = y_{p^\circ}) = 1 - \frac{\epsilon(1-\eta)}{1-\epsilon}$.

[9] The market expects that, if honest, the forecaster truthfully reports the additional signal.

(f_ℓ, f_r) conditional on the signals s_ℓ and s_r and (ii) a set of probability distributions $\pi'(\cdot|\cdot)$ over forecasts f_{p° conditional on the selected policy p°, the signals s_{p° and s'_{p° and the original forecasts (f_ℓ, f_r). See the appendix for a definition of the optimal strategy.

Analysis. We are interested in the persistence of the forecast bias, namely, whether the forecaster has strategic reasons to bias the additional forecast. The strategic forecaster chooses the additional forecast purely with an eye to her reputation: this forecast comes too late to influence the voter. Our first result is immediate: if the signals s'_{p° and s_{p° are perfectly correlated, the forecaster publishes an additional forecast identical to the initial forecast.

Proposition 2. *Let $\eta = 1$. Any optimal strategy requires that the forecaster publishes an additional forecast identical to the original forecast: $f'_{p^\circ} = f_{p^\circ}$.*

The logic is immediate. With perfect correlation, an honest forecaster publishes $f'_{p^\circ} = f_{p^\circ}$; a mismatch between f'_{p° and f_{p° thus reveals to the market that the forecaster is strategic.

We next consider the case of partial correlation. We say that a strategy (π, π') *requires forecast $(f^\dagger_\ell, f^\dagger_r)$ to be truthful about s_p* if $\pi((f^\dagger_\ell, f^\dagger_r)|(s_\ell, s_r)) = 0$ whenever $s_p \neq f^\dagger_p$; that is, the strategy requires publishing forecast $(f^\dagger_\ell, f^\dagger_r)$ only after observing $s_p = f^\dagger_p$. If this is not the case, we say that a strategy (π, π') *requires forecast $(f^\dagger_\ell, f^\dagger_r)$ to be biased about s_p*.

Proposition 3. *Let $\eta < 1$. Suppose an optimal strategy requires forecast $(f^\dagger_\ell, f^\dagger_r)$ to be biased about $s_{p^\dagger}$. If the forecaster publishes $(f^\dagger_\ell, f^\dagger_r)$ and policy $p^\dagger$ is selected, the strategy requires the publication of $f'_{p^\dagger} \neq s'_{p^\dagger}$ with some probability. Suppose instead that the strategy requires forecast $(f^\dagger_\ell, f^\dagger_r)$ to be truthful about $s_{p^\dagger}$. If the forecaster publishes $(f^\dagger_\ell, f^\dagger_r)$ and policy $p^\dagger$ is selected, the strategy requires publishing $f'_{p^\dagger} = s'_{p^\dagger}$.*

The proposition ensures that if the signals observed before and after the referendum are only partially correlated, biasing the additional forecast can be optimal. In particular, biasing the additional forecast is optimal only if the initial forecast is already biased.

The logic behind this result is best illustrated using an example. Consider a strategy that satisfies these two properties:

1. the strategy requires forecast $(\underline{\ell}, \underline{r})$ to be biased on ℓ, i.e., the strategy requires publishing $(\underline{\ell}, \underline{r})$ with some positive probability conditional on observing $s_\ell = \overline{\ell}$;
2. following the publication of forecast $(\underline{\ell}, \underline{r})$, if $p^\circ = \ell$, the strategy requires honestly publishing, that is, $f'_\ell = s'_\ell$.

We argue that this strategy cannot be optimal. Suppose that the forecaster adopts the strategy and that the market holds correct beliefs. Suppose also that the forecaster has published forecasts $(\underline{\ell}, \underline{r})$, the voter has selected Leave, and $s'_\ell = \overline{\ell}$. The strategy requires $f'_\ell = \overline{\ell}$ (Property 2). However, we argue that the forecaster is better off publishing $f'_\ell = \underline{\ell}$. Here is why. After observing forecasts $(\underline{\ell}, \underline{r})$, the market cannot tell whether the forecaster observed $s_\ell = \underline{\ell}$ or $s_\ell = \overline{\ell}$ (see Property 1). Furthermore, any piece of information that gives the market additional reasons to believe that $s_\ell = \overline{\ell}$ weakens the forecaster's reputation for honesty: after all, only a strategic forecaster could have published $(\underline{\ell}, \underline{r})$ after observing $s_\ell = \overline{\ell}$. However, publishing $f'_\ell = \overline{\ell}$ provides exactly such information. To see why, note that (i) after observing $f'_\ell = \overline{\ell}$, the market (correctly) conjectures that $s'_\ell = \overline{\ell}$ and (ii) signals s'_ℓ and s_ℓ are positively correlated; hence, the realization of s'_ℓ is informative about the realization of s_ℓ.

We next show using an example that as the correlation between signals s_{p° and s'_{p° becomes stronger, a forecaster that biased the forecast before the referendum is more likely to bias the forecast after the referendum.

Example 3. *Fix $\sigma \equiv U[-1, 1]$, $\mu_0 = 0.95$, $\rho = 5$, $\overline{r} = \underline{r}$, $\overline{\ell} - \underline{\ell} = 0.1$, $\epsilon = 0.2$ and $\underline{r} = \overline{\ell} + 0.6$.*[10] *Following a lie about Leave (i.e., $s_\ell = \overline{\ell}$ and $f_\ell = \underline{\ell}$) and a referendum that selects Leave, any optimal strategy requires lying again (that is, $f'_\ell = \underline{\ell}$ for $s'_\ell = \overline{\ell}$) with the probability shown in Figure 3. Note that the probability of a lie is directly proportional to the correlation between pre and postreferendum signals. For low degrees of correlation, the strategy requires mixing between a lie and a truthful forecast, with a probability of lie that increases with the correlation. For degrees of correlation sufficiently close to 1, the strategy requires to lie with probability 1.*

The correlation between the information available to the forecaster before and after the referendum is naturally bound to be perfect (or almost perfect) in the short run (e.g., days) after the referendum and partial, at best, in the longer run (e.g., months). Propositions 2 and 3 thus yield the last prediction of our model.

Prediction 3. *In the days after the referendum, a partisan forecaster sticks to the forecast published before the referendum. In the following months, the forecaster gradually reduces the bias in her forecasts.*

2.3 Rational Voter

We modify the model here by assuming that the voter is fully rational. The rationale for this modification is to ensure that our key theoretical predictions do not rest on specific

[10] Here, we assume that there is no uncertainty about the outcome associated with Remain ($\overline{r} = \underline{r}$). Although these parameter values are outside the range we considered in our baseline model, the model can accommodate this case.

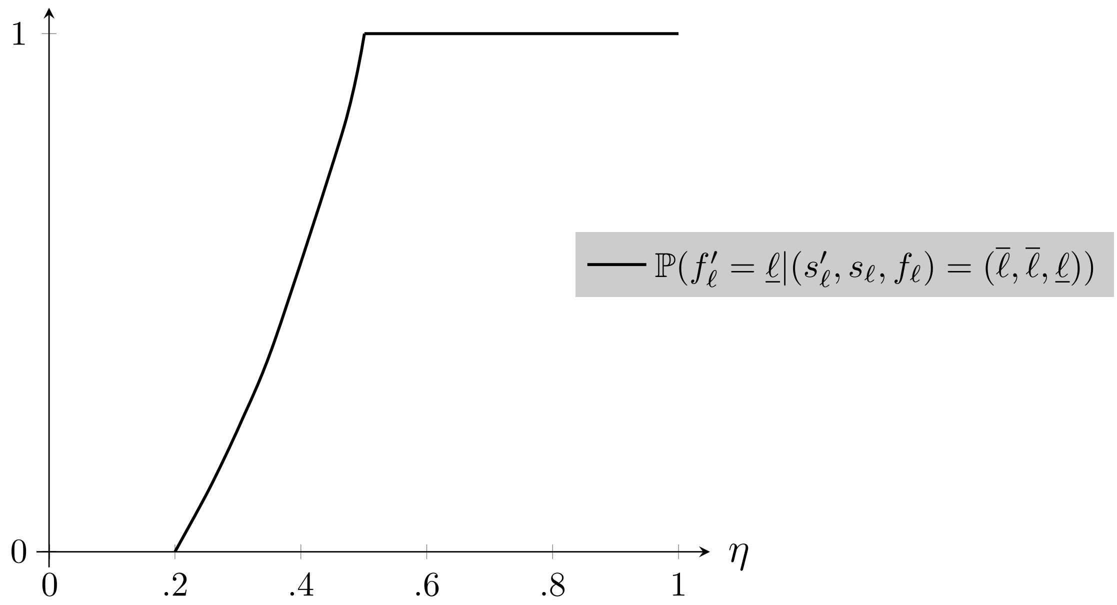


Figure 3

assumptions of how the voter processes macroeconomic forecasts. A rational voter prefers Remain if

$$\mathbb{E}(y_r - y_\ell | (f_\ell, f_r)) + \sigma \geq 0,$$

and prefers Leave otherwise. From the standpoint of the forecaster, the voter prefers Remain with probability $1 - F(\mathbb{E}(y_\ell - y_r | (f_\ell, f_r)))$. The forecaster's expected payoff for outcomes (y_ℓ, y_r), forecasts (f_ℓ, f_r) and market belief π^e is then:

$$(1 - F(\mathbb{E}(y_\ell - y_r | (f_\ell, f_r))))\, \rho + M((f_\ell, f_r), (y_\ell, y_r), \pi^e).$$

Everything else is the same as in the baseline model. In Appendix B, we characterize the optimal strategy for a numerical example. We show that the forecaster biases her forecast in favour of Remain selectively also when the voter is fully rational.

3 The Brexit Referendum

We test the predictions of our theoretical model in the context of the EU membership referendum, known as Brexit, held in the United Kingdom in 2016. In February 2016, the UK Prime Minister announced a referendum on the EU membership to be held on June 23 of the same year.[11] The referendum asked voters to choose between two options: Leave (the EU) or Remain. On the day of the referendum, a majority (51.9%) of voters voted for Leave. Table C1 in the Appendix summarizes the relevant dates. In this section,

[11] The referendum was nonbinding since the parliament maintained the right to make the final decision on the issue. Nevertheless, before the vote, the government clarified its willingness to commit to voters' preferences.

we provide evidence to support our claim that the referendum fits our theoretical model. We first argue that macroeconomic forecasts influenced voters. Next, we consider the assumptions, which we labelled Assumptions (i)–(iv) in Section 2.

Macroeconomic considerations seem to have played an important role in voters' decisions. According to the *British Election Study* panel, prior to the referendum, the economy was the most important issue at stake for the relative majority of voters.[12] One can also speculate that it must have been difficult for voters to anticipate the effects of Leave on the economy since no country had previously withdrawn from the EU. In this context, we should expect experts' opinions to have played a sizeable role. We indeed find evidence that voters were aware of macroeconomic forecasters ahead of the referendum and that forecasts affected voters' beliefs about the economic consequences of their choices.

First, we document that the release of a negative forecast of the immediate economic impact of Brexit by Her Majesty's (HM) Treasury on May 23 had a sizeable and statistically significant impact on voters' beliefs.[13] We use data from the *British Election Study* panel, in which individuals were randomly surveyed daily between May 6 and June 22, 2016 (i.e., before or after the release of the HM Treasury). In turn, we can compare the changes in individual beliefs between Wave 8, in which some voters were surveyed after the release of the HM Treasury forecasts and others before, and Wave 7, in which all voters were surveyed before the release. Formally, we estimate

$$Belief_i^{W8} - Belief_i^{W7} = \alpha + \beta \times PostRelease_i + \varepsilon_i. \tag{1}$$

Estimating (1) allows us to measure whether voters subjected to Wave 8 *exogenously* after the publication of the HM Treasury forecasts changed their views compared to the previous wave's self-reported views more than did individuals whose responses to Wave 8 were collected before the HM Treasury forecast release. To ensure the credibility of our results, we limit our attention to individuals surveyed by Wave 8 of the British Election Study Panel within a window of five calendar days before or after the forecast release. Figure 4 documents that respondents surveyed within a window of five days *after* the publication were more likely to understand the relevant issues, report their intention to participate in the referendum, and be interested in the debates than respondents surveyed in the five days *ahead* of the publication.

Second, in panel (a) of Figure C5, we document that 90 per cent of the forecasters included in our sample were mentioned by online media sources published in the UK

[12] The *British Election Study* panel is a representative survey of the UK population eligible to vote.

[13] On May 23, the HM Treasury released a report (HM Treasury, 2016) on the estimated immediate economic impact of a Leave victory. According to the report, leaving the EU would reduce the GDP by between 3.6 and 6 per cent within two years, with higher inflation and unemployment and a depreciation in house prices and pound sterling.

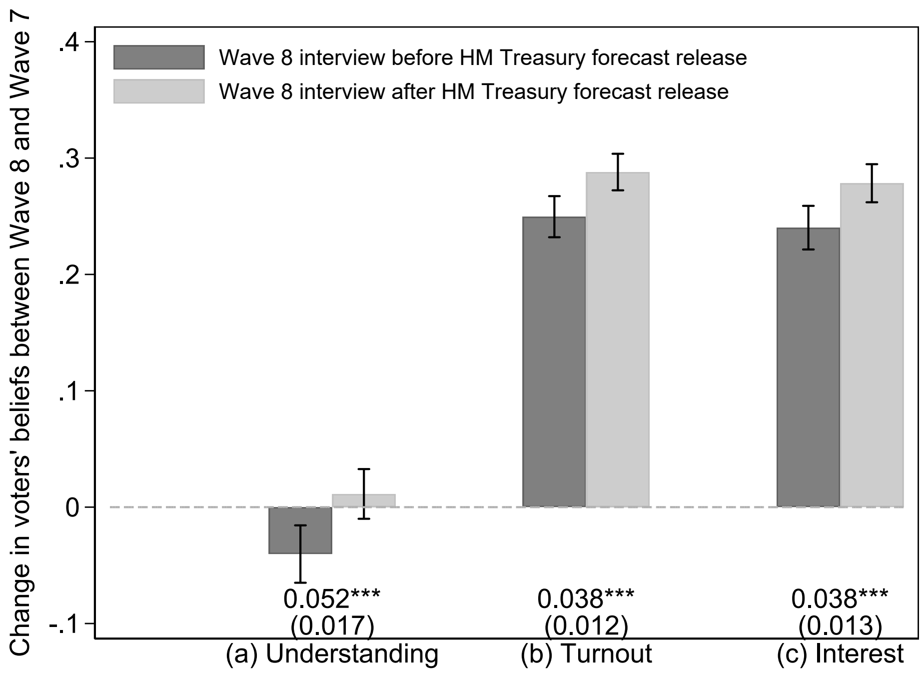


Figure 4: Voters' Beliefs and Forecast Release

Notes: This figure illustrates how respondents in the British Election Study panel changed their beliefs about the Brexit referendum between Wave 7 (April 14–May 4, 2016) and Wave 8 (May 6–June 22, 2016). Dark grey bars represent respondents surveyed for Wave 8 before the release of HM Treasury forecasts on May 23, whereas light grey bars represent respondents surveyed for Wave 8 after the release. The sample was restricted to include only individuals surveyed in a window of five calendar days around the forecast's release (N=6,115). Panel (a) reports the change in the probability of agreeing or strongly agreeing with the following statement: *I have a good understanding of the important issues at stake in the EU referendum.* Panel (b) reports the change in the probability that the respondent announces that he or she will very likely or likely vote in the EU membership referendum. Panel (c) reports the change in the probability that the respondent announces being very interested or somewhat interested in the EU referendum. In all panels, we report coefficients and confidence intervals for β in equation (1). Standard errors and 95% confidence intervals are robust to heteroskedasticity. Labels *, ** and *** represent significance levels of 10%, 5% and 1%.

and indexed in Google News prior to the announcement of the referendum (i.e., during 2015). The median forecaster was mentioned in 7,000 articles, whereas the most covered forecaster was mentioned 185,000 times.[14]

The combined evidence presented in Figure 4 and in Panel (a) of Figure C5 indicates that macroeconomic forecasts could have a strong impact on voters' beliefs. Nevertheless, we expect economic considerations and macroeconomic forecasts about the potential effects of Brexit to have played a much larger role in swing voters than in more ideologically oriented voters. We leverage this difference in the additional analysis in Section 5.2.

In panels (a) and (b) of Figure 5, we present evidence in support of Assumption (i).

[14] The number of mentions on UK media at the forecaster level positively correlates with the pre-referendum accuracy (as measured by the inverse of the root mean squared errors).

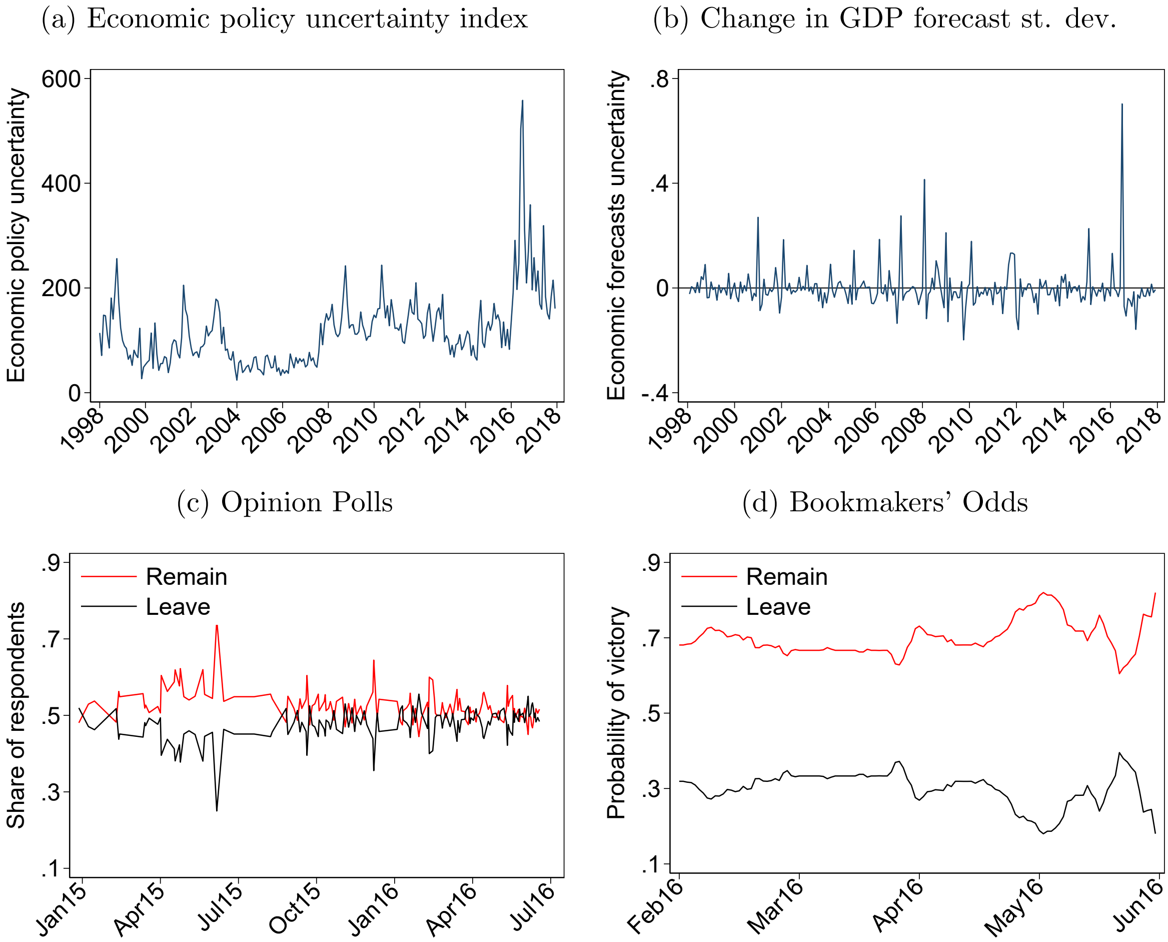


Figure 5: Opinion Polls and Bookmakers' Odds Approaching the Referendum

Notes: Panel (a) shows the United Kingdom's *Economic Policy Uncertainty Index* measured monthly between January 1998 and December 2017 according to PolicyUncertainty. Panel (b) plots monthly changes in the standard deviation of GDP growth forecasts for the next period between January 1998 and December 2017 among forecasters surveyed by HM Treasury and The National Archives. Panel (c) reports the daily averages of all opinion polls recorded by the FT Research between January 2015 and June 22, 2016. Panel (d) documents the daily average of the odds released by all bookmakers recorded by the portal BetData between the announcement of the referendum date and June 22, 2016.

