Good Judgment "Disruptions from Vehicle Innovations" Challenge
Year-End Summary of Forecaster Performance and Forecasting Results
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Overview

Together with Philip Tetlock and his team at Good Judgment Inc. (GJ), PVMI embarked in the fall of 2015 on the design and execution of a technology forecasting tournament focused on electric and autonomous vehicles. Our objective was to learn more about the likely trajectory of these emerging technologies using the wisdom of the crowd.

Overall, far from being a "tipping point" year for EVs, 2016 was instead a year of reality not matching EV advocates' optimism, as shown by the disappointing (relative to expectations) sales figures, lack of legislative action in the US, and less-than-expected impact of EV subsidies in Germany. The most positive trends for EVs are that battery costs are dropping relatively quickly and that Chinese government policy plus investments by Chinese domestic OEMs and entrepreneurs are fueling continued steep growth in EV sales.

In contrast, three of the four questions regarding autonomous vehicles resolved in ways that suggested significant progress in a short timeframe. The answer to a fourth question about Google announcing the public testing of its fully autonomous vehicles before 2017 turned out to be a "no." But then on April 25, 2017 Google did announce its first public testing program for residents in Phoenix, Arizona. Progress in autonomous vehicles in the short-run has been swift, with all major players making significant advances and with policymakers starting to allow autonomous vehicles to operate on public roads.

Launching this "Disruptions from Vehicle Innovations Challenge" involved three phases.

- In the first, we worked closely with the team from GJ to identify relevant topics around technology, auto firms, and policy, and to design short-term questions to help identify the overall long-term trajectory in demand for electric vehicles. The key was to balance the relevance of the question with the rigor required to resolve the question unambiguously.
- The second phase kicked off with the launch of the Challenge on the Good Judgment "Open" website. The launch occurred on Earth Day 2016, with six initial questions about electric vehicles. Over the next several weeks, we added new questions to keep the forecasting community engaged.
- For the third phase in August 2016, we broadened the challenge to include four new questions on autonomous vehicles (AVs), building on the enormous excitement around rapidly-advancing developments with this technology.

The Challenge closed on January 1, 2017. The 13 questions ultimately attracted 1,530 forecasters who made over 9,500 forecasts on the questions detailed below. We also asked two open questions regarding events that might drive technological innovation in the auto industry in 2017, and suggestions for questions to help predict the future of EVs.

Soon after January 1, 2017, we resolved all the questions from verifiable sources and reported results to the forecasting community. In this blog, we provide fuller performance results so forecasters can get feedback on how they performed on the challenge. We also analyze the forecasting data (both quantitative and qualitative) to identify the trends and the basis for predictions made by the forecasters. Table 1 below includes basic information on the questions included in the challenge.

We will build on what we learned in this Challenge to capture a broader range of positive and negative indicators for the next Challenge.

Table 1: Basic Information on All Questions

Question	Resolution	Forecasts	Forecasters
1. Will any other US state adopt California's Zero Emission Vehicle (ZEV) Mandate before 1 January 2017?	No	1015	357
2. Will Tesla Motors deliver more than 80,000 BEVs to customers in calendar year 2016?	No	1805	576
3. Will the 2016 industry-wide average cost of Li-on batteries used in battery-powered electric vehicles be less than $300 per kWh?	Yes	689	242
4. Will annual sales of electric vehicles in China reach 500,000 in 2016?	Yes	1063	416
5. Will Toyota sell or lease more than 750 Mirai in the US in 2016?	Yes	781	210
6. Will at least 400 employers participate as partners in the US Department of Energy's Workplace Charging Challenge in 2016?	N/A[1]	662	159
7. Will Faraday Future, NextEV, or Atieva start taking orders for electric vehicles in 2016?	Yes	586	145
8. Will more than 6,000 new battery electric vehicles be registered in Germany in the third quarter of 2016?	No	630	278
9. Will Nissan sell more than 15,000 units of the LEAF in the US in 2016?	No	595	265
10. Between 12 August 2016 and the end of 2016, will any US state enact legislation that allows autonomous vehicles to operate on its public roads?	Yes	499	249
11. When will Tesla release a software update that adds off-ramp capabilities to its Autopilot system?	"Before Nov 1"	268	118
12. Before 2017, will Google announce that it will conduct public testing of its fully autonomous vehicles in a US city?	No	483	229
13. Will an Uber self-driving car with a member of the public as a passenger be involved in an auto accident while driving autonomously between 14 October 2016 and 1 January 2017?	No	511	244

[1] As we discuss later, this question was voided because of the inconsistencies with respect to how Department of Energy counts partners.