Panel (a) plots the *Economic Policy Uncertainty Index* of the United Kingdom during 1998–2018. Economic policy uncertainty in the United Kingdom was historically relatively low until early 2016, in connection with the announcement of the referendum, when it jumped above 300 points for the very first time in recent history. The index peaked in connection with the referendum outcome at approximately 500 points and constantly remained at values higher than the historical trends thereafter. Panel (b) reports the monthly variation in the standard deviation of forecasts published by independent forecasters and included in the collection *Forecasts for the UK economy* collected and released by HM Treasury during 1998-2018. Again, we document that the measure peaked exactly at the time of the referendum outcome.

Clear evidence exists that Remain was considered the likely winner before the vote (Assumption (ii)). Specifically, according to 66% of the opinion polls, Remain led, often with a predicted winning margin of at least 5 percentage points (see Figure 5, panel (a)). Macroeconomic forecasters, as well as bookmakers, were predicting the victory of Remain. In the final days before the vote, forecasters assigned a probability of victory of 63% to Remain (Consensus Economics, 2016a), whereas bookmakers assigned a probability approximately equal to 85% (see Figure 5, panel (b)).

Assumption (iii), namely, the assumption that the result of the referendum was uncertain, is quite natural yet difficult to establish empirically. Perhaps the best (indirect) evidence comes from the fact that, as we just discussed, a victory of Remain was widely considered the most likely outcome; however, the referendum contradicted all predictions.

Finally, Assumption (iv) indicates that our results hold for a forecaster who was interested in boosting the odds of Remain, which we refer to as a partisan forecaster. Most experts agreed before the referendum that Remain was the best option for the UK economy. During the campaign, the economic effects of a withdrawal from the European Union and potentially from the European single market were central arguments deployed against Leave (see Dhingra et al. (2015); Kierzenkowski et al. (2016)). Government agencies, forecasters, media, and European and international public institutions warned British citizens about a substantial economic downturn, especially due to a decline in investments (Dhingra et al., 2016a) and exports (Dhingra et al., 2016b). It then stands to reason that any forecaster whose fortunes were tied to the performance of the UK economy should have been expected to be exposed to the risk of financial loss in the event of Brexit. When discussing our preferred proxies for partisanship in the next section, we show that many of the forecasters in our sample faced sharp reductions in their stock market capitalization in the immediate aftermath of the announcement of the referendum result.

4 Empirical Strategy

4.1 Institutional and Forecast Data

Testing empirically the predictions of our theoretical model is subject to two key challenges. First, ex post forecast errors do not necessarily imply that a forecaster was willingly releasing biased estimates ahead of the referendum: producing correct forecasts is a challenging task, especially during periods of high uncertainty, and forecasters often make genuine mistakes. Second, GDP is realized ex post (and thus observable) contingent only on the policy selected by the referendum. We cannot compare forecasts for Remain to actual GDP growth under that policy since that outcome is an unobservable counterfactual. Analogously, had UK voters chosen Remain, we would not have observed

GDP growth realization contingent on Leave.[15]

We address these empirical challenges by exploiting the heterogeneity in stakes – a measure of partisanship – across forecasters who released monthly estimates for the UK economy before and after the referendum. More specifically, we compare forecasts for the Remain and Leave scenarios published by forecasters that faced the risk of substantial financial losses in the event of Brexit with forecasts released by other institutions, arguably more likely to having been indifferent between the two alternatives. The intuition behind our empirical strategy is that predictions produced by forecasting institutions without stakes in the referendum should proxy for the most accurate estimate that forecasters with stakes would have published (i) given the information available at the time of the release and (ii) absent their incentive to influence voters' beliefs.

A standard approach used in the literature to compare estimates across forecasters relies on professional forecasters' surveys (see, e.g., Ramey, 2011; Rossi and Sekhposyan, 2015; Bordalo et al., 2020).In surveys, all forecasters report their best estimates for the same target year at the same point in time, given a common set of assumptions about what to forecast. We use the *Forecasts for the UK Economy* survey, a panel of nonanonymous forecasts collected and released monthly by HM Treasury.[16] The sample mainly covers financial institutions and research companies, which are also the forecasters that update their estimates most frequently.[17] As is common in major forecast surveys, participants in the *Forecasts for the UK Economy* survey are asked to report their central (a.k.a., modal) forecast (i.e., they are asked to report the most likely realization of the future given currently available information).

4.2 Measures of Partisanship

In Section 3, we discussed how the consensus among experts reflected Remain as the best alternative for the UK economy. Therefore, we set the partisanship of forecasters to be proportional to their stakes in the performance of the UK economy. Our preferred measure of stakes is an indicator variable (Bank) that takes the value of 1 for financial institutions and 0 otherwise. The selection of this proxy for stakes is motivated by the observation that the financial sector was substantially more exposed to the risk associated with Brexit than were forecasters belonging to other industries such as the academic or consulting sectors. Ramiah et al. (2017) estimates that, in the very short run, the victory of the Leave campaign reduced the stock market prices of the banking sector by

[15] This feature motivates why our theoretical model assumes that the forecaster is accountable only for the forecast contingent on the policy selected by the voter.

[16] The dataset is a monthly, publicly available survey of independent forecasters collected by the Treasury. Our main sample period covers 44 forecasters from January 2012 to April 2018.

[17] Figure C2 in the Appendix shows the distribution of forecasters by industry, whereas Table C3 in the Appendix offers a comparison of the forecasts released before the announcement of the EU membership referendum.

15.37% compared to the baseline. Our data show that the financial institutions in our sample faced, on average, a reduction in stock market prices of 16.37% in the two days after the referendum. We also propose three alternative measures of stakes. First, we use an indicator variable (City) that takes the value of 1 for forecasters in the City of London's financial district and 0 otherwise. Second, we use the percentage decline in the forecaster's stock prices between the referendum and the second market day after the vote and construct an indicator equal to 1 (stock price) for forecasters in the most negatively affected quartile. Third, we use the fraction of each forecaster's capital owned by investors based in the United Kingdom immediately preceding the referendum and construct an indicator variable taking the value 1 (UK holder) for forecasters in the top quartile.[18]

Figure 6 shows the substantial heterogeneity across forecasters in the latter continuous measures. Panel (a) shows that the most affected forecasters lost up to 30% of their value around the referendum, whereas other forecasters were unaffected by Brexit. The panel also shows that none of the forecasters included in our sample experienced an increase in stock price on realization of the referendum outcome. Panel (b) documents the variation in the proportion of shareholders in the UK. Most forecasters are owned only by non-UK individuals or companies, whereas a significant proportion of shares used to be in the hands of UK investors at the time of the referendum.[19]

4.3 Identifying Assumptions

Our empirical analysis, as explained in detail in the next subsection, builds on a difference-in-differences model. We assume that, in the absence of the referendum, forecasts released by forecasting institutions with and without stakes would have followed parallel trends.

Data constraints require us to state a further identifying assumption. At each point in time, professional forecasters' surveys only ask surveyed institutions for the central forecast, which is a forecast contingent on the outcome considered the most likely at the time. As the victory of Leave was unexpected (see Figure 5), this implies that we can only observe forecasts conditional on Leave in the period after the referendum.[20] This observation forces our empirical analysis to rely on the third prediction of our theoretical model, that is, the prediction that forecasts included in the first survey after the

[18] The City indicator turns out to be the least restrictive indicator, as all forecasters flagged as *high stakes* according to any other measure are also flagged according to the City indicator. Stock price and UK holder indicators are, instead, the most restrictive ones, as they only flag separate subsamples of financial institutions.

[19] See Section B in the Appendix for details about the measures. Table C2 in the Appendix shows that these measures are positively correlated; however, the correlation coefficients are far from 1.

[20] Importantly, the forecasts contingent on the Leave victory account for the fact that an actual withdrawal from the EU would take at least two years, according to the Treaty of the European Union (Art. 50). Therefore, the forecasts reflect the referendum outcome and not the actual withdrawal.

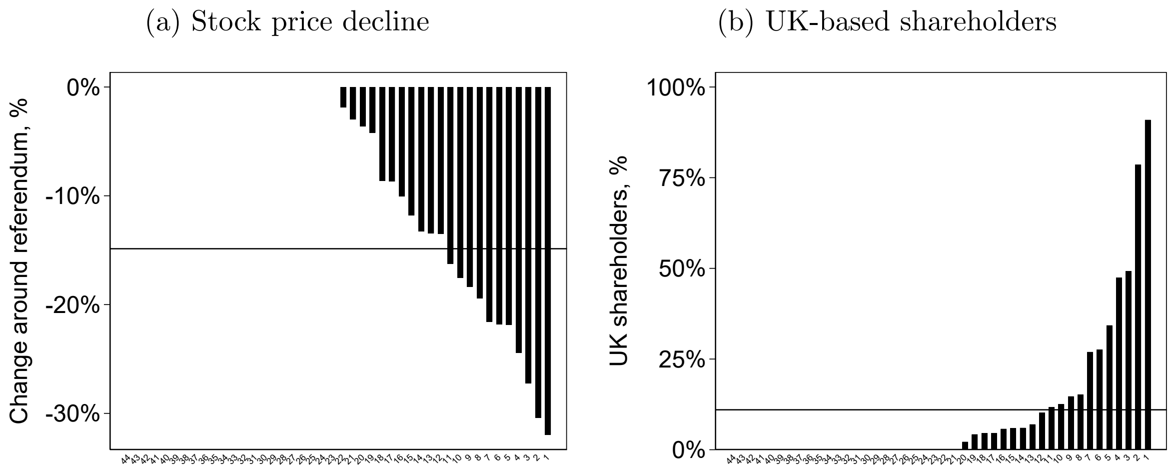


Figure 6: Decline in Forecasters' Stock Price and share of UK holders around the Referendum

Notes: Panel (a) shows the percentage variation in each forecaster's stock market price between the referendum date and the second market day after the vote. Panel (b) shows the share of each forecaster's stocks owned by UK-based holders at the end of 2015. See Section B in the Appendix for details.

referendum reflected the forecasts that forecasters were published immediately preceding the vote. We discuss the validity of this prediction, provide evidence of its validity, and discuss how our empirical results change had the assumption not been satisfied in the next paragraphs.

The prediction relies on the assumption that the information available to the forecasters is the same immediately before and immediately after the referendum (see Proposition 2). In this regard, we note that only seven calendar days separated the date of the referendum and the day on which the HM Treasury began the survey for the first postreferendum release.[21] In this window of time, forecasters unlikely obtained new, critical information about the economy beyond the referendum results.

We seek evidence from additional sources to support the prediction. At the aggregate level, forecasts conditional on Leave were the same immediately before and immediately after the referendum. Specifically, in the April, May, and June 2016 releases of the *Consensus Economics* report (Consensus Economics, 2016a), the surveyed forecasters were asked to anonymously report their forecasts conditional on Leave and their usual forecast contingent on the most likely realization of future shocks (i.e., conditional on Remain).[22] Figure 7 shows that the average forecast of GDP growth released in the last

[21] The first postreferendum release was the July 2016 edition of *Forecasts for the UK Economy*. This release was published on July 20 and contained information from forecasters surveyed between July 1 and July 13.

[22] The *Consensus Economics* report is largely equivalent to our primary data, although it reports information from a slightly smaller number of forecasters. Six institutions included in our primary data have not been surveyed by *Consensus Economics*, and *Consensus Economics* surveyed three institutions not included in our primary data.

release before the vote (the June one) was equal to the average forecast according to the first nonanonymous release published after the vote (the July one).

As further anecdotal evidence in favour of our theoretical model's prediction and identifying assumptions, we observe that some forecasters for whom we retrieved an estimate published before the vote did not revise it around the date of the referendum. For example, the forecast of GDP growth in 2017 released by the Economist Intelligence Unit in June 2016 was the same as the forecast included in the July 2016 release of the *Forecasts for the UK Economy*.

What can we learn from the empirical results if forecasts included in the first survey after the referendum do not match the forecasts available to voters before the vote? On the one hand, our theoretical model indicates that measuring bias using forecasts released after the vote may induce an underestimation of political forecast bias since forecasters may have already started to converge towards unbiased estimates. On the other hand, our results overestimate the political bias if forecasters with stakes reacted irrationally to the unexpected referendum result shock. Although the latter interpretation appears unlikely given the evidence presented in Figure 7, in Section 5.3, we perform a battery of robustness checks to exclude the possibility that forecasters labelled as high-stakes reacted irrationally to other large economic shocks over the last decades or to other information shocks related to Brexit in the year after the vote.

4.4 Specification

Our data allow us to identify three well-specified periods between the announcement of the referendum and the end of 2016. Forecasts included in *Forecasts for the UK economy* between March 2016 and June 2016 reflect forecasters' views about Remain in the prereferendum period. We assume that forecasts in the July 2016 issue of *Forecasts for the UK economy* reflect forecasters' views about Leave published immediately preceding the referendum. Forecasts included in *Forecasts for the UK economy* between August 2016 and November 2016 reflect forecasters' views about Leave published in the postreferendum period. We estimate the difference-in-differences model

$$f_{j,m}^{t+1} = \beta_1 Stakes_j \times \underbrace{\mathbb{1}(k_m \in [-4,-1])}_{f_r} + \beta_2 Stakes_j \times \underbrace{\mathbb{1}(k_m = 0)}_{f_\ell} + \beta_3 Stakes_j \times \underbrace{\mathbb{1}(k_m \in [1,5])}_{f'_\ell} + \theta_j + \delta_m + \varepsilon_{j,m}, \quad (2)$$

where k_m measures the distance (in months) of each survey release m from the first survey after the vote, θ_j represents forecaster fixed effects, and δ_m represents survey month effects. The dependent variable $f_{j,m}^{t+1}$ is the central forecast of GDP growth in year

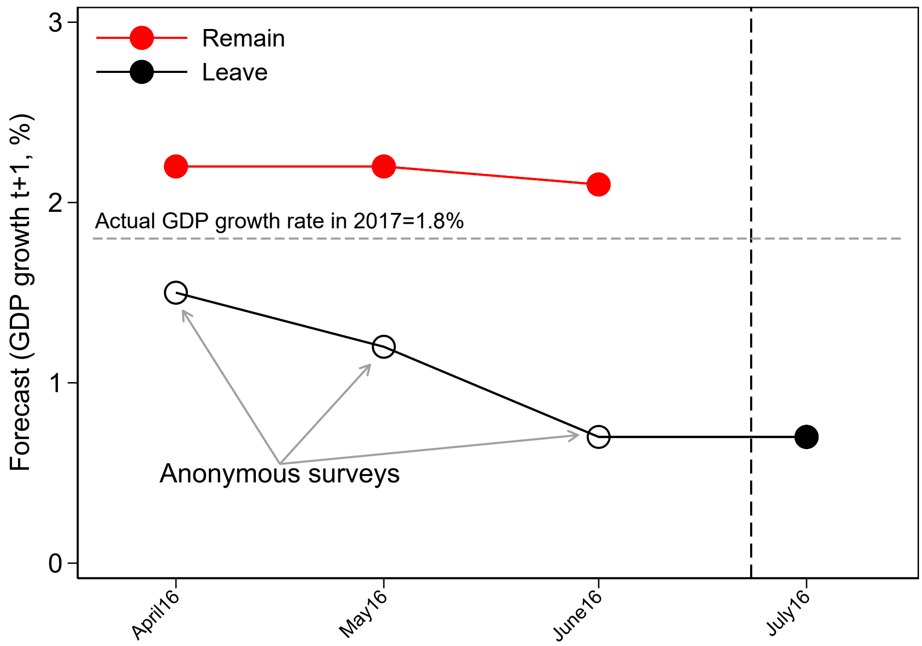


Figure 7: Average Forecasts around the Time of the Referendum

Notes: The chart shows the average forecast for the 2017 GDP growth rate conditional on Remain (red) and Leave (black) outcomes published by *Consensus Economics* in June and July 2016 (Consensus Economics, 2016a,b). The vertical line represents the referendum date, whereas the dashed horizontal line represents the actual GDP growth rate in 2017.

$t+1$ released by forecaster j in survey month m.[23]

Given the identifying assumptions stated in Section 4.3, the terms on the right-hand side of equation (2) have a straightforward interpretation in the theoretical model, summarized for clarity in curly brackets. The forecasts released between March and June 2016 (i.e., $k_m \in [-4, -1]$) measure f_r, whereas the forecasts released in July 2017 (i.e., $k_m = 0$) capture f_ℓ. Finally, for forecasts released after July 2017 (i.e., $k_m \in [1, 5]$) refer to f'_ℓ of the extended model in Section 2.2.

The data support Prediction 1 (a partisan forecast with a preference for Remain strategically underestimates Leave) if the coefficient β_2 is negative and statistically significant and the coefficient β_1 is not. The data also support Prediction 3 (the partisan forecaster reduces *slowly* the bias in her forecasts) if the coefficient β_3 is also negative and statistically significant, with $|\beta_2| > |\beta_3|$. Whether β_1 is positive and statistically

[23] We focus on short-term forecasts because only a subset of forecasters releases, on a quarterly basis, GDP growth forecasts in the medium term. However, short-term forecasts were very informative about the potential effects of Brexit in subsequent years, as short- and long-term forecasts were highly correlated. Figure C3 in the Appendix shows the correlation between GDP growth forecasts in year $t+1$ and $t+3$ among forecasters that release medium-term forecasts on a quarterly basis. Note also that our theoretical model considers forecasts before and after the referendum that focus on the same outcome. This feature of the theoretical model finds an exact empirical comparison: all forecasts published during 2016 have as the object 2017 yearly GDP growth.

significant or indistinguishable from zero is an empirical question: our theoretical model indicates that both options are viable depending on the values of the stakes parameter ρ. The theoretical model is, however, robust in predicting that $|\beta_2| > \beta_1$.

We test the validity of the parallel trends assumption by estimating a dynamic version of equation (2), in which we interact the Stakes indicator for monthly dummies before and after the announcement of the referendum. Detecting insignificant coefficients for β_{-7} and β_{-6} (i.e., the first two occurrences in which forecasters in our data are asked about their predictions for yearly GDP growth in 2017) would reassure us about the validity of the identifying assumption. Formally, we estimate

$$f_{j,m}^{t+1} = Stakes_j \times \sum_{k_m \in \{-7,+5\}; k_m \neq -5} \beta_k \mathbb{1}(m = k_m) + \theta_j + \delta_m + \varepsilon_{j,m}, \tag{3}$$

5 Results

5.1 Partisan Forecasters Release Biased Estimates

Figure 8 illustrates the main empirical results of the paper. Specifically, the figure shows the average GDP growth rate forecasts in year $t+1$ (i.e., calendar year 2017) released by partisan and nonpartisan forecasters. The visual evidence presented in Figure 8 contributes to showing the overall validity of the research design and strongly confirms Predictions 1 and 3. First, the figure shows that the parallel trends assumption is likely satisfied in this context since we do not find evidence that the two groups of forecasters released diverging estimates before the announcement of the referendum. Figure 8 shows that forecasters with and without stakes used to release the same forecasts on average before the announcement of the referendum. Second, in line with Prediction 1, forecasters identified as partisan released more pessimistic estimates around the referendum date; in contrast, we do not find any evidence that forecasters were releasing different estimates for the Remain scenario as the vote approached. Third, in line with Prediction 3, five months after the vote, partisan forecasters continued to release more pessimistic estimates than did other forecasters and slowly converged towards their competitors' reports.

We now turn to a formal estimation of the regression model. Table 1 reports the results of our empirical analysis. In column (1), we compare forecasts released by financial institutions with forecasts developed by other forecasters. In column (2), we compare forecasts released by institutions in the City of London's financial district with forecasts developed by other institutions. In columns (3) and (4), we measure partisanship using the percentage decline in the forecaster's stock price associated with the referendum and the share of capital owned by shareholders based in the UK, respectively.

All specifications confirm the first and third predictions of our theoretical model.

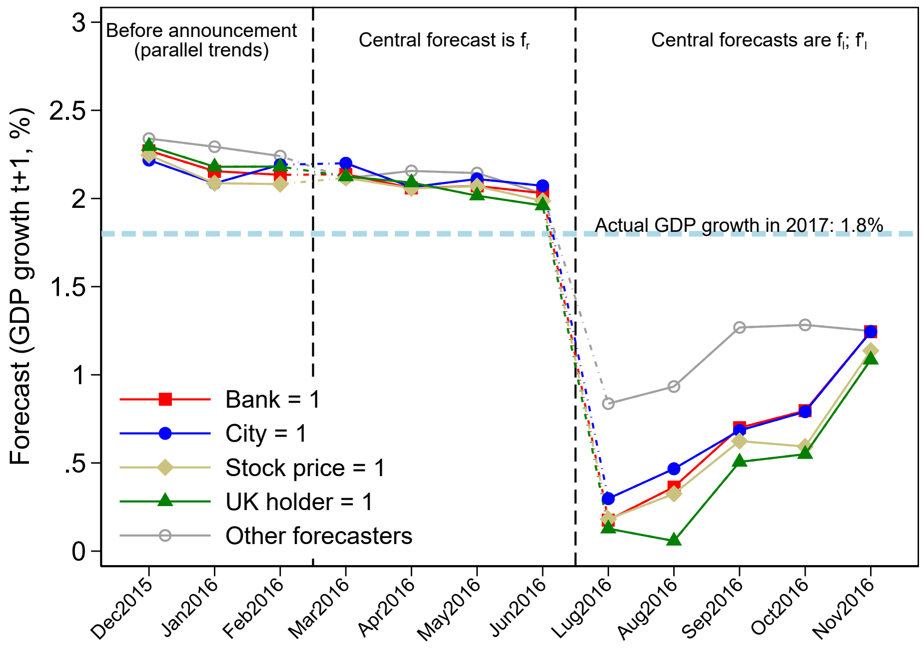


Figure 8: Pre- and Post-Referendum Trends

Notes: The coloured lines represent the average forecast of the GDP growth rate in period $t+1$ released by forecasters with stakes – i.e., with indicators Bank=1 (red); City=1 (blue); Stock price=1 (sand); UK holder=1 (green) – whereas the grey line represents the respective average forecast released by other forecasters – i.e., with Bank=0, City=0, Stock price=0, and UK holder = 0.