Top Forecasters

Table 2 identifies the top ten forecasters across the full set of questions in the Challenge. We used a cutoff of participation, including only those forecasters who submitted their predictions for 7 or more of the 13 questions listed above.

Table 2: Top Ten Forecasters (overall accuracy score for forecasting 7 or more questions)

Rank	Username	No. of Questions Forecasted	Brier	Median	Accuracy Score
1	Raisinville	12	0.411	0.617	**-2.476**
2	praedico	10	0.431	0.703	**-2.412**
3	The_Gnome	12	0.466	0.617	**-1.814**
4	dada	8	0.444	0.642	**-1.795**
5	seamusfag	7	0.591	0.811	**-1.751**
6	Hochstetler	7	0.081	0.403	**-1.618**
7	Dsarin	12	0.350	0.559	**-1.616**
8	53	8	0.578	0.869	**-1.57**
9	Kate	9	0.246	0.629	**-1.545**
10	Resonancia	11	0.253	0.573	**-1.481**

The striking fact about these top ten forecasters is that they achieved a high level of consistency in the accuracy of their predictions across a wide array of questions reflecting different topics, geographies, and areas of expertise. The most accurate forecaster on one question may have chosen a relatively extreme prediction, based either on knowledge, skillful modeling of probabilities, strong gut feel, or luck. However the approach that might deliver a highly accurate forecast for one question might often lead to many inaccurate forecasts across the full set of questions. We will award badges of achievement to these top 10 forecasters across the entire Challenge in order to recognize the value of their portfolio approach to achieving accurate predictions on these emerging technology topics.

Categories of Questions: Electric Vehicles (EV) and Autonomous Vehicles (AV)

Nine questions were part of the "EV Tipping Point" Challenge and four questions were part of the expansion to autonomous vehicles under the heading "Disruptions from Vehicle Innovations." For each question, we provide the exact wording as it appeared in the Challenge, along with the background information that we provided. We then describe the forecasting trends over time and provide a graphic with a visual portrait of those trends. Our summary report ends with lessons learned about how to write good questions, challenges in attracting forecasters, and plans for the next challenge.

Analysis of Electric Vehicle (EV) Questions

This part of the overall "Disruptive Vehicle Innovations" Challenge on GJ Open was launched on Earth Day 2016. The "EV Tipping Point" theme eventually encompassed nine questions on a range of issues from sales of EV and fuel cell models (in the U.S., China, Germany) and the fortunes of new entrant companies to policy issues at the national and state level as well as technology questions (battery pack cost per KwH).

Four questions resolved as "yes":

- Battery costs dropping below $300 per KwH
- Sales of EVs in China surpassing 500,000
- Sales of Toyota's Mirai fuel cell vehicle, after mid-year launch, surpassing 750
- Whether any of the three new luxury EV producers (Faraday Futures, Atieva, and NextEV) opening in the U.S. would take orders from consumers

The GJ forecasting community performed well in predictions with respect to battery cost and Mirai sales. 87% of forecasters were predicting Yes for battery cost by year's end after a steady rise from initial forecasts around 55%. What influenced the forecasters most, according to the top-voted comments, were announcements from industry leaders such as Tesla and GM reporting that their battery costs per KwH were already well below $300. Also influential were data about worldwide production capacity for batteries exceeding demand substantially, yielding predictions of price cuts.

100% of forecasters predicted Yes for Mirai sales reaching the target level. Here the change in forecasts was dramatic, rising from 1% on 9/1/16 to 100% on 10/11/16. Forecasters were in agreement that the main variable for Mirai was whether the state of California's investments in fuel cell recharging stations would occur quickly enough to support these sales. A secondary issue was whether Toyota would be able to supply enough Mirai given sales in Japan. With evidence of a big pickup of sales in October, forecasters quickly concluded that this goal was likely to be reached – and they were right.

The forecasting community did not expect EV sales in China to reach the stated level of 500,000, with only 7% predicting "Yes" by year's end. Forecasters engaged deeply with this question, tracking the monthly sales reports and incorporating a variety of methods for extrapolating from past trends. Also influential was news of a scandal in early 2016 involving improper filing for subsidies for false sales. Sales surged late in 2015 but the mix of government sales (purchases by government agencies, allowable) and false sales (leading to the scandal) was difficult to parse. While questions about the reliability of these statistics loom large for some, surpassing the sales level of 500,000 did have a basis in solid trends, such as: the government's crackdown on subsidy fraud but continuation of the subsides; strong government sales again in the last months of the year; heavy government investment in charging infrastructure, both underway and announced; substantial R&D investments in EVs by Chinese domestic OEMs, under encouragement by the government to move quickly for market share advantage over foreign OEMs. We are also aware of academic research, not identified by the GJ forecasters, of Chinese consumer openness to EVs that is higher than in the U.S. Overall, the strong and relatively effective push for EV sales growth in China, driven by a combination of government policy and domestic OEM ambitions, is the big global surprise in EV diffusion to most observers and it caught out the GJ forecasters too.

The question about the three new luxury EV producers and whether they would take an order in 2016 produced quite a bit of grumbling about the question wording from forecasters. They argued that "taking an order" as demonstrated only by announcing having done so was highly subject to manipulation by the company. A flurry of comments followed an announcement that NextEV had sold 10 vehicles to early investors since this seemed less like "taking an order" than

promising a vehicle in return for investment. The question ultimately resolved when Atieva (which was named Lucid Motors when the question was launched) took orders based on a $2500 deposit in December 2016. As all three companies appear to be backed by Chinese entrepreneurs, this question is actually related to the overall push for EVs from China and for one company to seek bragging rights by taking an order by year's end is not in the end too surprising given that no production date promise was involved. The most telling small detail came from a forecaster who spotted that Atieva was hiring a manager of after sales service!

In contrast to the "Yes" resolutions, four other questions resolved as "No". Two were sales-related and two were policy-related.

The Nissan Leaf is the world's best-selling EV based on cumulative sales and a new model with a higher battery range was launched in 2016. However, Leaf sales were already lower than predicted when the question was launched. Forecasters started low (4-5%) and kept revising downwards to a consensus of 0% well before year's end.

The Tesla question, in contrast, fluctuated around 50% for much of the forecast period. Forecasters scrutinized the news for production reports but also any news about Tesla that could lead to optimistic or pessimistic forecasts about how much managerial attention and resources were going to meeting the sales goal of 80,000. Tesla fell short but not by much and its higher-than-expected Q1 sales in 2017 helped to boost the company's already-high valuations to above the market value of Ford and GM, a truly remarkable (if ephemeral) development demonstrating the power of Tesla's appeal.

The policy question set in the US asked if more states would sign on to California's Zero Emission Vehicle standard beyond the 10 states that had already done so. Forecasters spotted that a few states had legislation prepared in the past that could be introduced but in general felt that the political climate in a presidential election year, amid high uncertainty about what future government policy towards EVs would be, made any passage of such legislation unlikely – and they were right.

The policy question in Germany concerned the sales impact of a government policy of providing subsidies for EV purchase that were announced in May 2016. Here we had set a close date of 30 September in order to see if the subsidies would produce a spurt of demand. Forecasters observed that the sales trend was slow and predicted "no". They were right; in fact, just over 50% of the target level of 6000 vehicles were sold.

One question had to be abandoned, on the US Department of Energy's Workplace Charging Challenge to recognize employers that installed charging stations in their company parking lots. The DOE changed how they counted subsidiaries of firms, making the ground rules for the initial question inaccurate. This reminded us of the importance of honoring the initial premises given to forecasters for any given question since they rely on those premises as the foundation for prediction.

Question-by-question details follow for the nine questions related to EVs.

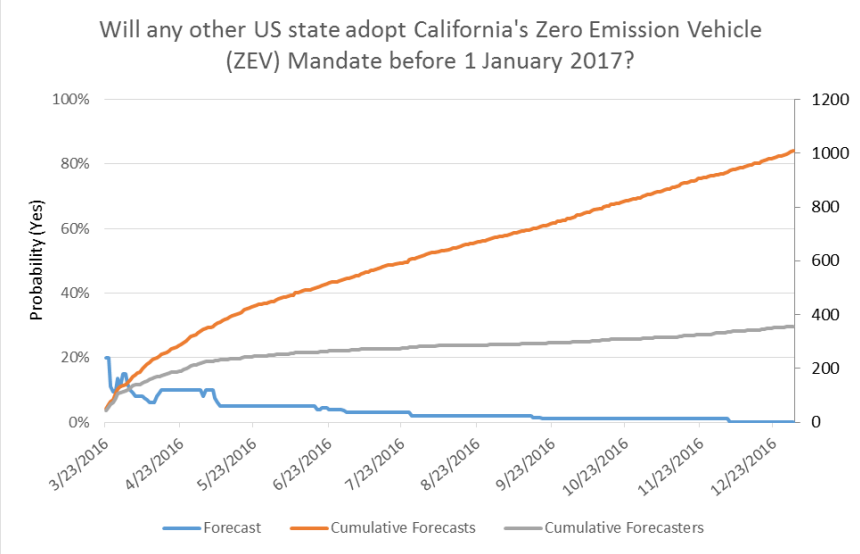
Question 1:
Will any other US state adopt California's Zero Emission Vehicle (ZEV) Mandate before 1 January 2017?