Column (1) reflects our estimate that financial institutions published a GDP growth rate forecast for the Leave scenario that was 0.73 percentage point lower than that of other institutions. The estimated political bias is very sizeable compared to the average GDP growth forecasts in the event of Brexit as published in July 2016 (equal to 0.48%) and to the actual GDP growth during 2017 (equal to 1.9%).[24] Column (2) reflects our estimate that forecasters in the City of London's financial district overestimated the negative impact of a victory of Leave on GDP by 0.52 percentage point more than did other forecasters.

In columns (3) and (4), forecasters exposed to a sizeable loss in stock market capitalization and forecasters with a higher exposure to UK investors overestimated the economic downturn associated with the Brexit referendum outcome by 0.47–0.51 percentage point more than did their competitors. In all columns, we also observe that forecasters with and without stakes did not publish significantly different forecasts for the Remain scenario. Moreover, in line with our third prediction, forecasts for the Leave scenario converged slowly in subsequent surveys, as the point estimates for the interaction term $Stakes \times f'_\ell$

[24] Figure C4 shows the distribution of released forecasts immediately preceding and immediately after the referendum. This demonstrates that in the first survey after the referendum, a clear cluster of forecasters had stakes at the bottom of the distribution of published scenarios. In contrast, this evidence did not appear in the June survey.

Table 1: Estimation of Political Bias in GDP Growth Forecasts

	(1)	(2)	(3)	(4)
	Dep. var.: Forecast (GDP growth t+1, %)			
Stakes $\times f_r$	-0.059	0.022	-0.054	-0.028
	(0.084)	(0.088)	(0.086)	(0.085)
Stakes $\times f_\ell$	-0.731***	-0.518***	-0.468***	-0.511***
	(0.148)	(0.175)	(0.167)	(0.145)
Stakes $\times f'_\ell$	-0.362**	-0.333*	-0.364*	-0.415**
	(0.178)	(0.182)	(0.189)	(0.194)
Observations	1,662	1,662	1,662	1,662
R^2	0.776	0.774	0.773	0.774
Fixed Effects	✓	✓	✓	✓
Survey Month Effects	✓	✓	✓	✓
Measure of Stakes	Bank	City	Stock price	UK holders

Notes: The estimated equation is (2). Standard errors robust to two-way clustering at the forecaster and survey levels are shown in parentheses. Labels *, ** and *** represent significance levels of 10%, 5% and 1%.

are consistently negative, smaller in magnitude than the coefficients on $Stakes \times f_\ell$ and statistically significant at the 5 or 10 per cent levels.[25]

Figure 9 provides further evidence of the validity of the parallel trends assumptions. In the figure, we plot the estimated coefficients obtained from estimating (3). The results document that financial institutions and other forecasters published comparable estimates before the announcement of the referendum.

5.2 More Influential Forecasters Provide More Biased Forecasts

To test Prediction 2 of our theoretical model (partisan bias increases – in absolute terms – in the forecaster's influence), we proxy for the influence of a forecaster with the coverage she received on all online media outlets and on five major UK newspapers during the period before the referendum. To avoid inducing simultaneity bias, we measure influence in the year 2015 (i.e., before the announcement of the referendum) such that our measure captures each forecaster's historical record of being more/less influential towards the general public rather than being reported because of the decision to publish bold estimates about the potential economic effects of Brexit.

Figure C5 shows that the number of articles mentioning each forecaster in our sample was heterogeneous across forecasters and media outlet. First, panel (a) of Figure C5 shows the log of the number of articles mentioning each forecaster on any online media

[25] In Table C5 in the Appendix, we estimate the political bias in each component of GDP growth. The results show that biased GDP growth forecasts arose from substantially biased investment and trade exposure growth forecasts. More specifically, financial institutions overestimated the negative impact of Brexit on investments by 2.3 percentage points and on exports by 1.2 percentage points.

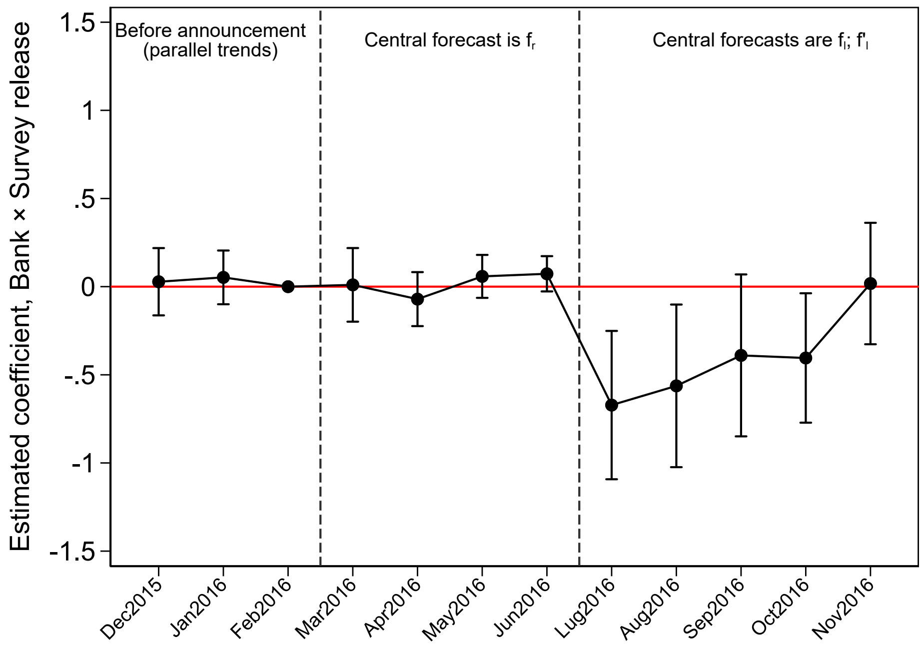


Figure 9: Dynamic Specification

Notes: The estimated equation is (3) and 95% confidence intervals are based on standard errors robust to two-way clustering at the forecaster and survey levels are shown in parentheses. The measure of stakes is Bank.

outlet covered by Google News. Second, panel (b) of Figure C5 documents the total coverage of each forecaster in four major UK general-interest daily newspapers (*The Times*, *The Daily Mail*, *The Guardian*, and *The Telegraph*), as well as a daily newspaper specializing in the financial sector (*Financial Times*). Finally, panels (c)–(g) document each forecaster's coverage on each of the five newspapers mentioned above. The most reported forecaster was mentioned 42 times in the Daily Mail (i.e., almost once per week) and 101 times in the Financial Times (i.e., twice per week).[26]

In addition to constructing a measure of influence towards the general UK population, we also construct measures of influence towards individuals who intended to vote for Remain, who intended to vote for Leave, or who were on the fence between the two options (swing voters). Specifically, we combine information on each forecasters' coverage of each of the five top newspapers with each newspaper's diffusion among the entire UK population and among groups of voters with specific voting intentions. Figure 10 shows that *The Times* and *The Telegraph* were read by Leave and Remain supporters in similar shares. Conversely, *The Guardian* was popular among the Remain supporters and unpopular among the Leave supporters, whereas *The Daily Mail* was mostly read by the Leave supporters. Last, the *Financial Times*, with readers having a special interest in

[26] Table C4 shows the correlation between the number of articles that mentioned a forecaster in each media outlet.

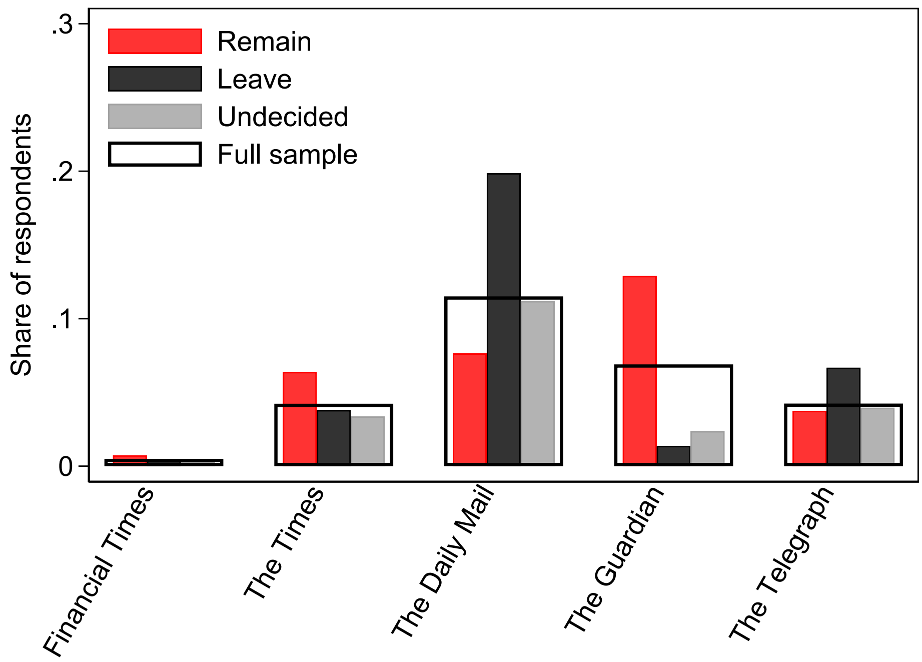


Figure 10: Newspaper Consumption by Referendum Preferences

Notes: The chart shows the share of respondents in Wave 8 of the *British Election Study* panel who mentioned each newspaper as the one they read most often. The sample is divided based on the self-reported voting decision in the EU Membership referendum.

the financial sector, was not particularly popular across any of the different voter groups.

Specifically, we create six measures of influence to correlate the GDP growth forecasts released by each forecaster around the referendum with its influence across all media outlets and on voters with a certain ideological standpoint on the Brexit referendum. The first measure of influence is an indicator equal to 1 if the number of mentions of a forecaster on any media source indexed in Google News was above the median forecaster. The second indicator takes a value of 1 if the number of mentions in any of the five reference newspapers was greater than the number of mentions of the median forecaster on those outlets. The third indicator takes the value of 1 if the sum of mentions of a forecaster across the five reference newspapers weighted by the share of readers of each newspaper in the UK population according to the *British Election Study* was above the median. Formally, we construct the variable

$$Coverage_j^w = \sum_k \iota_k \times Mentions_{j,k}, \tag{4}$$

where ι_k denotes the readership share of newspaper k, and $Mentions_{j,k}$ denotes the historical coverage of forecaster i on newspaper k. Then, we assign the value of 1 to forecasters above the median value of $Coverage_j^w$. Fourth, we construct an indicator equal to 1 for forecasters whose number of mentions in the five reference newspapers, weighted by the share of readers of each newspaper among swing voters on the Brexit referendum according to the *British Election Study*, was above the median number. More precisely, we measure $Coverage_j^{ws}$ by replacing ι_k in (4) with the readership share of newspaper k among swing voters ι_k^s, and we create an indicator equal to 1 for forecasters above the median value of $Coverage_j^{ws}$. Fifth, we construct one indicator equal to 1 if the number of mentions in any of the five newspapers weighted by the share of Remain-leaning readers exceeds the number of mentions weighted by the share of Leave-leaning readers and one indicator equal to 1 if the reverse holds. Specifically, we construct the variables $Coverage_j^{wr}$ and $Coverage_j^{w\ell}$ by replacing ι_k in (4) with the readership shares of newspaper k among Remain-leaning voters ι_k^r and the readership shares of newspaper k among Leave-leaning voters ι_k^ℓ. Then, we construct an indicator that takes the value of 1 if $Coverage_j^{w\ell} > Coverage_j^{wr}$ and an indicator that takes the value of 1 if $Coverage_j^{w\ell} < Coverage_j^{wr}$.[27] Indicators of influence 1–3 aim to capture a forecaster's influence among the general UK public, whereas indicator 4 aims to proxy for a forecaster's influence among swing voters. Finally, indicators 5 and 6 aim to measure whether a forecaster is more exposed to Remain-leaning voters or to Leave-leaning voters.

Figure 11 correlates the GDP growth forecasts released around the referendum with the heterogeneity across forecasters and media outlets in influence measures. Formally, we estimate the following regression model:

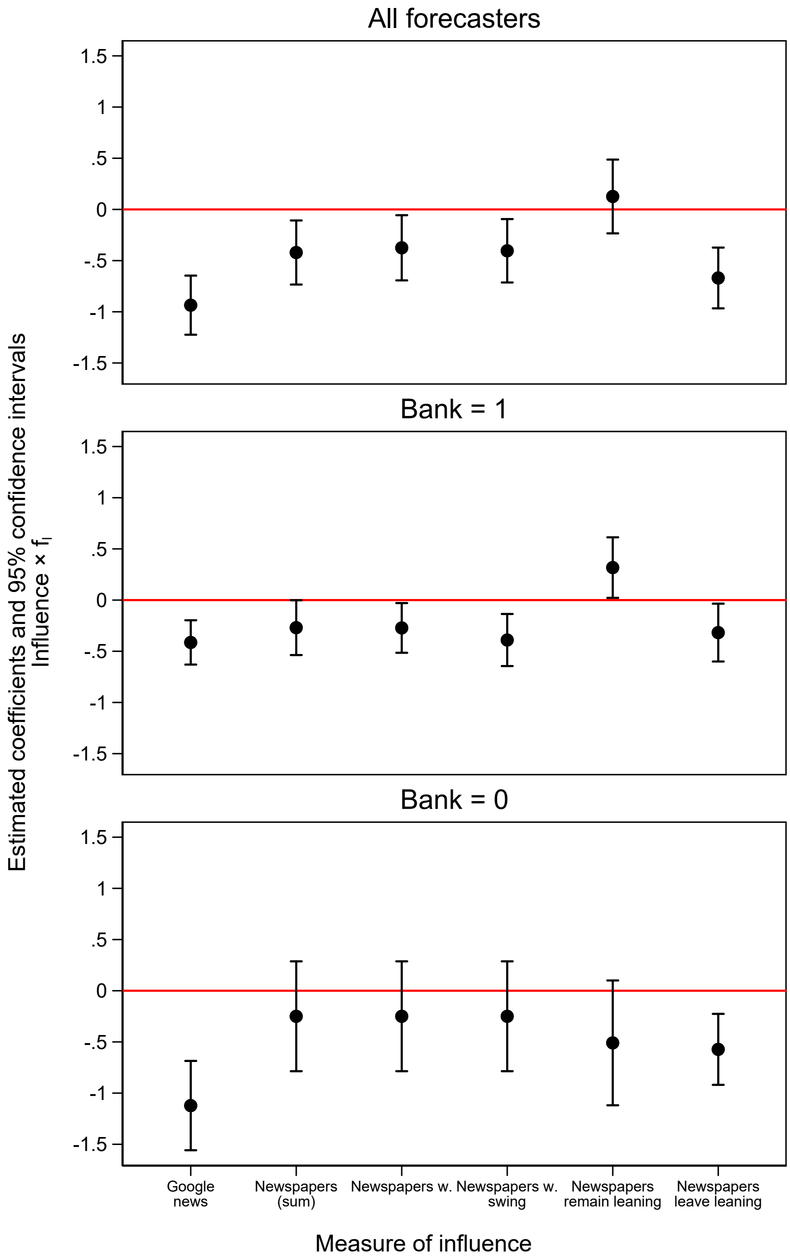
$$\begin{aligned} f_{j,m}^{t+1} = {} & \beta_1 Influence_j \times \underbrace{\mathbb{1}(k_m \in [-4,-1])}_{f_r} + \beta_2 Influence_j \times \underbrace{\mathbb{1}(k_m = 0)}_{f_\ell} \\ & + \beta_3 Influence_j \times \underbrace{\mathbb{1}(k_m \in [1,5])}_{f'_\ell} + \theta_j + \delta_m + \varepsilon_{j,m}, \end{aligned} \tag{5}$$

where $Influence_j$ is defined using the six indicators defined above. We estimate equation (5) for both the full sample of forecasters and in the subsamples of financial institutions (i.e., Bank=1) and of the other institutions (i.e., Bank=0).

We detect a substantial impact of forecasters' influence on the magnitude of political bias estimated in connection with the Brexit referendum. The leftmost coefficients of Figure 11 show that forecasters often mentioned in articles indexed by Google News published GDP growth rate forecasts for the Leave scenario that were 0.94 percentage point lower than those of other institutions. We also observe that influence matters among financial institutions. Forecasters in the financial sector often mentioned in the UK media were on average 0.42 percentage point more pessimistic and incorrect than their competitors on the short-run impact of Brexit on GDP growth. The second and third coefficients (i.e., labelled in the figure as "Newspapers (sum)" and as "Newspapers

[27] The two indicators are not mutually exclusive solely because both indicators take the value of 0 for forecasters never mentioned in any of the five newspapers.

Figure 11: Estimation of Political Bias in GDP Growth Forecasts—Influence



Notes: The figure reports the coefficients β_2 for the interaction term $Influence_j \times \mathbb{1}(k_m = 0)$, i.e., $Influence_j \times f_\ell$. The estimated equation is (5). Ninety-five per cent confidence intervals are based on standard errors robust to two-way clustering at the forecaster and survey levels.

w.", respectively) document qualitatively analogous results using alternative measures of influence across the general population.

These results are strongly consistent with the mechanism depicted in the theoretical model. Pessimistic forecasts released around the time of the referendum do not depend only on the stakes a forecaster has over the referendum outcome. They also strongly depend on the effective influence that a forecaster has on the formation of the voter's voting strategy (Prediction 2). Indeed, a forecaster with large stakes but who is not influential enough to affect any voters' choice does not have any incentive to manipulate her forecasts. The results obtained relying on indicators 1–3 are also helpful for ruling out the possibility that our results reflect biased beliefs (see, e.g., Gentzkow and Shapiro, 2006; Gentzkow et al., 2020; Sethi and Yildiz, 2016) about the impact of Brexit on the economy rather than intentional manipulation.[28] Although one could worry that forecasters with and without high stakes over the referendum outcome have different beliefs, we do not see any reasons for why beliefs should also depend on a forecaster's influence, holding stakes constant.

The remaining coefficients strengthen the relationship between influence and bias by exploiting heterogeneity in forecasters' exposure to media outlets consumed by voters with certain policy preferences. In particular, we observe that forecasters often mentioned in outlets consumed by many swing voters or many Leave-leaning voters used to release more pessimistic views than other forecasters. According to the fifth coefficient (forecasters mentioned on Remain-leaning outlets), we do not find any evidence that forecasters often mentioned in Remain-leaning media outlets were more pessimistic about the potential effects of Brexit than their competitors were.

Taken together, the results presented in Figure 11 highlight that the most pessimistic and incorrect forecasters were those with high stakes in support of the Remain choice and who were mentioned by media outlets consumed by many swing or Leave-leaning voters. We do not find any evidence that forecasters often mentioned in newspapers mainly consumed by Remain-leaning voters overestimated the negative impact of Brexit on the economy relative to other forecasters.[29] On the one hand, these results confirm the main intuition contained in our theoretical model: being exposed to financial loss in the event of Brexit leads to a release of biased estimates only if the forecaster had a real chance to impact voters' beliefs and voting strategies. On the other hand, these results are not consistent with the conjecture that forecasters release biased estimates in response to voters' will to read information consistent with their priors (see, e.g., Arceneaux et al., 2012; Iyengar et al., 2008).[30] In that case, we would have detected a more considerable

[28] This conjecture relates to the possibility that forecasters with stakes had biased beliefs about the underlying economic effects of a Brexit vote, whereas other forecasters relied on more objective estimates. Therefore, our results reflect differences in beliefs rather than in the attempt to influence the referendum outcome.

[29] For completeness, the bottom panel documents the role of influence among other forecasters (i.e., forecasters such that Bank = 0). Although these results do not have an immediate interpretation in our theoretical model, they are informative in documenting the overall validity of our theory. First, the correlation between a forecaster's influence and the bias that we find in the top panel among all forecasters is primarily driven by financial institutions. Second, the results confirm that the most pessimistic forecasters do not have a historical record of having often been mentioned in Remain-leaning newspapers.

[30] This conjecture relates to voters' selective exposure to mass media. Suppose that voters with different idiosyncratic preferences choose to gather information from alternative media outlets because such

bias among forecasters often mentioned in the media consumed by voters leaning towards supporting the Remain choice.

5.3 Robustness Checks

Figure 8 shows that the parallel trends assumption is likely satisfied in this context. Moreover, forecasts reported in Consensus Economics (2016b) reflect, on average, the views expressed before the referendum (see Figure 7). We perform several robustness checks to further validate our empirical strategy and exclude the possibility that our estimates depend on alternative mechanisms.

We start by excluding the possibility that comparable results can be estimated in connection with other highly uncertain events that did not involve elections in the United Kingdom. The following exercises aim to further exclude the possibility that our results reflect an irrational reaction to the referendum shock of forecasters with stakes rather than an intentional attempt to manipulate voters (which indicates that one of our identifying assumptions might not hold).

In Figure 12, we estimate the same regression model as in (2) at different points in time to assess whether similar evidence of bias exists in other periods. The figure shows a sizable jump in the estimates at the time of and in the months immediately after the referendum, whereas the prereferendum estimates are centred at zero. Moreover, forecasters with and without stakes published very similar estimates throughout 2017, especially in the releases published exactly one year after this paper's main focus – and, hence, at a constant forecast horizon.

In Figure 13, we estimate (2) before and after numerous paramount shocks with potential consequences to the economy that could mimic markets' and forecasters' reactions but that did not entail a referendum in the UK. Specifically, we assess whether a similar pattern of results could be detected in concurrence with the unexpected beginning of the 2008 financial crisis, the referendum that took place in France in 2005, after which the approval process of the EU Constitution was stopped, and the 2001 attack on the World Trade Center in New York.[31,32] The results show no evidence of differences in the be-

voters are more willing to believe information that confirms their priors. Market incentives induce mass media to publish information aligned with the opinions of their customers and, in turn, select macroeconomic forecasts aligned with those views. Accordingly, market incentives also induce forecasters to please their actual readers and media outlets in which their estimates are published more often.

[31] We identify the unexpected beginning of the financial crisis as the bankruptcy of Lehman Brothers Holdings Inc. on September 15, 2008.

[32] We do not identify any adverse events comparable to the withdrawal from the European Union during the period of our primary data (from January 2012 to April 2018). Therefore, we digitize older publications of the *Forecasts for the UK Economy* collection from the The National Archives, which extends the sample back to 1998. We investigate forecasters' behaviour around the time of the 2001 terrorist attack by estimating equation (2) for a sample between 1998 and 2003, whereas we explore the reaction to the lack of French approval of the EU referendum by restricting the sample to observations

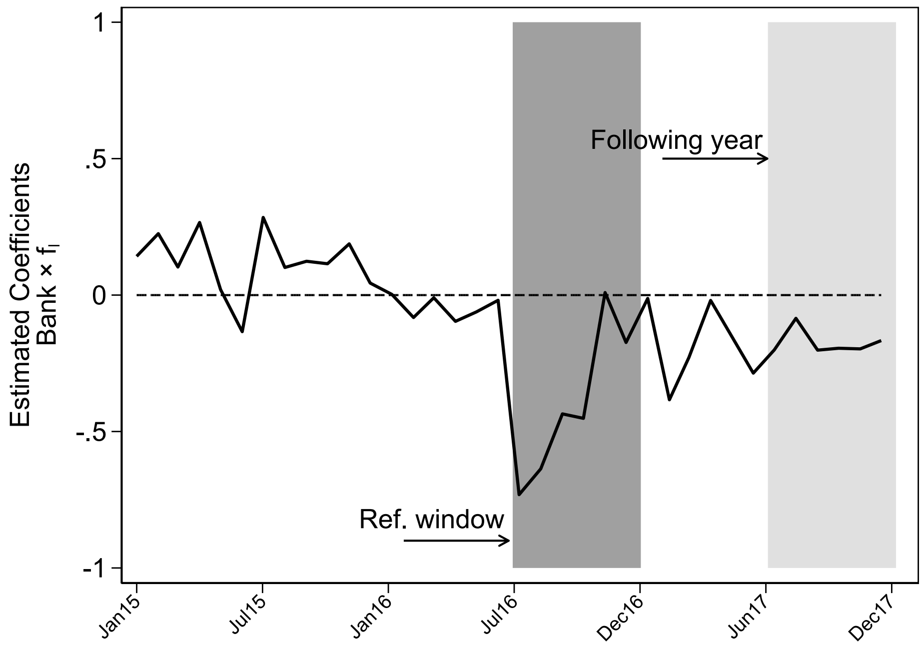


Figure 12: Estimated Political Bias at Different Points in Time

Notes: In this figure, we estimate (2) by assuming that a placebo referendum occurs in every month between January 2015 and April 2018. The solid line represents the estimated coefficient of β_2 obtained at each iteration. The dark grey area represents the coefficient estimated in July 2016; August 2016; September 2016; October 2016; and November 2016. The light grey area represents result estimated for surveys released during the same months of the following year. The measure of stakes is Bank.

haviour of institutions with and without stakes in the surveys after each event compared with that of their competitors. The coefficients are not statistically distinguishable from zero in the four surveys after the event.

We then ruled out the possibility that financial institutions (i.e., the institutions with stakes over the referendum outcome) usually release more incorrect estimates than the other forecasters. This exercise further mitigates the possibility that institutions with stakes released more incorrect estimates because their beliefs were less accurate than those of the control forecasters. In Table C6 in the Appendix, we show that there is no difference in forecast performance between forecasters with and without stakes by regressing the absolute forecast error on survey fixed effects and a stakes indicator. The results show that the stakes coefficients are indistinguishable from zero both between 2012 and 2015 and in an extended sample that includes all monthly forecasts released between 1998 and 2015. Hence, we conclude that no evidence suggests that financial institutions have lower forecasting ability than do their competitors.

We also show that our results do not depend on the number of surveys included in the

between 2000 and 2007 and the reaction to the unexpected beginning of the financial crisis by restricting the sample to observations between 2004 and 2010. Notably, the group of forecasters surveyed changes slightly when the different analysis samples are compared.

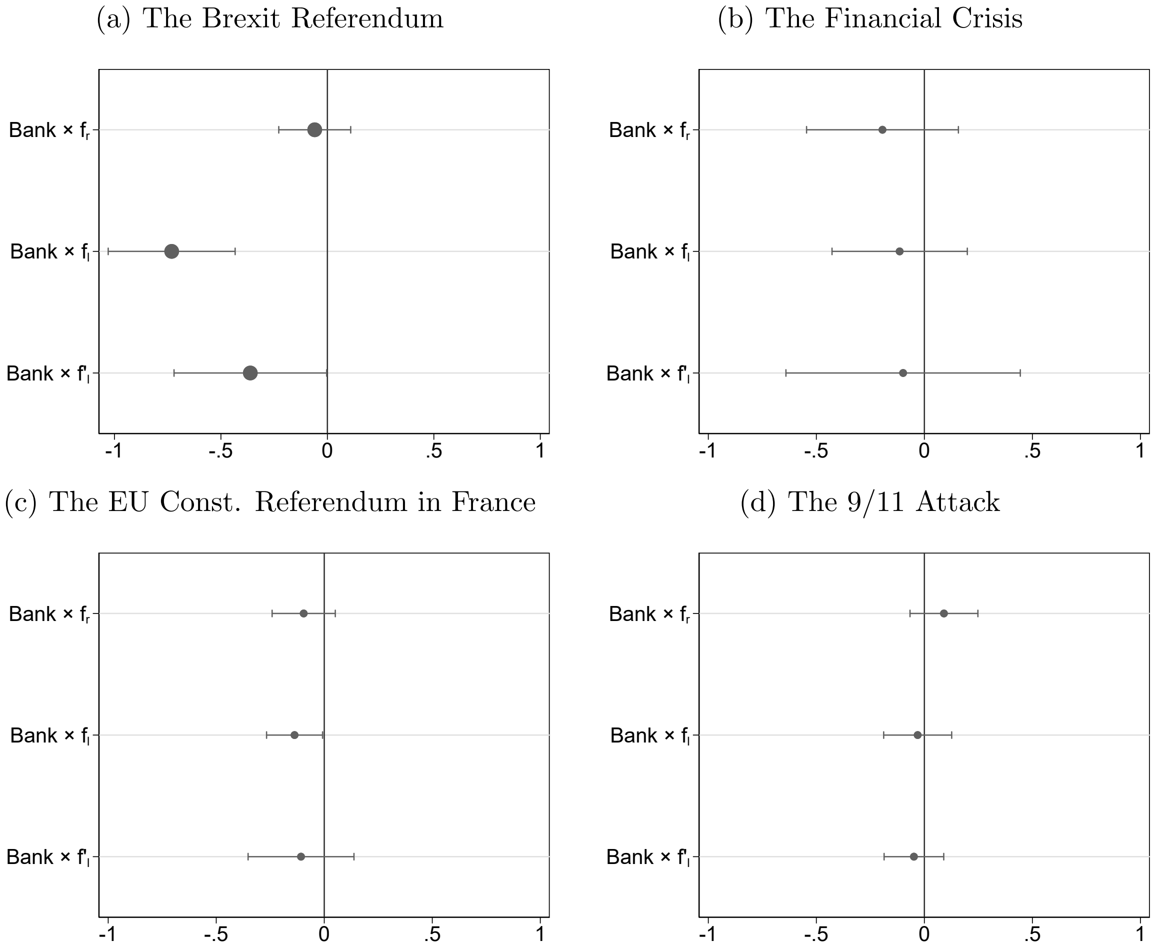


Figure 13: Effects during the EU Referendum and in the Case of Other Events

Notes: The figure reports estimated coefficients and 95% confidence intervals resulting from estimating (2) for the occasions of the EU membership referendum, the bankruptcy of Lehman Brothers, and the attacks on the World Trade Center in New York. Estimates of 95% confidence intervals are based on standard errors robust to two-way clustering at the forecaster and survey levels.

analysis. Figure C6 in the Appendix reports the estimated coefficients and confidence intervals for β_0 obtained for several different temporal windows. The estimated coefficients are stable for all specifications and are not sensitive to the data's time span.

Furthermore, we show that our results are robust to alternative definitions of stakes. First, in Table C7, we exclude from the sample other forecasters that might have had stakes in the referendum outcomes, such as the confederation of UK firms and international institutions. Reassuringly, the results are similar and stronger than those in our main specification.

Finally, we provide evidence that the statistical significance of our estimates does not depend on our specific choice of imposing standard errors that are robust to two-way clustering at the forecaster and survey month levels. Specifically, we show in Figure C7 in the Appendix that imposing other assumptions on standard errors yields conclusions analogous to our main results.

6 Concluding Remarks

Voters are seldom entirely aware of the economic consequences of their choices before they cast a vote. Traditionally, we think of special interest groups and media as potentially releasing biased information to affect individual beliefs and, in turn, voting behaviour.

In this paper, we introduce macroeconomic forecasters as political agents. We suggest that they exploit their information advantage about the economy's future states to influence the policymaking process. We theoretically analyse a framework with asymmetric information between a forecaster and a voter in the period approaching a referendum. The forecaster is better informed about the future state of the economy under each of the two policies the voter can pick. The voter relies on the professional forecaster's predictions to form beliefs before casting his or her vote. The forecaster prefers one of the two policies; however, releasing biased estimates is costly in terms of reputation. Under our model's assumptions, it is optimal for a forecaster with an economic preference for one of the two policies to publish biased forecasts instead of the best estimate. We test the model's predictions using the EU membership referendum, also known as the Brexit referendum, held in the UK in 2016.

The empirical results are consistent with the theoretical model. First, we observe that forecasters with stakes supporting Remain released GDP growth forecasts contingent on the victory of Leave that were more pessimistic than the forecasts released by other institutions. Second, we do not find any evidence that forecasters with and without stakes published different estimates contingent on the victory of Remain. Third, we observe that after the referendum, forecasters converged slowly to release unbiased estimates only a few months after the vote. Fourth, we disclose that forecasters' influence was an important determinant of the bias.

Political bias might impact the welfare of both voters and forecasters. In the Brexit referendum won by the Leave campaign, voters did not face any welfare loss compared to a counterfactual in which all forecasts were unbiased. In contrast, forecasters with higher stakes and influence paid a high reputation cost and faced the economic losses associated with Brexit. In addition to the losses presented in the model, political forecast bias might generate additional welfare reductions if consumers and investors make consumption and investment decisions based on biased forecasts.

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A Proofs

Proofs for Section 2.1

First, an optimal strategy must lie about both outcomes only if $(y_\ell, y_r) = (\overline{\ell}, \underline{r})$.

Lemma A1. *If π^* is optimal, then:*

$$\pi^*((\overline{\ell}, \underline{r})|(\underline{\ell}, \overline{r})) = \pi^*((\overline{\ell}, \overline{r})|(\underline{\ell}, \underline{r})) = \pi^*((\underline{\ell}, \underline{r})|(\overline{\ell}, \overline{r})) = 0.$$

Proof. Let $y_\ell^\dagger \neq y_\ell^\bullet$, $y_r^\dagger \neq y_r^\bullet$ and $(y_\ell^\dagger, y_r^\dagger) \neq (\underline{\ell}, \overline{r})$. Then:

$$u((\underline{\ell}, \overline{r}), (y_\ell^\bullet, y_r^\bullet), \pi^*) \geq (1 - F(\underline{\ell} - \overline{r}))\rho > (1 - F(y_\ell^\dagger - y_r^\dagger))\rho = u((y_\ell^\dagger, y_r^\dagger), (y_\ell^\bullet, y_r^\bullet), \pi^*),$$

hence $\pi^*((y_\ell^\dagger, y_r^\dagger)|(y_\ell^\bullet, y_r^\bullet)) = 0$. □

Second, if an optimal strategy is to lie, then the lie bolsters the odds of the voter selecting Remain.

Lemma A2. *If π^* is optimal, then for any y_r and any y_ℓ:*

$$\pi^*((\overline{\ell}, y_r)|(\underline{\ell}, y_r)) = \pi^*((y_\ell, \underline{r})|(y_\ell, \overline{r})) = 0.$$

Proof. We proceed by contradiction. Suppose that $\pi^*((\overline{\ell}, y_r)|(\underline{\ell}, y_r)) > 0$ for some y_r. It must then be the case that

$$\begin{aligned} u((\overline{\ell}, y_r), (\underline{\ell}, y_r), \pi^*) &\geq u((\underline{\ell}, y_r), (\underline{\ell}, y_r), \pi^*) \Leftrightarrow \\ M((\overline{\ell}, y_r), (\underline{\ell}, y_r), \pi^*) - M((\underline{\ell}, y_r), (\underline{\ell}, y_r), \pi^*) &\geq (F(\overline{\ell} - y_r) - F(\underline{\ell} - y_r))\rho. \end{aligned} \tag{A1}$$

As $F(\overline{\ell} - y_r) > F(\underline{\ell} - y_r)$, then (A1) holds only if:

$$M((\overline{\ell}, y_r), (\underline{\ell}, y_r), \pi^*) > M((\underline{\ell}, y_r), (\underline{\ell}, y_r), \pi^*). \tag{A2}$$

In general, if the outcome matches the forecast, then the updated reputation satisfies

$$\mu \in \left[\frac{\mu_0}{2 - \mu_0}, 1\right],$$

while $\mu = 0$ when the outcome does not match the forecast. Hence, (A2) holds only if:

$$\begin{aligned} (1 - F(\overline{\ell} - y_r)) \cdot 1 &> F(\underline{\ell} - y_r) \cdot \frac{\mu_0}{2 - \mu_0} + (1 - F(\underline{\ell} - y_r)) \cdot \frac{\mu_0}{2 - \mu_0} \Leftrightarrow \\ 1 - F(\overline{\ell} - y_r) &> \frac{\mu_0}{2 - \mu_0}. \end{aligned} \tag{A3}$$

Assumption (v) ensures that the inequality is violated for $y_r = \overline{r}$. As $1 - F(\overline{\ell} - y_r)$ is an increasing function of y_r, the inequality is violated for all y_r. This contradiction proves that $\pi^*((\overline{\ell}, y_r)|(\underline{\ell}, y_r)) = 0$ for all y_r.
As $1 - F(y_\ell - y_r) > F(y_\ell - y_r)$ for any pair (y_ℓ, y_r) the same argument can be used to prove that $\pi^*((y_\ell, \underline{r})|(y_\ell, \overline{r})) = 0$ for any y_ℓ. □

Proof of Lemma 1. Combining Lemmata A1 and A2 yields Lemma 1. □

In light of Lemma 1, we focus on strategies that require $f_\ell = \underline{\ell}$ if $y_\ell = \underline{\ell}$ and $f_r = \overline{r}$ if $y_r = \overline{r}$. We refer to them as *candidate strategies*. Any candidate strategy π is fully characterized by a tuple $\phi \in \Phi$, where

$$\Phi \equiv \left\{(\phi_\emptyset, \phi_{\underline{r}}, \phi_{\overline{\ell}}, \phi_{\overline{r}}, \phi_{\underline{\ell}}) \in [0,1]^5 | \phi_\emptyset + \phi_{\underline{r}} + \phi_{\overline{\ell}} \leq 1\right\},$$

and

$$\phi_\emptyset \equiv \pi((\underline{\ell}, \overline{r})|(\overline{\ell}, \underline{r})); \quad \phi_{\underline{r}} \equiv \pi((\underline{\ell}, \underline{r})|(\overline{\ell}, \underline{r})); \quad \phi_{\overline{\ell}} \equiv \pi((\overline{\ell}, \overline{r})|(\overline{\ell}, \underline{r}));$$
$$\phi_{\overline{r}} \equiv \pi((\underline{\ell}, \overline{r})|(\overline{\ell}, \overline{r})); \quad \phi_{\overline{\ell}} \equiv \pi((\overline{\ell}, \overline{r})|(\overline{\ell}, \underline{r})).$$

In what follows, *forecasting according to* $\phi_{\overline{r}}$ means following a candidate strategy π such that $\pi((\underline{\ell}, \overline{r})|(\overline{\ell}, \overline{r})) \equiv \phi_{\overline{r}}$. We define *forecasting according to* $\phi_{\underline{\ell}}$ and *forecasting according to* $(\phi_\emptyset, \phi_{\underline{r}}, \phi_{\overline{\ell}})$ in the same way. We use $u(\cdot, \cdot, \phi^e)$, $\mu(\cdot, \cdot, \phi^e)$ and $M(\cdot, \cdot, \phi^e)$ instead of $u(\cdot, \cdot, \pi^e)$, $\mu(\cdot, \cdot, \pi^e)$ and $M(\cdot, \cdot, \pi^e)$, respectively. We say that a tuple $\phi \in \Phi$ is *optimal* if it is associated with an optimal strategy.
We define a mapping from a tuple $\phi^e \in \Phi$ describing the belief of the market to the set of forecasts that are optimal on observing $(\overline{\ell}, \underline{r})$:

$$m(\phi^e) \equiv arg\,max_{\left\{(\overline{\ell}, \underline{r}), (\underline{\ell}, \overline{r}), (\underline{\ell}, \underline{r}), (\overline{\ell}, \overline{r})\right\}} u(x, (\overline{\ell}, \underline{r}), (\phi^e)),$$

Three additional definitions are needed.