This question was closed as "No" with an end date of 31 December 2016.

Background Information
California's Zero Emission Vehicle (ZEV) mandate requires auto companies to produce a certain percentage of zero emission vehicles, such as those using hydrogen fuel cell cars and battery electric vehicles (Edmunds). The Clean Air Act permits other states to adopt California standards and nine other states plus the District of Columbia have already adopted California's ZEV mandate (Center for Climate and Energy Solutions).

Stats (# of forecasts, # of forecasters, resolved yet?):
357 forecasters, 1015 forecasts, closed on Dec 31, 2016 with 0% "Yes"

Verbal description of forecast trend from launch to present:
The question opened on 3/22/16 at a probability of around 20%. Since then there was a steady decline in percent as the probability dropped to 5% in May and 1% in September. By the end of November, the percentage finally dropped to 0%.



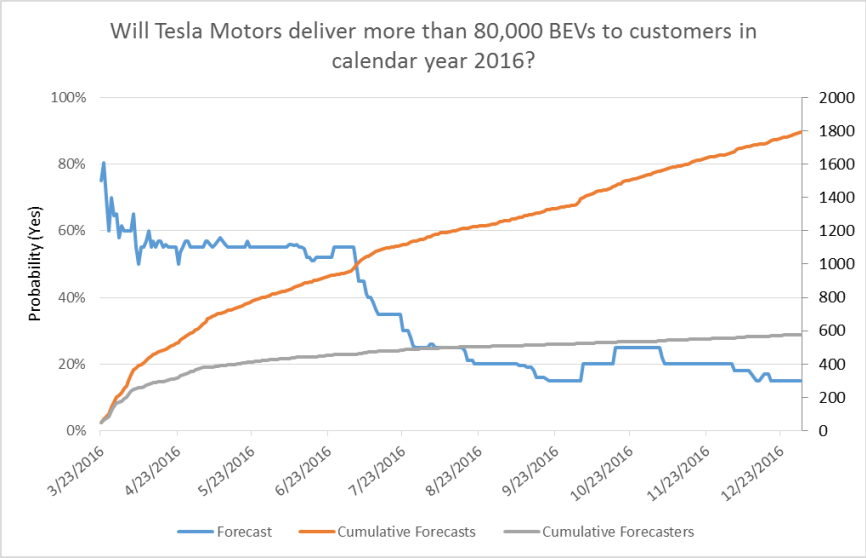
Question 2:
Will Tesla Motors deliver more than 80,000 BEVs to customers in calendar year 2016?

This question was closed as "no" with an end date of 31 December 2016. Tesla did not deliver more than 80,000 BEVs to customers in 2016 (Wall Street Journal).

Stats (# of forecasts, # of forecasters, resolved yet?):
576 forecasters, 1805 forecasts, closed Dec 31, 2016 with 0% "Yes"

Background Information
Tesla Motors was created in 2003 by engineers in Silicon Valley with the mindset that battery-powered electric vehicles (BEVs) could be better than gasoline-powered cars, and with the mission to accelerate the world's transition to sustainable transport. Tesla delivered 32,000 BEVs in 2014 and 50,000 BEVs in 2015. The company predicts that it will deliver between 80,000 and 90,000 BEVs in 2016 (Tesla). Yearly deliveries can be extracted from the cumulative delivery data provided on page 4 of the letter. The question will be suspended on 31 December 2016 and will be closed when the 2016 data is released by Tesla.

Verbal description of forecast trend from launch to present:
This question opened on 3/22/16. After opening, the probability of "Yes" rapidly increased to 85% before falling to a relatively constant 55% in the beginning of April. This probability stayed around 50-55% for the next couple months until 7/3/16 when a slow decline occurred. This probability decrease continued until a period from August to late December when the probability remained in a range from about 25% to 15%. Finally, on 12/31/16, the probability dropped to 0%.