Definition A1. *If forecasting according to* $(\phi^\dagger_\emptyset, \phi^\dagger_{\underline{r}}, \phi^\dagger_{\overline{\ell}})$ *is optimal conditional on (i) the market believing* $\phi^e = (\phi^\dagger_\emptyset, \phi^\dagger_{\underline{r}}, \phi^\dagger_{\overline{\ell}}, \phi^\dagger_{\overline{r}}, \phi^\dagger_{\underline{\ell}})$*, and (ii) the forecaster forecasting according to* $\phi^\dagger_{\overline{r}}$ *and* $\phi^\dagger_{\underline{\ell}}$*, then* $(\phi^\dagger_\emptyset, \phi^\dagger_{\underline{r}}, \phi^\dagger_{\overline{\ell}})$ *is consistent with* $(\phi^\dagger_{\overline{r}}, \phi^\dagger_{\underline{\ell}})$*.*

Definition A2. *If forecasting according to* $\phi^\dagger_{\overline{r}}$ *is optimal conditional on (i) the market believing* $\phi^e = (\phi^\dagger_\emptyset, \phi^\dagger_{\underline{r}}, \phi^\dagger_{\overline{\ell}}, \phi^\dagger_{\overline{r}}, \phi^\dagger_{\underline{\ell}})$*, where* $(\phi^\dagger_\emptyset, \phi^\dagger_{\underline{r}}, \phi^\dagger_{\overline{\ell}})$ *is consistent with* $(\phi^\dagger_{\overline{r}}, \phi^\dagger_{\underline{\ell}})$*, and (ii) forecaster forecasting according to* $\phi^\dagger_{\underline{\ell}}$ *and* $(\phi^\dagger_\emptyset, \phi^\dagger_{\underline{r}}, \phi^\dagger_{\overline{\ell}})$*; then,* $\phi^\dagger_{\overline{r}}$ *is consistent with* $\phi^\dagger_{\underline{\ell}}$*.*

Definition A3. *If forecasting according to* $\phi^\dagger_{\underline{\ell}}$ *is optimal conditional on (i) the market believing* $\phi^e = (\phi^\dagger_\emptyset, \phi^\dagger_{\underline{r}}, \phi^\dagger_{\overline{\ell}}, \phi^\dagger_{\overline{r}}, \phi^\dagger_{\underline{\ell}})$*, where* $\phi^\dagger_{\overline{r}}$ *is consistent with* $\phi^\dagger_{\underline{\ell}}$ *and* $(\phi^\dagger_\emptyset, \phi^\dagger_{\underline{r}}, \phi^\dagger_{\overline{\ell}})$ *is consistent with* $(\phi^\dagger_{\underline{\ell}}, \phi^\dagger_{\overline{r}})$*, and (ii) the forecaster forecasting according to* $\phi^\dagger_{\overline{r}}$ *and* $(\phi^\dagger_\emptyset, \phi^\dagger_{\underline{r}}, \phi^\dagger_{\overline{\ell}})$*, then* $\phi^\dagger_{\underline{\ell}}$ *is an equilibrium* $\phi^\dagger_{\underline{\ell}}$*.*

We prove Lemma 2 by way of a sequence of lemmata.

Lemma A3. *For any* $(\phi_{\overline{r}}, \phi_{\underline{\ell}}) \in [0,1]^2$*, there exists a triple* $(\phi_{\emptyset}, \phi_{\underline{r}}, \phi_{\overline{\ell}})$ *consistent with* $(\phi_{\overline{r}}, \phi_{\underline{\ell}})$*.*

Proof. The following property can be readily verified.
Property A1. *The function* $u((f_\ell, f_r), (y_\ell, y_r), \phi^e)$ *is continuous in every element of* ϕ^e*. Furthermore,* $u((\underline{\ell}, \overline{r}), (\overline{\ell}, \underline{r}), \phi^e)$ *is constant in every element of* ϕ^e*, function* $u((\underline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^e)$ *is decreasing in* $\phi^e_{\underline{r}}$*, function* $u((\overline{\ell}, \overline{r}), (\overline{\ell}, \underline{r}), \phi^e))$ *is decreasing in* $\phi^e_{\overline{\ell}}$*, and function* $u((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^e)$ *is increasing in* $\phi^e_{\emptyset}$*,* $\phi^e_{\underline{r}}$ *and* $\phi^e_{\overline{\ell}}$*.*
Now, fix a pair $(\phi_{\overline{r}}, \phi_{\underline{\ell}}) \in [0,1]^2$. If $(\overline{\ell}, \underline{r}) \in m(0,0,0,\phi^\dagger_{\overline{r}}, \phi^\dagger_{\underline{\ell}})$, then triple $(0,0,0)$ is consistent with $(\phi_{\underline{\ell}}, \phi_{\overline{r}})$. Suppose $(\overline{\ell}, \underline{r}) \notin m(0,0,0,\phi_{\overline{r}}, \phi_{\underline{\ell}})$. Property A1 ensures that there exists an $\epsilon > 0$ such that at least one of these conditions holds:

(A. I) if $\phi_{\emptyset} \in [0,\epsilon]$, then $(\underline{\ell}, \overline{r}) \in m(\phi_{\emptyset}, 0, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}})$;

(A. II) if $\phi_{\underline{r}} \in [0,\epsilon]$, then $(\underline{\ell}, \underline{r}) \in m(0, \phi_{\underline{r}}, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}})$;

(A. III) if $\phi_{\overline{\ell}} \in [0,\epsilon]$, then $(\overline{\ell}, \overline{r}) \in m(0, 0, \phi_{\overline{\ell}}, \phi_{\overline{r}}, \phi_{\underline{\ell}})$.

Suppose that Condition A.I holds. If $(\underline{\ell}, \overline{r}) \in m(1,0,0,\phi_{\overline{r}}, \phi_{\underline{\ell}})$, then triple $(1,0,0)$ is consistent with $(\phi_{\overline{r}}, \phi_{\underline{\ell}})$. If instead $(\underline{\ell}, \overline{r}) \notin m(1,0,0,\phi_{\overline{r}}, \phi_{\underline{\ell}})$, then Property A1 ensures the existence of a $\psi_a \in (0,1)$ such that $\{(\underline{\ell}, \overline{r}), (\overline{\ell}, \underline{r})\} \subseteq m(\psi_a, 0, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}})$. Triple $(\psi_a, 0, 0)$ is consistent with $(\phi^\dagger_{\overline{r}}, \phi^\dagger_{\underline{\ell}})$. Hence, if Condition (A.I) holds, a triple consistent with $(\phi^\dagger_{\overline{r}}, \phi^\dagger_{\underline{\ell}})$ exists.
Suppose that Condition A.I is violated and that Condition A.II holds. The proof in the case where Condition A.I is violated and Condition A.III holds is identical and therefore omitted. If

$$(\underline{\ell}, \underline{r}) \in m(0,1,0,\phi_{\overline{r}}, \phi_{\underline{\ell}}),$$

, then triple $(0,1,0)$ is consistent with $(\phi_{\overline{r}}, \phi_{\underline{\ell}})$. If instead $(\underline{\ell}, \underline{r}) \notin m(0,1,0,\phi^\dagger_{\overline{r}}, \phi^\dagger_{\underline{\ell}})$, then Property A1 implies the existence of a $\psi_a \in (0,1)$ such that

$$(\underline{\ell}, \underline{r}) \in m(0, \psi_a, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}}),$$

and at least one of these conditions holds:

(A.II.1) $(\overline{\ell}, \underline{r}) \in m(0, \psi_a, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}})$;

(A.II.2) $(\underline{\ell}, \overline{r}) \in m(0, \psi_a, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}})$ and $(\overline{\ell}, \underline{r}) \notin m(0, \psi_a, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}})$;

(A.II.3) $(\overline{\ell}, \overline{r}) \in m(0, \psi_a, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}})$ and $(\overline{\ell}, \underline{r}) \notin m(0, \psi_a, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}})$.

If Condition A.II.1 holds, then triple $(0, \psi_a, 0)$ is consistent with $(\phi_{\overline{r}}, \phi_{\underline{\ell}})$. If Condition A.II.2 holds, we distinguish two mutually exclusive cases. Either

$$\{(\underline{\ell}, \underline{r}), (\underline{\ell}, \overline{r})\} \subseteq m(1 - \psi_a, \psi_a, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}}),$$

or not. In the former case, $(1 - \psi_a, \psi_a, 0)$ is consistent with $(\phi_{\overline{r}}, \phi_{\underline{\ell}})$. In the latter case, Property A1 ensures that there exists a $\psi_b \in [0, 1 - \psi_a)$ such that $\{(\overline{\ell}, \underline{r}), (\underline{\ell}, \underline{r}), (\underline{\ell}, \overline{r})\} \subseteq m(\psi_b, \psi_a, 0, \phi_{\overline{r}}, \phi_{\underline{\ell}})$; triple $(\psi_b, \psi_a, 0)$ is then consistent with $(\phi_{\overline{r}}, \phi_{\underline{\ell}})$.

Suppose now that Condition A.II.3 holds. Property A1 ensures that there exists a $\psi_b \in (\psi_a, 1]$ such that at least one of the following cases holds:

(A.II.3:1) $\{(\underline{\ell}, \underline{r}), (\overline{\ell}, \overline{r})\} \subseteq m(0, \psi_b, 1 - \psi_b, \phi_{\overline{r}}, \phi_{\underline{\ell}})$;

(A.II.3:2) $\exists \psi_c \in (0, 1 - \psi_b)$ such that $\{(\underline{\ell}, \underline{r}), (\overline{\ell}, \overline{r}), (\overline{\ell}, \underline{r})\} \subseteq m(0, \psi_b, \psi_c, \phi_{\overline{r}}, \phi_{\underline{\ell}})$;

(A.II.3:3) $\exists \psi_c \in (0, 1 - \psi_b)$ such that $\{(\underline{\ell}, \underline{r}), (\overline{\ell}, \overline{r}), (\underline{\ell}, \overline{r})\} \subseteq m(1 - \psi_b - \psi_c, \psi_b, \psi_c, \phi_{\overline{r}}, \phi_{\underline{\ell}})$;

(A.II.3:4) $\exists \psi_c \in (0, 1 - \psi_b)$ and $\exists \psi_d \in (0, 1 - \psi_b - \psi_c)$ such that $\{(\underline{\ell}, \underline{r}), (\overline{\ell}, \overline{r}), (\underline{\ell}, \overline{r}), (\overline{\ell}, \underline{r})\} = m(\psi_d, \psi_b, \psi_c, \phi_{\overline{r}}, \phi_{\underline{\ell}})$.

The following list provides, for each case, a triple that is consistent with $(\phi^{\dagger}_{\overline{r}}, \phi^{\dagger}_{\underline{\ell}})$:

- $(0, \psi_b, 1 - \psi_b)$ (in case A.II.3:1);
- $(0, \psi_b, \psi_c)$ (in case A.II.3:2);
- $(1 - \psi_b - \psi_c, \psi_b, \psi_c)$ (in case A.II.3:3);
- (ψ_d, ψ_b, ψ_c) (in case A.II.3:4).

This concludes the proof of the lemma. □

Lemma A4. *For any pair* $(\phi_{\overline{r}}, \phi_{\underline{\ell}}) \in [0, 1]^2$*, the triple* $(\phi^{\dagger}_{\emptyset}, \phi^{\dagger}_{\underline{r}}, \phi^{\dagger}_{\overline{\ell}})$ *consistent with* $(\phi_{\overline{r}}, \phi_{\underline{\ell}})$ *is unique. The function that maps pairs* $(\phi_{\overline{r}}, \phi_{\underline{\ell}})$ *into consistent triples is continuous.*

Proof. We proceed by contradiction. Suppose that for some pair $(\phi_{\overline{r}}, \phi_{\underline{\ell}}) \in [0, 1]^2$ there exist two consistent triples $(\phi^{\dagger}_{\emptyset}, \phi^{\dagger}_{\underline{r}}, \phi^{\dagger}_{\overline{\ell}}) \neq (\phi^{\bullet}_{\emptyset}, \phi^{\bullet}_{\underline{r}}, \phi^{\bullet}_{\overline{\ell}})$. We denote with $\pi^{\dagger}$ and $\pi^{\bullet}$ the candidate strategies characterized, respectively, by $(\phi^{\dagger}_{\emptyset}, \phi^{\dagger}_{\underline{r}}, \phi^{\dagger}_{\overline{\ell}}, \phi_{\overline{r}}, \phi_{\underline{\ell}})$ and $(\phi^{\bullet}_{\emptyset}, \phi^{\bullet}_{\underline{r}}, \phi^{\bullet}_{\overline{\ell}}, \phi_{\overline{r}}, \phi_{\underline{\ell}})$. Let $\phi^{\dagger}_{\emptyset} + \phi^{\dagger}_{\underline{r}} + \phi^{\dagger}_{\overline{\ell}} < \phi^{\bullet}_{\emptyset} + \phi^{\bullet}_{\underline{r}} + \phi^{\bullet}_{\overline{\ell}}$. Then, $\pi^{\dagger}((\overline{\ell}, \underline{r})|(\overline{\ell}, \underline{r})) > \pi^{\bullet}((\overline{\ell}, \underline{r})|(\overline{\ell}, \underline{r}))$; hence,

$$u((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), (\phi^{\bullet}_{\emptyset}, \phi^{\bullet}_{\underline{r}}, \phi^{\bullet}_{\overline{\ell}}, \phi_{\overline{r}}, \phi_{\underline{\ell}})) > u((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), (\phi^{\dagger}_{\emptyset}, \phi^{\dagger}_{\underline{r}}, \phi^{\dagger}_{\overline{\ell}}, \phi_{\overline{r}}, \phi_{\underline{\ell}})). \tag{A4}$$

Suppose $\phi^{\dagger}_{\emptyset} < \phi^{\bullet}_{\emptyset}$. Then,

$$u((\underline{\ell}, \overline{r}), (\overline{\ell}, \underline{r}), (\phi^{\bullet}_{\emptyset}, \phi^{\bullet}_{\underline{r}}, \phi^{\bullet}_{\overline{\ell}}, \phi_{\overline{r}}, \phi_{\underline{\ell}})) \leq u((\underline{\ell}, \overline{r}), (\overline{\ell}, \underline{r}), (\phi^{\dagger}_{\emptyset}, \phi^{\dagger}_{\underline{r}}, \phi^{\dagger}_{\overline{\ell}}, \phi_{\overline{r}}, \phi_{\underline{\ell}})). \tag{A5}$$

Conditions (A4) and (A5), together with $\phi_\emptyset^\dagger < \phi_\emptyset^\bullet$, lead to a contradiction; hence, $\phi_\emptyset^\dagger \geq \phi_\emptyset^\bullet$. If we assume that $\phi_{\underline{r}}^\dagger < \phi_{\underline{r}}^\bullet$, and/or $\phi_{\overline{\ell}}^\dagger < \phi_{\overline{\ell}}^\bullet$, we reach a similar contradiction. Hence, we can rule out $\phi_\emptyset^\dagger + \phi_{\underline{r}}^\dagger + \phi_{\overline{\ell}}^\dagger < \phi_\emptyset^\bullet + \phi_{\underline{r}}^\bullet + \phi_{\overline{\ell}}^\bullet$. Clearly, $\phi_\emptyset^\dagger + \phi_{\underline{r}}^\dagger + \phi_{\overline{\ell}}^\dagger > \phi_\emptyset^\bullet + \phi_{\underline{r}}^\bullet + \phi_{\overline{\ell}}^\bullet$ can be ruled out by the same argument. Hence,

$$\phi_\emptyset^\dagger + \phi_{\underline{r}}^\dagger + \phi_{\overline{\ell}}^\dagger = \phi_\emptyset^\bullet + \phi_{\underline{r}}^\bullet + \phi_{\overline{\ell}}^\bullet \Leftrightarrow$$
$$u((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), (\phi_\emptyset^\bullet, \phi_{\underline{r}}^\bullet, \phi_{\overline{\ell}}^\bullet, \phi_{\overline{r}}, \phi_{\underline{\ell}})) = u((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), (\phi_\emptyset^\dagger, \phi_{\underline{r}}^\dagger, \phi_{\overline{\ell}}^\dagger, \phi_{\overline{r}}, \phi_{\underline{\ell}})). \tag{A6}$$

Combining $(\phi_\emptyset^\dagger, \phi_{\underline{r}}^\dagger, \phi_{\overline{\ell}}^\dagger) \neq (\phi_\emptyset^\bullet, \phi_{\underline{r}}^\bullet, \phi_{\overline{\ell}}^\bullet)$ and $(\phi_\emptyset^\dagger, \phi_{\underline{r}}^\dagger, \phi_{\overline{\ell}}^\dagger) \neq (\phi_\emptyset^\bullet, \phi_{\underline{r}}^\bullet, \phi_{\overline{\ell}}^\bullet)$, we conclude that the two triples must differ in at least two elements. In particular, either $\phi_{\underline{r}}^\dagger \neq \phi_{\underline{r}}^\bullet$ or $\phi_{\overline{\ell}}^\dagger \neq \phi_{\overline{\ell}}^\bullet$, or both. Suppose $\phi_{\underline{r}}^\dagger \neq \phi_{\underline{r}}^\bullet$. The case $\phi_{\overline{\ell}}^\dagger \neq \phi_{\overline{\ell}}^\bullet$ is identical and therefore omitted. W.l.o.g. $\phi_{\underline{r}}^\dagger > \phi_{\underline{r}}^\bullet$. This implies:

$$u((\underline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), (\phi_\emptyset^\bullet, \phi_{\underline{r}}^\bullet, \phi_{\overline{\ell}}^\bullet, \phi_{\overline{r}}, \phi_{\underline{\ell}})) > u((\underline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), (\phi_\emptyset^\dagger, \phi_{\underline{r}}^\dagger, \phi_{\overline{\ell}}^\dagger, \phi_{\overline{r}}, \phi_{\underline{\ell}})). \tag{A7}$$

However, (A6) and (A7) together with $\phi_{\underline{r}}^\dagger > \phi_{\underline{r}}^\bullet$ lead to a contradiction. This observation proves that the triple consistent with $(\phi_{\overline{r}}, \phi_{\underline{\ell}})$ is unique. The second half of the lemma follows from the continuity of $u(\cdot, \cdot, \phi^e)$ in ϕ^e. □

Lemma A5. *An optimal strategy exists.*

Proof. To prove the lemma, it is enough to establish that an equilibrium $\phi_{\underline{\ell}}$ exists. We first prove that for any $\phi_{\underline{\ell}}$, there exists a $\phi_{\overline{r}}$ consistent with $\phi_{\underline{\ell}}$.
Fix a $\phi_{\underline{\ell}}^\dagger \in [0,1]$. Let $f(\phi_{\underline{\ell}}, \phi_{\overline{r}})$ be the continuous function mapping each pair $(\phi_{\underline{\ell}}, \phi_{\overline{r}})$ into the unique triple $(\phi_\emptyset, \phi_{\underline{r}}, \phi_{\overline{\ell}})$ consistent with it (see Lemmata A3 and A4). Define:

$$v((x,y),(\phi_{\overline{r}}, \phi_{\underline{\ell}}^\dagger)) \equiv u((x,y), (\overline{\ell}, \overline{r}), (f(\phi_{\overline{r}}, \phi_{\underline{\ell}}^\dagger), \phi_{\overline{r}}, \phi_{\underline{\ell}}^\dagger)).$$

If $v((\overline{\ell}, \overline{r}), (0, \phi_{\underline{\ell}}^\dagger)) \geq v((\underline{\ell}, \overline{r}), (0, \phi_{\underline{\ell}}^\dagger))$, then $\phi_{\overline{r}} = 0$ is consistent with $\phi_{\underline{\ell}}^\dagger$. If $v((\overline{\ell}, \overline{r}), (1, \phi_{\underline{\ell}}^\dagger)) \leq v((\underline{\ell}, \overline{r}), (1, \phi_{\underline{\ell}}^\dagger))$, then $\phi_{\overline{r}} = 1$ is consistent with $\phi_{\underline{\ell}}^\dagger$. If neither of these conditions holds, that is, if $v((\overline{\ell}, \overline{r}), (0, \phi_{\underline{\ell}}^\dagger)) < v((\underline{\ell}, \overline{r}), (0, \phi_{\underline{\ell}}^\dagger))$ and $v((\overline{\ell}, \overline{r}), (1, \phi_{\underline{\ell}}^\dagger)) > v((\underline{\ell}, \overline{r}), (1, \phi_{\underline{\ell}}^\dagger))$, then, as $v(\cdot, (\phi_{\overline{r}}, \cdot))$ is continuous in $\phi_{\overline{r}}$, we can invoke the intermediate value theorem to establish that $v((\overline{\ell}, \overline{r}), (x, \phi_{\underline{\ell}}^\dagger)) = v((\underline{\ell}, \overline{r}), (x, \phi_{\underline{\ell}}^\dagger))$ for some $x \in (0,1)$. In this case, $\phi_{\overline{r}} = x$ is consistent with $\phi_{\underline{\ell}}^\dagger$. We have thus proven that for any $\phi_{\underline{\ell}}$, there exists a $\phi_{\overline{r}}$ consistent with $\phi_{\underline{\ell}}$.
It is easy to verify that the mapping from $\phi_{\underline{\ell}}^\dagger$ to $\phi_{\overline{r}}$ consistent with $\phi_{\underline{\ell}}^\dagger$ is a continuous function. An argument akin to the one just used to prove that a $\phi_{\overline{r}}$ consistent with $\phi_{\underline{\ell}}^\dagger$ exists for any $\phi_{\underline{\ell}}^\dagger \in [0,1]$ can be used to prove that an equilibrium $\phi_{\underline{\ell}}^\dagger$ exists. □

Lemma A6. *The optimal strategy is unique.*

Proof. Proving the lemma amounts to proving that the optimal tuple is unique.

We proceed by contradiction. Let $\phi^\bullet$ and $\phi^\dagger$ be the optimal tuples. Note first that

$$M((\underline{\ell},\overline{r}),(\overline{\ell},\underline{r}),\phi^\bullet)=M((\underline{\ell},\overline{r}),(\overline{\ell},\underline{r}),\phi^\dagger), \tag{A8}$$

as $M((\underline{\ell},\overline{r}),(\overline{\ell},\underline{r}),\phi^e)=(1-F(\underline{\ell}-\overline{r}))\rho$ for any ϕ^e. Suppose

$$M((\overline{\ell},\underline{r}),(\overline{\ell},\underline{r}),\phi^\bullet)>M((\overline{\ell},\underline{r}),(\overline{\ell},\underline{r}),\phi^\dagger). \tag{A9}$$

Combining (A9) and (A8) ensures that if $\phi^\dagger_\emptyset<1$, then $\phi^\bullet_\emptyset=0$. In fact, (A9) implies $\phi^\dagger_\emptyset<1$, ($\phi^\dagger_\emptyset=1$ would imply $M((\overline{\ell},\underline{r}),(\overline{\ell},\underline{r}),\phi^\dagger)=1\geq M((\overline{\ell},\underline{r}),(\overline{\ell},\underline{r}),\phi^\bullet)$). We conclude that:

$$\phi^\bullet_\emptyset=0\leq\phi^\dagger_\emptyset. \tag{A10}$$

Combining (A9) and (A10) gives, by Bayes Rule, $\phi^\dagger_{\underline{r}}+\phi^\dagger_{\overline{\ell}}<\phi^\bullet_{\underline{r}}+\phi^\bullet_{\overline{\ell}}$. Clearly, either $\phi^\dagger_{\overline{\ell}}<\phi^\bullet_{\overline{\ell}}$ or $\phi^\dagger_{\underline{r}}<\phi^\bullet_{\underline{r}}$, or both.
Suppose $\phi^\dagger_{\overline{\ell}}<\phi^\bullet_{\overline{\ell}}$. Then, $\phi^\dagger_{\overline{\ell}}<1$, and $\phi^\bullet_{\overline{\ell}}>0$, which imply the following:

$$(\overline{\ell},\overline{r})\in m(\phi^\bullet_\emptyset,\phi^\bullet_{\underline{r}},\phi^\bullet_{\overline{\ell}},\phi^\bullet_{\overline{r}},\phi^\bullet_{\underline{\ell}}), \tag{A11}$$

and

$$(\overline{\ell},\underline{r})\in m(\phi^\dagger_\emptyset,\phi^\dagger_{\underline{r}},\phi^\dagger_{\overline{\ell}},\phi^\dagger_{\overline{r}},\phi^\dagger_{\underline{\ell}}). \tag{A12}$$

Note that (A9), (A11) and (A12) can hold at the same time only if:

$$M((\overline{\ell},\overline{r}),(\overline{\ell},\underline{r}),\phi^\bullet)>M((\overline{\ell},\underline{r}),(\overline{\ell},\overline{r}),\phi^\dagger), \tag{A13}$$

or, equivalently:

$$\mu((\overline{\ell},\overline{r}),\overline{\ell},\phi^\bullet)>\mu((\overline{\ell},\overline{r}),\overline{\ell},\phi^\dagger). \tag{A14}$$

Combining $\phi^\dagger_{\overline{\ell}}<\phi^\bullet_{\overline{\ell}}$ and (A14) yields, by Bayes Rule: $\phi^\dagger_{\overline{r}}<\phi^\bullet_{\overline{r}}$. This last inequality implies, once again by Bayes Rule:

$$\mu((\overline{\ell},\overline{r}),\overline{r},\phi^\bullet)>\mu((\overline{\ell},\overline{r}),\overline{r},\phi^\dagger). \tag{A15}$$

and

$$\mu((\underline{\ell},\overline{r}),\overline{r},\phi^\bullet)<\mu((\underline{\ell},\overline{r}),\overline{r},\phi^\dagger). \tag{A16}$$

However, combining (A14), (A15), and (A16) implies that on observing $(\overline{\ell},\overline{r})$, the incentive to forecast $(\underline{\ell}, \overline{r})$ instead of $(\overline{\ell}, \overline{r})$ is strictly larger when the market expects $\phi^\dagger$ than when the market expects $\phi^\bullet$, that is,

$$u((\underline{\ell}, \overline{r}), (\overline{\ell}, \overline{r}), \phi^\dagger) - u((\overline{\ell}, \overline{r}), (\overline{\ell}, \overline{r}), \phi^\dagger) > u((\underline{\ell}, \overline{r}), (\overline{\ell}, \overline{r}), \phi^\bullet) - u((\overline{\ell}, \overline{r}), (\overline{\ell}, \overline{r}), \phi^\bullet).$$

This contradicts $\phi^\dagger_{\overline{r}} < \phi^\bullet_{\overline{r}}$. This contradiction implies that $\phi^\dagger_{\overline{\ell}} \geq \phi^\bullet_{\overline{\ell}}$.
A similar argument ensures that $\phi^\dagger_{\underline{r}} \geq \phi^\bullet_{\underline{r}}$ and leads to a contradiction with $\phi^\dagger_{\underline{r}} + \phi^\dagger_{\overline{\ell}} < \phi^\bullet_{\underline{r}} + \phi^\bullet_{\overline{\ell}}$. We conclude that $\mu((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^\dagger) = \mu((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^\bullet)$.
Let

$$\phi^\bullet_{\overline{\ell}} > \phi^\dagger_{\overline{\ell}}. \tag{A17}$$

As $\phi^\bullet_{\overline{\ell}} > \phi^\dagger_{\overline{\ell}}$ and $M((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^\bullet) = M((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^\dagger)$, it must be the case that

$$M((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^\bullet) \geq M((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^\dagger). \tag{A18}$$

However, combining $\phi^\bullet_{\overline{\ell}} > \phi^\dagger_{\overline{\ell}}$ and (A18) gives $\phi^\bullet_{\overline{r}} > \phi^\dagger_{\overline{r}}$. We then reach a contradiction in the same way as above. Therefore, it must be the case that $\phi^\bullet_{\overline{\ell}} = \phi^\dagger_{\overline{\ell}}$. An identical argument ensures that $\phi^\bullet_{\underline{r}} = \phi^\dagger_{\underline{r}}$.
When $\phi^\bullet_{\overline{\ell}} = \phi^\dagger_{\overline{\ell}}$, $\phi^\bullet_{\underline{r}} = \phi^\dagger_{\underline{r}}$ and $\mu((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^\dagger) = \mu((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^\bullet)$ (which implies $\phi^\dagger_{\overline{\ell}} + \phi^\dagger_{\underline{r}} + \phi^\dagger_{\emptyset} = \phi^\bullet_{\overline{\ell}} + \phi^\bullet_{\underline{r}} + \phi^\bullet_{\emptyset}$; then, it must be the case that $\phi^\dagger_{\emptyset} = \phi^\bullet_{\emptyset}$.
Standard arguments then ensure that $\phi^\dagger_{\overline{r}} = \phi^\bullet_{\overline{r}}$ and $\phi^\dagger_{\underline{\ell}} = \phi^\bullet_{\underline{\ell}}$. We conclude that $\phi^\dagger = \phi^\bullet$. □

Proof of Lemma 2. Combining Lemmata A5 and A6 yields Lemma 2. □

Proof of Proposition 1. Let π^* be an optimal strategy characterized by a tuple ϕ^* such that

$$\phi^*_{\overline{r}} + \phi^*_{\underline{r}} < \phi^*_{\underline{\ell}} + \phi^*_{\overline{\ell}}. \tag{A19}$$

Condition (A19) is equivalent to:

$$\mu((\overline{\ell}, \overline{r}), \overline{\ell}, \phi^*) < \mu((\underline{\ell}, \underline{r}), \underline{r}, \phi^*). \tag{A20}$$

Condition (A19) holds only if at least one of these conditions holds:

(i) $\phi^*_{\overline{r}} < \phi^*_{\underline{\ell}}$;

(ii) $\phi^*_{\underline{r}} < \phi^*_{\overline{\ell}}$.

We show, in turn, that neither (i) nor (ii) hold. Suppose (i) holds. Then,

$$\mu((\underline{\ell},\overline{r}),\overline{r},\phi^*) > \mu((\underline{\ell},\overline{r}),\underline{\ell},\phi^*). \tag{A21}$$

Furthermore, by Lemmata A1 and A2, condition (i) implies the following:

$$\mu((\overline{\ell},\overline{r}),\overline{r},\phi^*) < \mu((\underline{\ell},\underline{r}),\underline{\ell},\phi^*). \tag{A22}$$

Define:

$$g_{\underline{\ell}}(\phi_{\underline{\ell}},\phi_{\overline{r}}) \equiv u((\underline{\ell},\overline{r}),(\underline{\ell},\underline{r}),(\phi^*_{\emptyset},\phi^*_{\underline{r}},\phi^*_{\overline{\ell}},\phi_{\overline{r}},\phi_{\underline{\ell}})) - u((\underline{\ell},\underline{r}),(\underline{\ell},\underline{r}),(\phi^*_{\emptyset},\phi^*_{\underline{r}},\phi^*_{\overline{\ell}},\phi_{\overline{r}},\phi_{\underline{\ell}})); \tag{A23}$$

$$g_{\overline{r}}(\phi_{\overline{r}},\phi_{\underline{\ell}}) \equiv u((\underline{\ell},\overline{r}),(\overline{\ell},\overline{r}),(\phi^*_{\emptyset},\phi^*_{\underline{r}},\phi^*_{\overline{\ell}},\phi_{\overline{r}},\phi_{\underline{\ell}})) - u((\overline{\ell},\overline{r}),(\overline{\ell},\overline{r}),(\phi^*_{\emptyset},\phi^*_{\underline{r}},\phi^*_{\overline{\ell}},\phi_{\overline{r}},\phi_{\underline{\ell}})). \tag{A24}$$

For $i \in \{\underline{\ell},\overline{r}\}$, function g_i is strictly decreasing and continuous in its first argument and constant in the second argument. If $g_i(1,\cdot) \geq 0$, then $\phi^*_i = 1$; if $g_i(0,\cdot) \leq 0$, then $\phi^*_i = 0$; if $g_i(1,\cdot) < 0 < g_i(0,\cdot)$, then $\phi^*_i = x$, where x is the unique value that satisfies $g_i(x,\cdot) = 0$. Hence, (i) implies

$$\begin{aligned} g_{\overline{r}}(\phi^*_{\overline{r}},\phi^*_{\underline{\ell}}) < g_{\underline{\ell}}(\phi^*_{\underline{\ell}},\phi^*_{\overline{r}}) \Leftrightarrow \\ \left(F(\underline{\ell}-\underline{r}) - F(\overline{\ell}-\overline{r})\right)\rho + M((\underline{\ell},\overline{r}),(\underline{\ell},\underline{r}),\phi^*) - M((\underline{\ell},\underline{r}),(\underline{\ell},\underline{r}),\phi^*) > \\ M((\underline{\ell},\overline{r}),(\overline{\ell},\overline{r}),\phi^*) - M((\overline{\ell},\overline{r}),(\overline{\ell},\overline{r}),\phi^*). \end{aligned}$$

As $(1-F(\underline{\ell}-\overline{r})) > 1/2 > F(\underline{\ell}-\overline{r})$, then (A21) implies $M((\underline{\ell},\overline{r}),(\underline{\ell},\underline{r}),\phi^*) < M((\underline{\ell},\overline{r}),(\overline{\ell},\overline{r}),\phi^*)$. Hence, the last highlighted inequality holds only if:

$$\left(F(\underline{\ell}-\underline{r}) - F(\overline{\ell}-\overline{r})\right)\rho + M((\overline{\ell},\overline{r}),(\overline{\ell},\overline{r}),\phi^*) > M((\underline{\ell},\underline{r}),(\underline{\ell},\underline{r}),\phi^*).$$

Combining (A20) and (A22) establishes that the last highlighted inequality holds only if

$$\begin{aligned} \left(F(\underline{\ell}-\underline{r}) - F(\overline{\ell}-\overline{r})\right)\rho + F(\overline{\ell}-\overline{r})\mu((\overline{\ell},\overline{r}),\overline{\ell},\phi^*) + (1-F(\overline{\ell}-\overline{r}))\mu((\overline{\ell},\overline{r}),\overline{r},\phi^*) > \\ F(\underline{\ell}-\underline{r})\mu((\overline{\ell},\overline{r}),\overline{\ell},\phi^*) + (1-F(\underline{\ell}-\underline{r}))\mu((\overline{\ell},\overline{r}),\overline{r},\phi^*) \end{aligned}$$

Rearranging terms, the last highlighted inequality can be written as:

$$\left(F(\underline{\ell}-\underline{r}) - F(\overline{\ell}-\overline{r})\right)\left(\rho + \mu((\overline{\ell},\overline{r}),\overline{r},\phi^*) - \mu((\overline{\ell},\overline{r}),\overline{\ell},\phi^*)\right) > 0. \tag{A25}$$

Note that:

$$\overline{r} - \underline{r} \leq \overline{\ell} - \underline{\ell} \Leftrightarrow \tag{A26}$$
$$\underline{\ell} - \underline{r} \leq \overline{\ell} - \overline{r} \Leftrightarrow \tag{A27}$$
$$F(\underline{\ell} - \underline{r}) \leq F(\overline{\ell} - \overline{r}), \tag{A28}$$

where the first line corresponds to Assumption (i). Note also that

$$\mu((\overline{\ell}, \overline{r}), \overline{r}, \phi^*) = \frac{\mu_0}{\mu_0 + (1-\mu_0)(1-\phi_{\overline{r}})} \geq \frac{\mu_0}{\mu_0 + (1-\mu_0)(1-\phi_{\overline{r}} + \phi_{\overline{\ell}})} = \mu((\overline{\ell}, \overline{r}), \overline{\ell}, \phi^*). \tag{A29}$$

Combining (A28) and (A29), we conclude that (A25) cannot hold. This contradiction proves that (i) does not hold.
Suppose now that (ii) holds, that is, $\phi^*_{\underline{r}} < \phi^*_{\overline{\ell}}$.
Note that the optimal strategy is such that the gain from forecasting $(\underline{\ell}, \underline{r})$ instead of $(\overline{\ell}, \underline{r})$ upon observing $(\overline{\ell}, \underline{r})$, that is, $u((\underline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^*) - u((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^*)$, is equal to

$$\big(F(\overline{\ell} - \underline{r}) - F(\underline{\ell} - \underline{r})\big)\, \rho + M((\underline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^*) - M((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^*). \tag{A30}$$

while the gain from forecasting $(\overline{\ell}, \overline{r})$ instead of $(\overline{\ell}, \underline{r})$ on observing $(\overline{\ell}, \underline{r})$, that is, $u((\overline{\ell}, \overline{r}), (\overline{\ell}, \underline{r}), \phi^*) - u((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^*)$, is equal to

$$\big(F(\overline{\ell} - \underline{r}) - F(\overline{\ell} - \overline{r})\big)\, \rho + M((\overline{\ell}, \overline{r}), (\overline{\ell}, \underline{r}), \phi^*) - M((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^*). \tag{A31}$$

Subtracting (A31) from (A30), we obtain:

$$\big(F(\overline{\ell} - \overline{r}) - F(\underline{\ell} - \underline{r})\big)\, \rho + (1 - F(\underline{\ell} - \underline{r}))\mu((\underline{\ell}, \underline{r}), \underline{r}, \pi^*) - F(\overline{\ell} - \overline{r})\mu((\overline{\ell}, \overline{r}), \overline{\ell}, \pi^*). \tag{A32}$$

Note first that $F(\overline{\ell} - \overline{r}) - F(\underline{\ell} - \underline{r}) > 0$. Second, $\mu((\underline{\ell}, \underline{r}), \underline{r}, \pi^*) > \mu((\overline{\ell}, \overline{r}), \overline{\ell}, \pi^*)$ (see (A20)). Third, $(1 - F(\underline{\ell} - \underline{r})) > 1/2 > F(\overline{\ell} - \overline{r})$. We conclude that the expression in (A32) is positive. Therefore, if $\phi^*_{\underline{r}} < 1$, then $\phi^*_{\overline{\ell}} = 0$, which contradicts (ii). Hence, (ii) does not hold. As neither (i) nor (ii) holds, then condition (A19) does not hold. This observation concludes the proof. □

Proofs for Section 2.2

Here, we consider the extended version of the model. The timeline is as follows.

1. Nature draws $\{y_\ell, y_r\}$ and signals $\{s_\ell, s_r\}$;

2. The forecaster observes $\{s_\ell, s_r\}$ and publishes (f_ℓ, f_r);

3. The voter observes (f_ℓ, f_r) and chooses some policy p°);

4. Nature draws s'_{p°;

5. The forecaster observes s'_{p° and publishes f'_{p°;

6. The market observes (f_ℓ, f_r), f'_{p° and y_{p°.

A strategy (π, π') is *optimal* if for any outcome realization, any set of signals and any outcomes of the referendum, the strategy maximizes the forecaster's expected payoff conditional on the market expecting the forecaster to adopt that strategy.
The proof of Proposition 2 is given in the text.
If an optimal strategy is biased towards policy p° for (f_ℓ, f_r), then following that pair of forecasts, the strategy requires the publication of $f'_{p^\circ} \neq s'_{p^\circ}$ with some probability. If, instead, the strategy is truthful on f_{p°, then it is necessary to publish $f'_{p^\circ} = s'_{p^\circ}$.

Proof of Proposition 3. The argument of the proof is given in the text. We propose here the same argument with a few extra details.
Suppose that the market expects the forecaster to follow a strategy (π, π') that is biased towards policy ℓ for $(\underline{\ell}, \underline{r})$. This implies that π satisfies $\tilde{\pi} > 0$, where

$$\tilde{\pi} \equiv \frac{1}{4}\pi((\underline{\ell}, \underline{r})|(\overline{\ell}, \underline{r})) + \frac{1}{4}\pi((\underline{\ell}, \underline{r})|(\overline{\ell}, \overline{r})).$$

This means that, if the market believes that the forecaster observed $s_\ell = \overline{\ell}$, the market infers that the forecaster is strategic for sure, whereas if the market believes that the forecaster observed $s_\ell = \underline{\ell}$, then the market must believe that the forecaster is honest with some probability $y \in (0, 1)$. Suppose the market expects the forecaster to publish truthfully ($f'_\ell = s'_\ell$) following forecasts $(\underline{\ell}, \underline{r})$. Based on observations $f'_\ell = \overline{\ell}$ and $y_\ell = \overline{\ell}$, the market believes that the forecaster certainly observed signal $s'_\ell = \overline{\ell}$ and observed $s_\ell = \underline{\ell}$ with probability

$$\begin{aligned}\frac{\mathbb{P}((s_\ell, s'_\ell) = (\underline{\ell}, \overline{\ell})|y_\ell = \overline{\ell})}{\mathbb{P}((s_\ell, s'_\ell) = (\underline{\ell}, \overline{\ell})|y_\ell = \overline{\ell}) + \mathbb{P}((s_\ell, s'_\ell) = (\overline{\ell}, \overline{\ell})|y_\ell = \overline{\ell})} &= \frac{\epsilon(1-\eta)}{\epsilon(1-\eta) + (1-\epsilon)(1 - \frac{\epsilon(1-\eta)}{1-\epsilon})} \\ &= \frac{\epsilon(1-\eta)}{1-\epsilon},\end{aligned}$$

Therefore, the reputation of the forecaster is $\frac{\epsilon(1-\eta)}{1-\epsilon}y$.
Based instead on observing $f'_\ell = \underline{\ell}$ and $y_\ell = \overline{\ell}$, the market believes that the forecaster certainly observed signal $s'_\ell = \underline{\ell}$ and observed $s_\ell = \underline{\ell}$ with probability

$$\frac{\mathbb{P}((s_\ell, s'_\ell) = (\underline{\ell}, \underline{\ell})|y_\ell = \overline{\ell})}{\mathbb{P}((s_\ell, s'_\ell) = (\underline{\ell}, \underline{\ell})|y_\ell = \overline{\ell}) + \mathbb{P}((s_\ell, s'_\ell) = (\overline{\ell}, \underline{\ell})|y_\ell = \overline{\ell})} = \frac{\epsilon\eta}{\epsilon\eta + (1-\epsilon)\frac{\epsilon(1-\eta)}{1-\epsilon}} = \eta,$$

Therefore, in this case, the reputation of the forecaster is ηy. Note that

$$\frac{\epsilon(1-\eta)}{1-\epsilon} < \eta \Leftrightarrow \epsilon < \eta.$$

Hence, if $y_\ell = \overline{\ell}$, the forecaster ensures a better reputation by publishing $f'_\ell = \underline{\ell}$ than by publishing $f_\ell = \underline{\ell}$. It is immediate to verify that the same is true if $y_\ell = \underline{\ell}$. Hence, the optimal strategy cannot require truthful publication in s'_ℓ after the forecast $(\underline{\ell}, \overline{\ell})$. Noting that the same logic applies any time a strategy is biased on some p for some forecasts, (f_ℓ, f_r) gives the first part of the proposition.

The second half of the proposition is proven in the text. □

B Data

B.1 Measures of Stakes

Bank. We determine whether a forecaster is a financial institution by referring to the forecaster's official web page and relying on how the institution describes itself. We label using the indicator Bank==1 those that can be best described as financial institutions. We also confirm that all institution-labelled banks are quoted on international financial markets.