Question 3:
Will the 2016 industry-wide average cost of Li-on batteries used in battery-powered electric vehicles be less than $300 per kWh?
This question was closed as "Yes" with an end date of 1 January 2017.

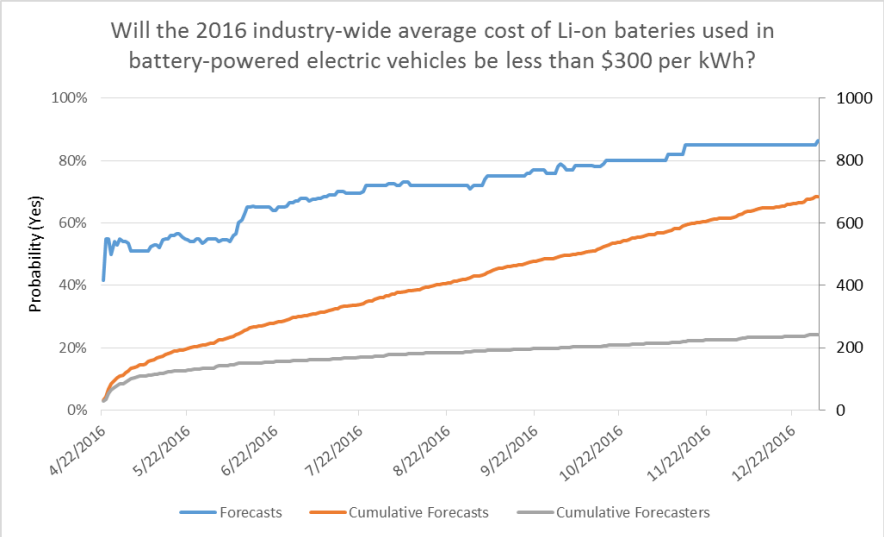
Background Information
Lowering the cost of battery packs through R&D investments, manufacturing improvements, and economies of scale is a major consideration for bringing down the price of battery-powered electric vehicles (BEVs) and making them more competitive with gasoline-fueled internal combustion engines.

A study published in Nature Climate Change in 2015 analyzed the cost of battery packs between 2007 and 2014 based on estimates from over 80 different publicly-available data sources. This study calculated that industry-wide average cost of lithium-ion (Li-ion) battery packs declined by approximately 14% annually between 2007 and 2014, from more than US $1,000 per kWh in 2007 to around US $410 per kWh in 2014 (Nature). If this trend holds through 2016, the industry-wide average cost would be about $300 per kWh.

This question was closed as "yes" with an end date of 31 December 2016. See the detailed analysis here.

Stats (# of forecasts, # of forecasters, resolved yet?):
242 Forecasters, 689 Forecasts, closed Jan 1, 2017 at 87% “Yes”

Verbal description of forecast trend from launch to present:
This question opened on 4/21/16 and the probability settled in the mid 50s. In early June, the probability began to steadily rise and sat at 85% for most of November and all of December until hitting 87% right before the closing of the question.



Question 4:
Will annual sales of electric vehicles in China reach 500,000 in 2016?

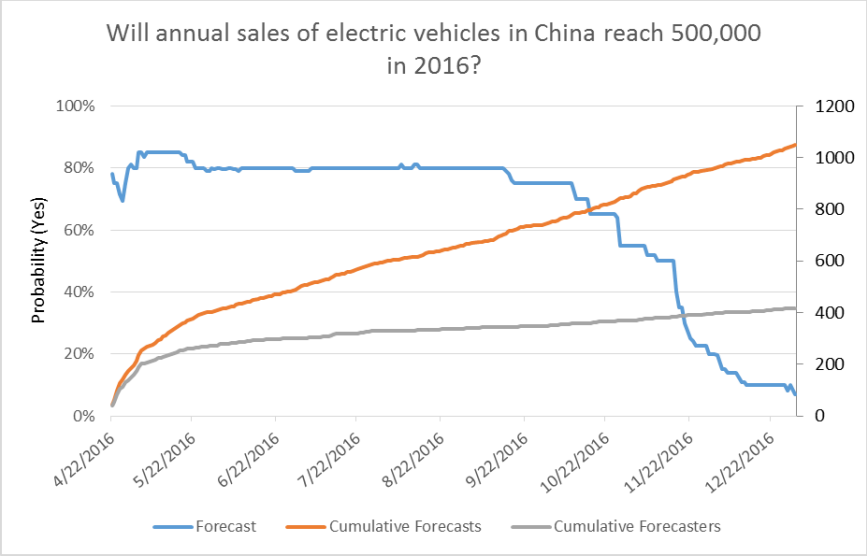
This question was resolved as "yes" with an end date of 31 December 2016. The English Language press releases on the Chinese Association of Automotive Statistics have not included annual sales for electric vehicles in 2016 (CAAM), but the Chinese language press release (CAAM) shows that 507,000 electric vehicles were sold in 2016. The numbers increased 63.9%