City. We use the City/Non-City group assignment made by HM Treasury in its *Forecasts for the UK Economy* data collection.

Stock Price. We compute for each forecaster (of those quoted) the percentage decline in the stock market price after the referendum –specifically, between the referendum date (since both the London and New York stock markets closed before the announcement of the referendum results) and the second banking day after the referendum results. We make this choice based on the stylized fact that the decline in market prices was continuous on not only the very first day (Friday) after the vote but also the subsequent Monday. However, we did not retrieve data for one forecaster (IHS Global Insight), as its parent company (IHS) was involved in a merger (with Markit) during the referendum period. The data source for this analysis was Thomson Reuters Eikon.

B.2 Measures of Influence

Google News. The number of search results on Google News provides an indication of an institution's influence according to the media. An institution is more influential if it is frequently mentioned in the news than if it is very rarely mentioned. We recorded the number of mentions in a Google News search in the United Kingdom during 2015. Then, a binary measure of influence is constructed based on a threshold of 7,000 citations such that half of the forecasters are above, and half are below it.

Influence of the Newspaper. Using the Dow Jones Factiva newspaper search engine, we compute measures of influence by different media outlets, which vary in terms of the political and referendum preferences of their readers. For each forecaster, we search for its name associated with the words "GDP" and "forecast" and export the number of articles reporting this information during 2015. We then construct an indicator that equals 1 if the forecaster has been mentioned by each specific medium more often than the median forecaster and is zero otherwise.

C Additional Empirical Results

C.1 Figures

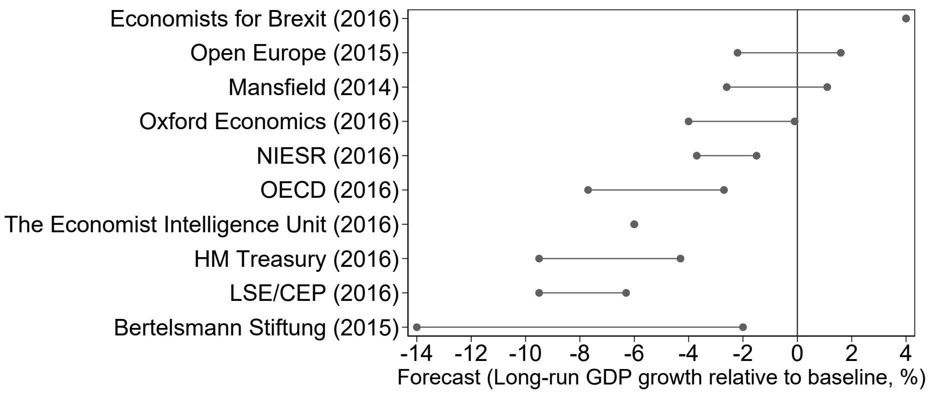

Figure C1: Long-run Forecasts

Notes: See cited papers for the respective sources. Economists for Brexit are cited as Minford (2016), NIESR as Ebell and Warren (2016), and LSE/CEP as Dhingra et al. (2016a).

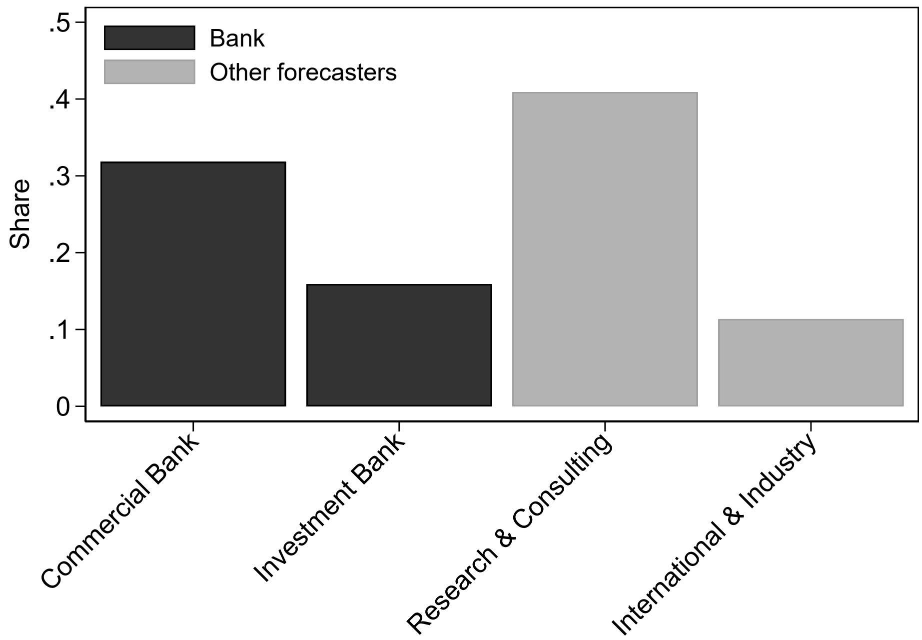

Figure C2: Distribution of Sampled Forecasters by Industry

Notes: The figure reports the proportion of forecasters in the sample by type. International & Industry refer to international organizations and industry & trade associations.

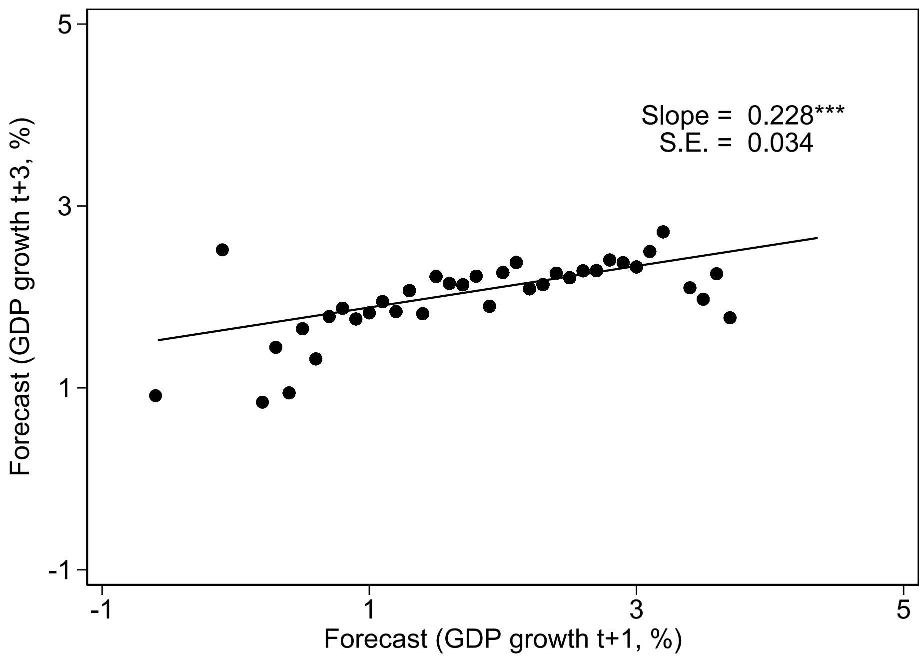

Figure C3: Correlation between Short- and Medium-term Forecasts

Notes: All forecasters surveyed by HM Treasury between January 2012 and June 2016 that announced within the same release both short- and medium-term forecasts are considered. The figure shows the results of a bivariate regression $F_{j,t}^{t+3} = \alpha + F_{j,t}^{t+1} + \varepsilon_{j,t}$. Heteroskedasticity-robust standard errors are reported. Labels *, ** and *** represent significance levels of 10%, 5% and 1%. Markers represent the sample average of $F_{j,t}^{t+3}$ within bins of 0.1 percentage point of $F_{j,t}^{t+1}$.

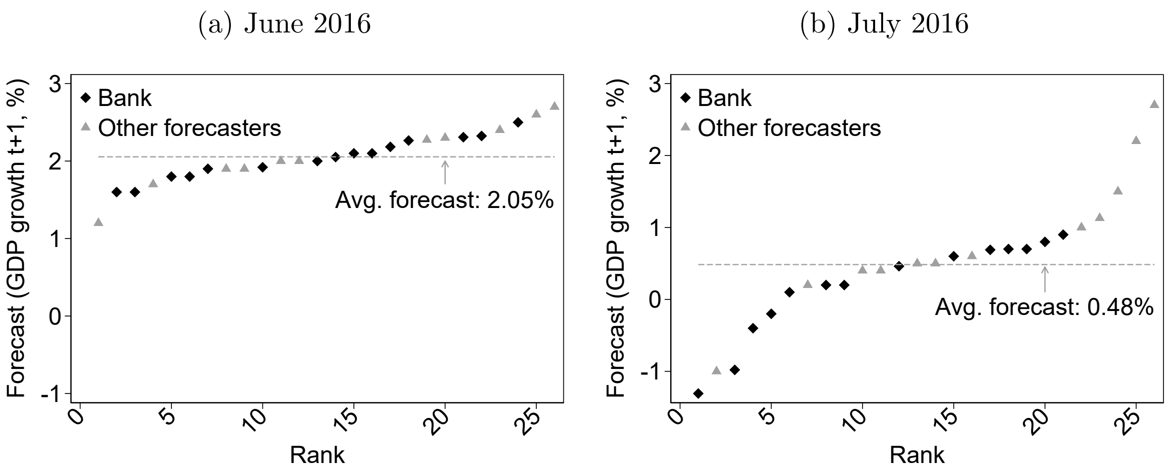

Figure C4: Forecast for the 2017 GDP Growth Rate Before and After the Referendum

Notes: All forecasters surveyed by HM Treasury in June and July 2016 are considered. Each marker represents an individual GDP growth forecast for period $t + 1$. Black diamonds represent forecasts made by forecasters with stakes, while grey triangles represent forecasts released by the control group's institutions. The horizontal line indicates the average forecast.

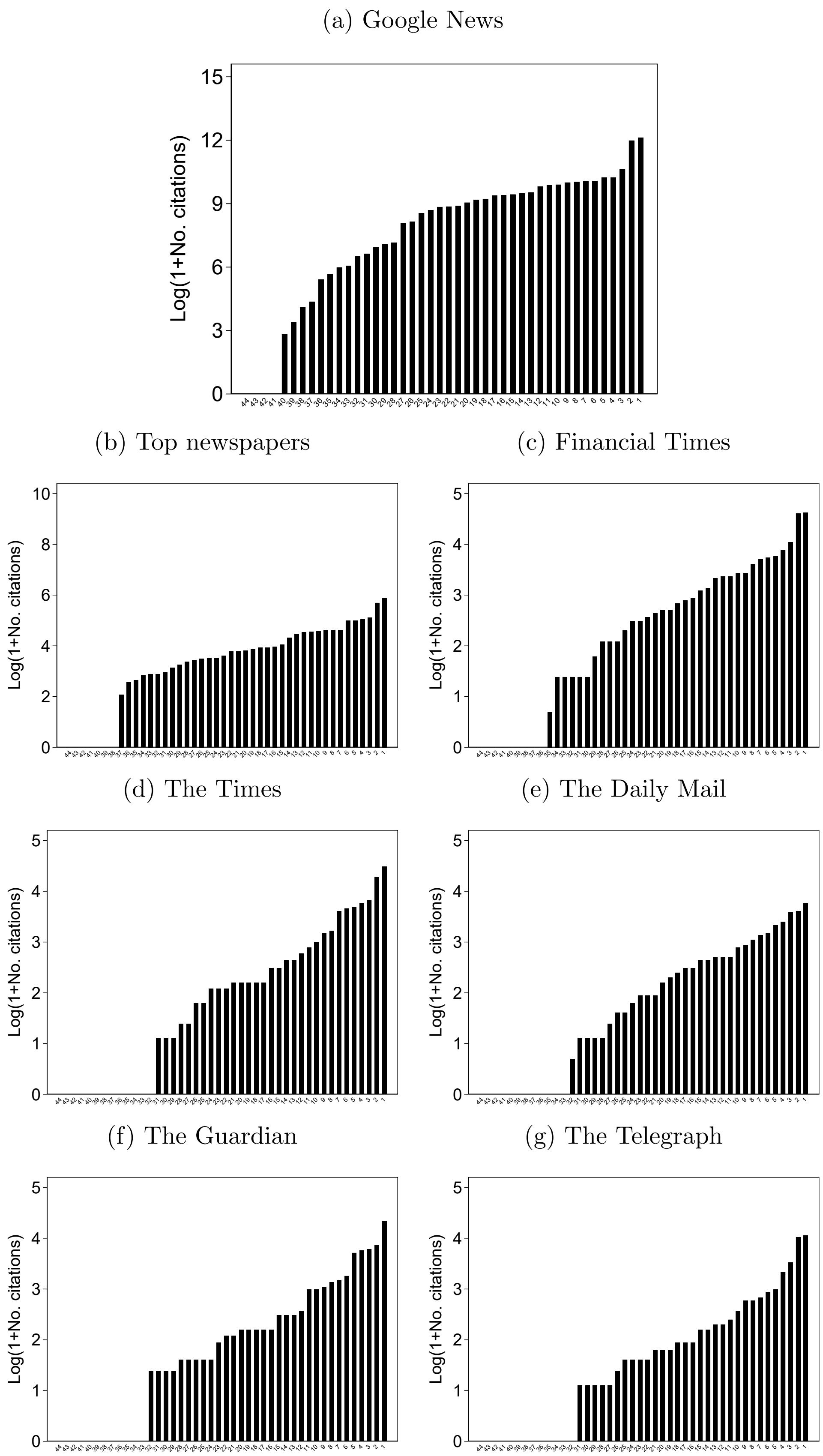

Figure C5: Measures of Influence

Notes: The charts show values by forecaster. Panels (a), (b), (c), (d), (e), (f), and (g) plot the logarithm of the number of citations of each forecaster in Google News, the top newspapers in the United Kingdom (Financial Times, The Times, The Daily Mail, The Guardian and The Telegraph), and in each of the five aforementioned news outlets, respectively.

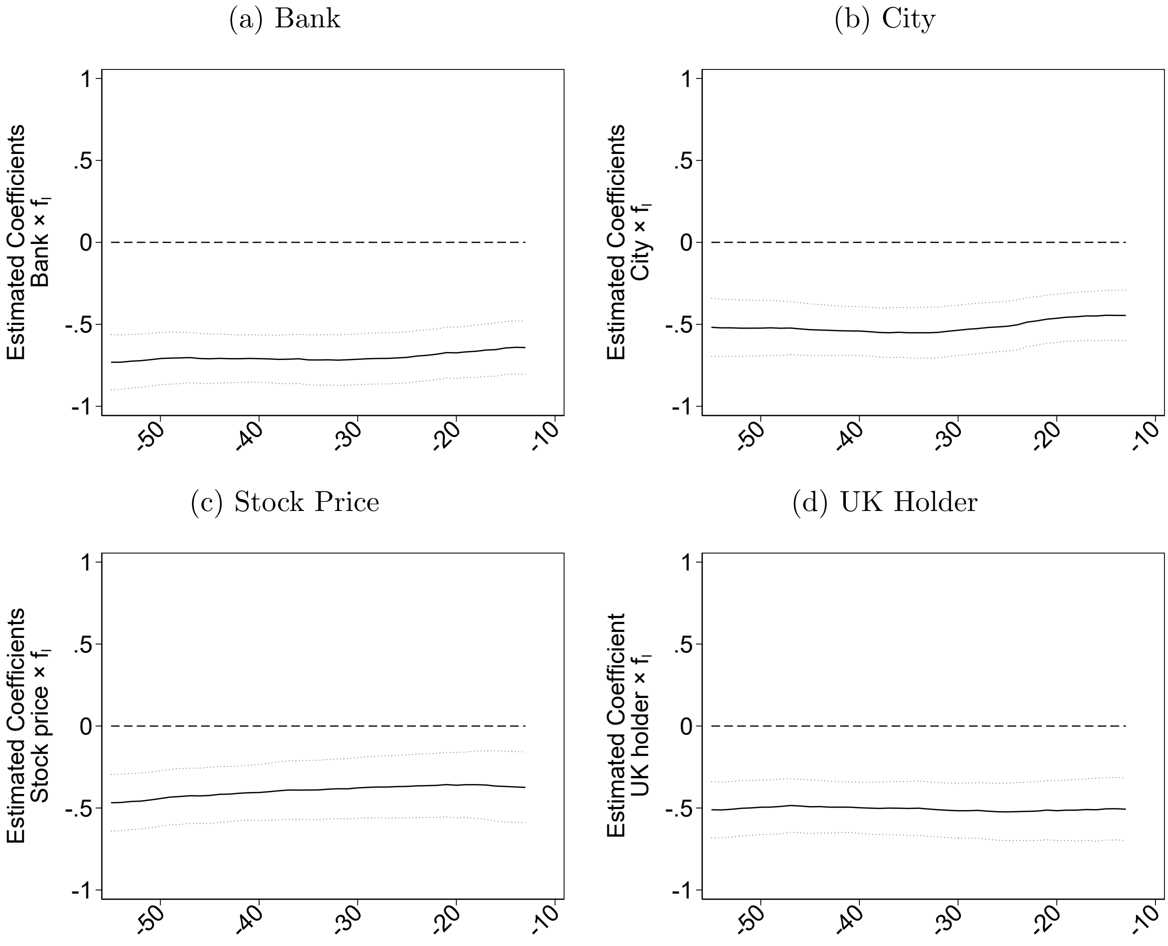

Figure C6: Sensitivity to Changes in the Time Span

Notes: In each graph, we estimate (2) by restricting the sample in terms of months before the referendum, as specified on the horizontal axis. For instance, at -54 we consider all data starting from January 2012. The solid black line represents estimated coefficients, whereas dotted lines represent 95% confidence intervals. All specifications include forecasters' fixed effects and survey fixed effects.

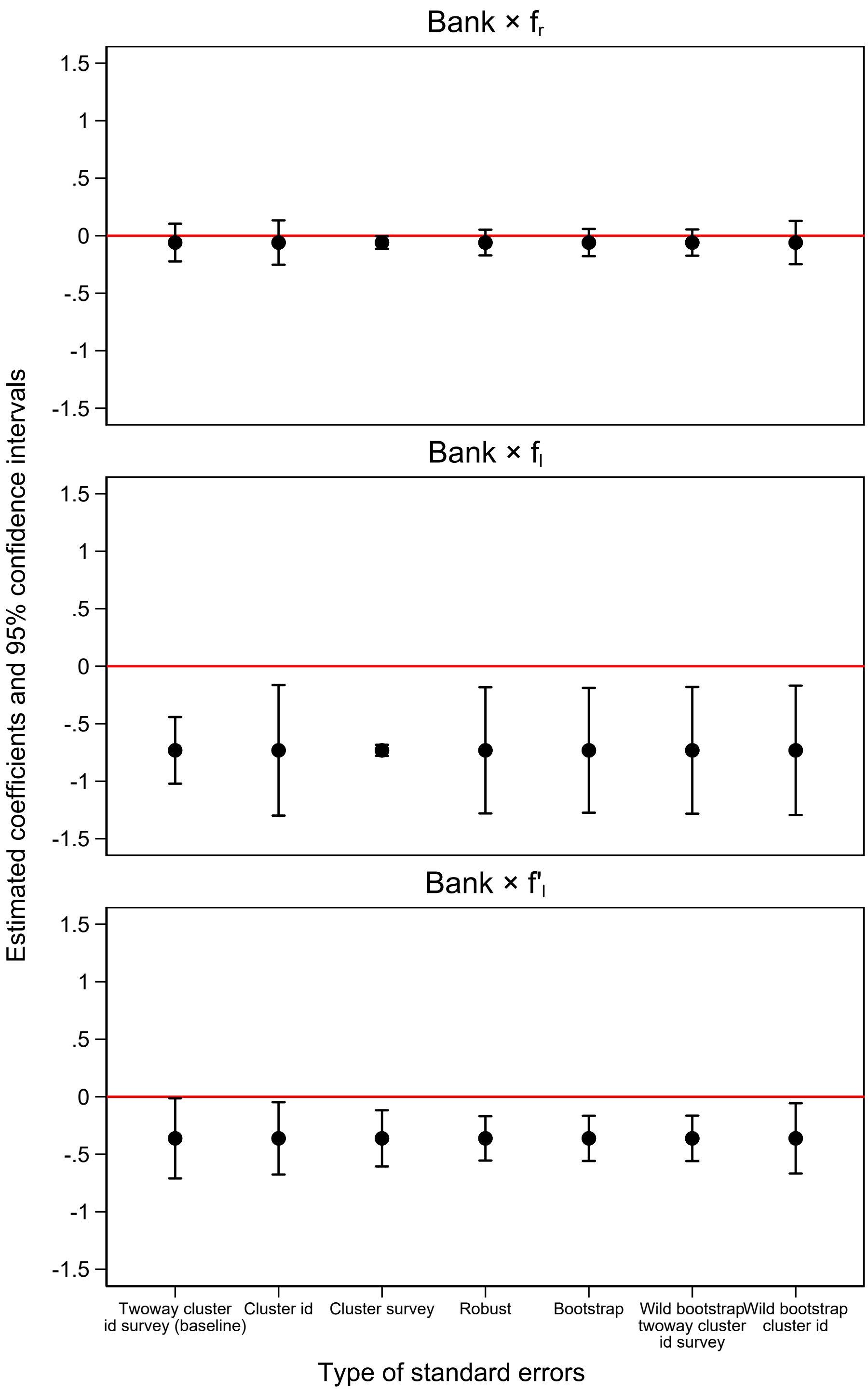

Figure C7: Alternative Inference Approaches

Notes: The estimated equation is (2). The figure reports estimated coefficients and 95% confidence intervals obtained using alternative inference approaches as specified in the horizontal axis. Bootstrap and wild-clustered bootstrap confidence intervals are based on 1,000 replications.

C.2 Tables

Table C1: Timeline of the United Kingdom's European Union Membership Referendum

Jan. 22, 2013	Incumbent Prime Minister David Cameron commits to holding a referendum on the EU membership if he is reelected in 2015.
May 22, 2014	EU-sceptical UKIP receives 26% of votes in European elections and becomes the largest UK party in the EU parliament.
May 7, 2015	Conservative Party wins the majority in the 2015 general election.
May 27, 2015	The Queen unveils the European Union Referendum Act 2015 (c. 36).
Dec. 17, 2015	The Act is given Royal Assent.
Jan. 5, 2016	PM Cameron says ministers are free to campaign on either side.
Feb. 20, 2016	PM Cameron announces the referendum date (June 23, 2016).
Apr. 15, 2016	Official start of the referendum campaign.
May 6, 2016	Start of the British Election Study panel (Wave 8).
May 23, 2016	HM Treasury analysis: the immediate economic impact of leaving the EU.
June 22, 2016	End of the British Election Study panel (Wave 8).
June 23, 2016	The United Kingdom's European Union membership referendum.
June 24, 2016	PM Cameron resigns after the Brexit victory.
July 9, 2016	The government rejects the petition for a second referendum.
July 11, 2016	Theresa May is elected as the new leader of the Conservative Party.
July 13, 2016	Theresa May is appointed Prime Minister by the Queen.
Mar. 29, 2017	PM May triggers Article 50, officially starting the process of withdrawal.
Jan. 31, 2020	The United Kingdom leaves the EU.

Notes: This table reports the key dates of the UK membership referendum, before and after the vote. Source: Authors' analysis of information from https://www.bbc.com/news/politics.

Table C2: Correlation Matrix—Stakes

	Banks	City	Stock price	UK holders
Banks	1.00	0.83	0.57	0.50
City	0.83	1.00	0.47	0.40
Stock price	0.57	0.47	1.00	0.44
UK holders	0.50	0.40	0.44	1.00

Notes: All forecasters surveyed by HM Treasury between January 2012 and April 2018 are considered. This table reports the correlation between the measures of stakes introduced in Section 4.

Table C3: Forecasts before the Referendum Announcement by Forecaster Type

	Forecast (GDP growth t+1, %)		
Type	Mean	SD	N
Commercial Bank	2.04	0.73	350
Investment Bank	1.86	0.76	163
Research & Consulting	1.96	0.68	457
International & Industry	2.19	0.55	56

Notes: All forecasts collected by HM Treasury between January 2012 and December 2015 are considered by forecaster type. International & Industry refer to international organizations and industry & trade associations.

Table C4: Correlation Matrix—Influence

	Google News	Financial Times	The Times	The Daily Mail	The Guardian	The Telegraph
Google News	1.00	0.17	0.14	–0.15	0.13	0.10
Financial Times	0.17	1.00	0.50	0.51	0.46	0.41
The Times	0.14	0.50	1.00	0.37	0.68	0.73
The Daily Mail	–0.15	0.51	0.37	1.00	0.50	0.37
The Guardian	0.13	0.46	0.68	0.50	1.00	0.59
The Telegraph	0.10	0.41	0.73	0.37	0.59	1.00

Notes: All forecasters surveyed by HM Treasury between January 2012 and April 2018 are considered. This table reports the correlation between the number of times each forecaster was mentioned in Google News, the Financial Times, The Times, The Daily Mail, The Guardian, and The Telegraph in 2015.

Table C5: Estimation of Propaganda Bias in GDP Components' Growth Forecasts

	(1) Private consumption	(2) Fixed investment	(3) Government consumption	(4) Total exports	(5) Total imports
Stakes $\times f_r$	-0.082	-0.701*	0.126	-0.583	-0.725***
	(0.102)	(0.394)	(0.155)	(0.370)	(0.268)
Stakes $\times f_\ell$	-0.285	-2.307***	0.473***	-1.123**	-0.472
	(0.259)	(0.781)	(0.131)	(0.526)	(0.642)
Stakes $\times f'_\ell$	0.035	-1.731*	0.246	-0.546	0.682
	(0.234)	(0.870)	(0.222)	(0.376)	(0.590)
Observations	1,636	1,642	1,634	1,534	1,532
R^2	0.720	0.692	0.719	0.574	0.667
Fixed Effects	✓	✓	✓	✓	✓
Survey Month Effects	✓	✓	✓	✓	✓
Measure of Stakes	Bank	Bank	Bank	Bank	Bank

Notes: The estimated equation is (2). In column (1), the dependent variable is the forecast of the growth in household consumption in year $t+1$. In column (2), the dependent variable is the growth in the forecast of fixed investments in year $t+1$. In column (3), the dependent variable is the growth in the forecast of government consumption in year $t+1$. In column (4), the dependent variable is the growth in the forecast of total exports in year $t+1$. In column (5), the dependent variable is the growth in the forecast of total import in year $t+1$. Standard errors robust to two-way clustering at the forecaster and survey levels are shown in parentheses. Labels *, ** and *** represent significance levels of 10%, 5% and 1%.

Table C6: Forecast Performance by Group

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dep. var.: Absolute Forecast Error (GDP growth t+1, %)							
Bank	0.032				–0.022			
	(0.070)				(0.047)			
City		0.093				–0.033		
		(0.064)				(0.051)		
Stock price			–0.082				0.044	
			(0.053)				(0.065)	
UK holders				–0.086				0.052
				(0.056)				(0.064)
Observations	1,038	1,038	1,038	1,038	4,886	4,886	4,886	4,886
R^2	0.476	0.486	0.482	0.481	0.884	0.884	0.884	0.884
Survey Month Effects	✓	✓	✓	✓	✓	✓	✓	✓
Sample Period	2012–2015	2012–2015	2012–2015	2012–2015	1998–2015	1998–2015	1998–2015	1998–2015

Notes: The estimated equation is: $|E^{t+1}_{j,m}| = Stakes_j + \delta_m + \varepsilon_{j,m}$, where $|E^{t+1}_{j,m}|$ is the absolute value of the forecast error produced by forecaster j in release m targeting year $t+1$; $Stakes_j$ is an indicator for being a bank or being in the city of London, respectively; δ_m is a set of survey fixed effects. Standard errors robust to two-way clustering at the forecaster and survey levels are shown in parentheses. Labels *, ** and *** represent significance levels of 10%, 5% and 1%.

Table C7: Results excluding forecasts from the *International & Industry* Sectors

	(1)	(2)	(3)	(4)
	Dep. var.: Forecast (GDP growth t+1, %)			
Stakes $\times f_r$	-0.093	-0.005	-0.074	-0.048
	(0.097)	(0.103)	(0.091)	(0.092)
Stakes $\times f_\ell$	-0.735***	-0.521***	-0.472***	-0.515***
	(0.161)	(0.190)	(0.170)	(0.150)
Stakes $\times f'_\ell$	-0.401**	-0.374*	-0.377*	-0.434**
	(0.184)	(0.193)	(0.190)	(0.193)
Observations	1,554	1,554	1,554	1,554
R^2	0.769	0.766	0.765	0.766
Fixed Effects	✓	✓	✓	✓
Survey Month Effects	✓	✓	✓	✓
Measure of Stakes	Bank	City	Stock price	UK holders

Notes: Forecasters labelled *International & Industry* have been removed from the sample. The estimated equation is (2). Standard errors robust to two-way clustering at the forecaster and survey levels are shown in parentheses. Labels *, ** and *** represent significance levels of 10%, 5% and 1%.

Online Appendix: Calculations for Examples

Example 1

We first list a few indifference conditions that play a role in the optimal strategy:

$$u((\bar{\ell},\bar{r}),(\bar{\ell},\bar{r}),\phi^e) = u((\underline{\ell},\bar{r}),(\bar{\ell},\bar{r}),\phi^e); \tag{OA1}$$
$$u((\bar{\ell},\underline{r}),(\bar{\ell},\underline{r}),\phi^e) = u((\underline{\ell},\underline{r}),(\bar{\ell},\underline{r}),\phi^e); \tag{OA2}$$
$$u((\underline{\ell},\underline{r}),(\bar{\ell},\underline{r}),\phi^e) = u((\underline{\ell},\bar{r}),(\bar{\ell},\underline{r}),\phi^e); \tag{OA3}$$
$$u((\underline{\ell},\underline{r}),(\underline{\ell},\underline{r}),\phi^e) = u((\underline{\ell},\bar{r}),(\underline{\ell},\underline{r}),\phi^e). \tag{OA4}$$

For the parameter values described in Example 1, the optimal strategy ϕ^* is equal to:

- $(0,0,0,0,0)$, for $\rho \leq \frac{19}{10}$;
- $(0,0,0,\phi^*_{\bar{r}},0)$, where $\phi^e = \phi^*$ satisfies (OA1), for $\rho \in (\frac{19}{10},\frac{57}{20}]$;
- $(0,\phi^*_{\underline{r}},0,\phi^*_{\bar{r}},0)$, where $\phi^e = \phi^*$ satisfies (OA1) and (OA2) for $\rho \in (\frac{57}{20},\frac{26}{7}]$;
- $(0,\phi^*_{\underline{r}},0,1,0)$, where $\phi^e = \phi^*$ satisfies (OA2), for $\rho \in (\frac{26}{7},\frac{97}{21}]$;
- $(0,1,0,1,0)$, for $\rho \in (\frac{97}{21},\frac{323}{21}]$;
- $(\phi^*_{\emptyset},1-\phi^*_{\emptyset},0,1,0)$, where $\phi^e = \phi^*$ satisfies (OA3), for $\rho \in (\frac{323}{21},\frac{323}{20}]$;
- $(1,0,0,1,0)$, for $\rho \in (\frac{323}{20},\frac{171}{10}]$;
- $(1,0,0,1,\phi^*_{\underline{\ell}})$, where $\phi^e = \phi^*$ satisfies (OA4), for $\rho \in (\frac{171}{10},\frac{382}{21}]$;
- $(1,0,0,1,1)$, for $\rho > \frac{382}{21}$.

For any given value of ρ, it is easy to verify that this strategy is optimal. Lemma 2 ensures that the optimal strategy is unique.

Example 2

For the parameter values described in Example 2, the optimal strategy ϕ^* is equal to:

- $(0,0,0,0,0)$, for $\sigma \geq \frac{276}{95}$;
- $(0,0,0,\phi^*_{\bar{r}},0)$, where $\phi^e = \phi^*$ satisfies (OA1), for $\sigma \in [\frac{533}{190},\frac{276}{95})$;
- $(0,\phi^*_{\underline{r}},0,\phi^*_{\bar{r}},0)$, where $\phi^e = \phi^*$ satisfies (OA1) and (OA2) for $\sigma \in (\frac{286}{115},\frac{533}{190}]$;
- $(0,\phi^*_{\underline{r}},0,1,0)$, where $\phi^e = \phi^*$ satisfies (OA2), for $\rho \in (\frac{553}{230},\frac{286}{115}]$;
- $(0,1,0,1,0)$, for $\sigma \in (\frac{287}{190},\frac{553}{230}]$;

- $(\phi^*_\emptyset, 1-\phi^*_\emptyset, 0, 1, 0)$ where $\phi^e = \phi^*$ satisfies (OA3), for $\rho \in (\frac{267}{190}, \frac{287}{190}]$;
- $(1, 0, 0, 1, 0)$, for $\sigma \in (\frac{248}{190}, \frac{267}{190}]$;
- $(1, 0, 0, 1, \phi^*_{\underline{\ell}})$, where $\phi^e = \phi^*$ satisfies (OA4), for $\sigma \in (\frac{232}{190}, \frac{248}{190}]$;
- $(1, 0, 0, 1, 1)$, for $\sigma < \frac{232}{190}$.

For any given value of σ, it is easy to verify that this strategy is optimal. Lemma 2 ensures that the optimal strategy is unique.

Example 3

Let $\mu(f'_\ell, y_\ell, \phi)$ be the reputation for forecasts $f_\ell = \underline{\ell}$, f_ℓ and the observed outcome y_ℓ if the market expects the forecaster to publish $f'_\ell = \underline{\ell}$ with probability 1 on observing $s'_\ell = \underline{\ell}$ and with probability ϕ on observing $s'_\ell = \overline{\ell}$. Then:

$$\begin{aligned}
\mu(\overline{\ell}, \overline{\ell}, \phi) &= \frac{\mu_0 \epsilon(1-\eta)}{\epsilon(1-\eta) + (1-\mu_0)(1-2\epsilon+\eta\epsilon)(1-\phi)}; \\
\mu(\underline{\ell}, \overline{\ell}, \phi) &= \frac{\mu_0 \epsilon\eta}{\epsilon\eta + (1-\mu_0)(\epsilon(1-\eta) + (1-2\epsilon+\epsilon\eta)\phi)}; \\
\mu(\overline{\ell}, \underline{\ell}, \phi) &= \frac{\mu_0(1-\eta)}{1-\eta+(1-\mu_0)\eta(1-\phi)}; \\
\mu(\underline{\ell}, \underline{\ell}, \phi) &= \frac{\mu_0(1-2\epsilon+\epsilon\eta)}{1-2\epsilon+\epsilon\eta+(1-\mu_0)\epsilon(\eta\phi+1-\eta)}.
\end{aligned}$$

Let:

$$(1-2\epsilon+\epsilon\eta)(\mu(\overline{\ell}, \overline{\ell}, 1) - \mu(\underline{\ell}, \overline{\ell}, 1)) < \epsilon\eta(\mu(\underline{\ell}, \underline{\ell}, 1) - \mu(\overline{\ell}, \underline{\ell}, 1)); \tag{OA5}$$

$$(1-2\epsilon+\epsilon\eta)(\mu(\overline{\ell}, \overline{\ell}, 0) - \mu(\underline{\ell}, \overline{\ell}, 0)) > \epsilon\eta(\mu(\underline{\ell}, \underline{\ell}, 0) - \mu(\overline{\ell}, \underline{\ell}, 0)); \tag{OA6}$$

$$(1-2\epsilon+\epsilon\eta)(\mu(\overline{\ell}, \overline{\ell}, \phi^*) - \mu(\underline{\ell}, \overline{\ell}, \phi^*)) = \epsilon\eta(\mu(\underline{\ell}, \underline{\ell}, \phi^*) - \mu(\overline{\ell}, \underline{\ell}, \phi^*)). \tag{OA7}$$

The strategy requires $\phi = 1$ if (OA5) holds, $\phi = 0$ if (OA6) holds and $\phi = \phi^*$ if (OA7) holds. Figure 3 illustrates

Example with Rational Voter

We first list a few indifference conditions that play a role in the optimal strategy:

$$u^\dagger((\overline{\ell}, \overline{r}), (\overline{\ell}, \overline{r}), \phi^e) = u^\dagger((\underline{\ell}, \overline{r}), (\overline{\ell}, \overline{r}), \phi^e); \tag{OA8}$$

$$u^\dagger((\overline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^e) = u^\dagger((\underline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^e); \tag{OA9}$$

$$u^\dagger((\underline{\ell}, \underline{r}), (\overline{\ell}, \underline{r}), \phi^e) = u^\dagger((\underline{\ell}, \overline{r}), (\overline{\ell}, \underline{r}), \phi^e); \tag{OA10}$$

$$u^\dagger((\underline{\ell}, \underline{r}), (\underline{\ell}, \underline{r}), \phi^e) = u^\dagger((\underline{\ell}, \overline{r}), (\underline{\ell}, \underline{r}), \phi^e). \tag{OA11}$$

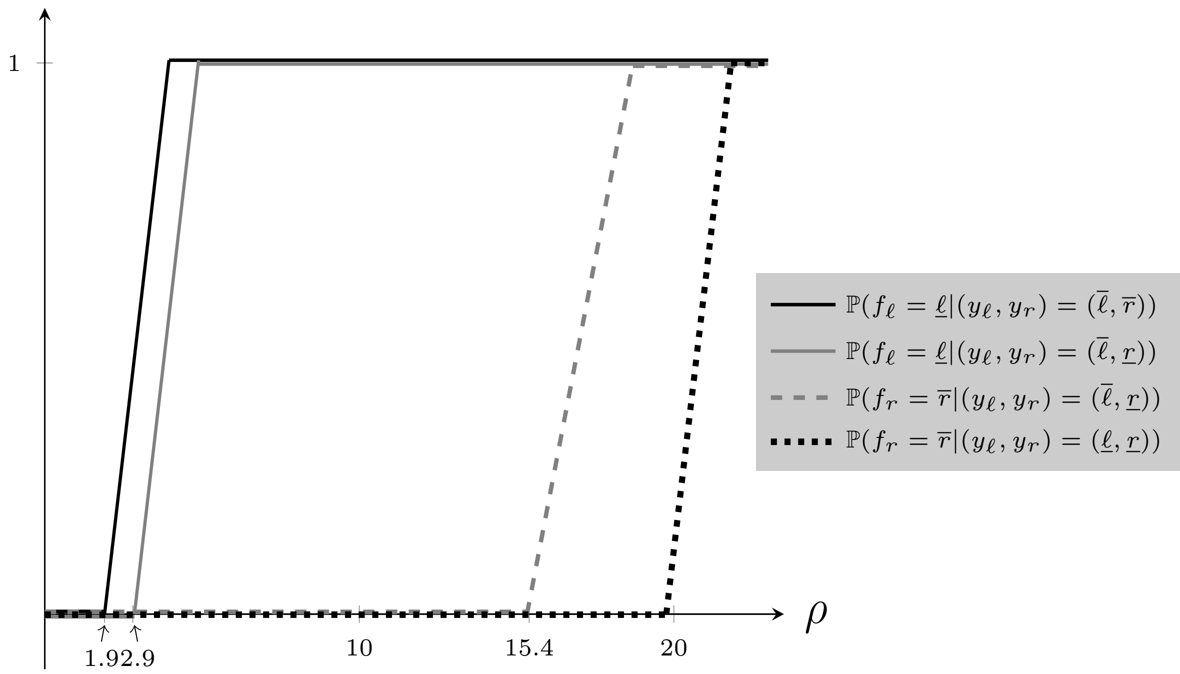

Figure OA1

The optimal strategy ϕ^* is equal to:

- $(0, 0, 0, 0, 0)$, for $\rho \leq \frac{19}{10}$;
- $(0, 0, 0, \phi^*_{\overline{r}}, 0)$, where $\phi^e = \phi^*$ satisfies (OA8), for $\rho \in (\frac{19}{10}, \frac{57}{20}]$;
- $(0, \phi^*_{\underline{r}}, 0, \phi^*_{\overline{r}}, 0)$, where $\phi^e = \phi^*$ satisfies (OA8) and (OA9) for $\rho \in (\frac{57}{20}, \frac{1216}{399}]$;
- $(0, \phi^*_{\underline{r}}, 0, 1, 0)$, where $\phi^e = \phi^*$ satisfies (OA9), for $\rho \in (\frac{1216}{399}, \frac{514}{105}]$;
- $(0, 1, 0, 1, 0)$, for $\rho \in (\frac{514}{105}, \frac{6764}{441}]$;
- $(\phi^*_{\emptyset}, 1 - \phi^*_{\emptyset}, 0, 1, 0)$ where $\phi^e = \phi^*$ satisfies (OA10), for $\rho \in (\frac{6764}{441}, \frac{187}{10}]$;
- $(1, 0, 0, 1, 0)$, for $\rho \in (\frac{187}{10}, \frac{7885}{399}]$;
- $(1, 0, 0, 1, \phi^*_{\underline{\ell}})$, where $\phi^e = \phi^*$ satisfies (OA11), for $\rho \in (\frac{7885}{399}, \frac{8710}{399}]$;
- $(1, 0, 0, 1, 1)$, for $\rho > \frac{8710}{399}$.

For any ρ, it is easy to verify that this strategy is the (unique) optimal strategy. Figure OA1 illustrates this.

It is easy to see that the qualitative features of the optimal strategy closely resemble those of the strategy in the case of naive voter(s). In particular, the forecaster is more likely to bias the forecast associated with Leave than the forecast associated with Remain.