and 65.1% respectively comparing to the year before, with 409,000 BEV units sold and 98,000 PHEV units sold.

Background Information
In 2012 the Chinese government set a target of reaching 500,000 annual unit sales of electric vehicles by 2015 (Forbes, CleanTechnica, Scientific American). In 2015, electric vehicle sales, including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), in China were 331,092 (China Association of Automobile Manufacturers). The data source is the China Association of Automobile Manufacturers' (CAAM) website. Monthly and yearly data on electric vehicle sales are included in periodic press releases titled "New Energy Vehicles." The 2015 sales data, above, is from this source.

Stats (# of forecasts, # of forecasters, resolved yet?):
416 Forecasters, 1063 Forecasts, closed on Jan 1, 2017 with 7% "Yes"

Verbal description of forecast trend from launch to present:
This question opened on 4/21/16 with the probability of "Yes" reaching the 80s within the first week. It stayed around 80% until 9/13/16 when the probability began to slowly decline. It declined at a decreasing rate until sticking at 10% in mid-December for some time and then finally ending at 7%.



Question 5:
Will Toyota sell or lease more than 750 Mirai in the US in 2016?

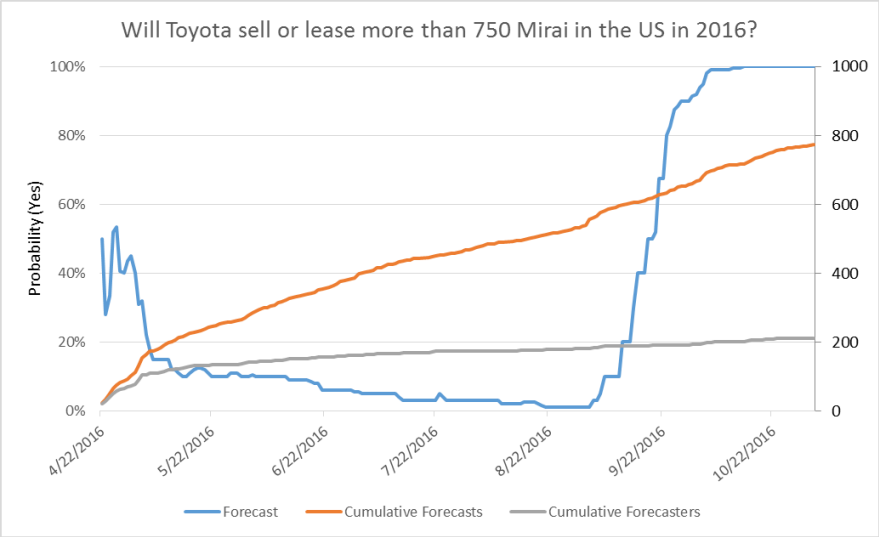
This question was closed with the correct answer "Yes" with an end date of 1 November 2016. Good Car Bad Car reports that Toyota sold 103 Mirai in October, pushing their yearly sales total to 813.

Stats (# of forecasts, # of forecasters, resolved yet?):
210 Forecasters, 781 Forecasts, Closed on Nov. 1, 2016 with the answer "Yes"

Background Information
The Mirai is Toyota's first commercially launched fuel cell-powered electric vehicle (Mirai, Forbes 1, Forbes 2). In late 2014, Toyota announced the goal of selling 3,000 Mirai in the U.S. by the end of 2017 (Forbes 3). However, only 72 were sold in the last three months of 2015 (Toyota).

Toyota Mirai sales data can be tracked both during and after the challenge here. Note that sales figures reported include all vehicles acquired by a customer, regardless of how that customer is defined or what kind of payment they made in order to register the vehicle. Hence, sales figures also include leases, and refers to both individual and business customers.

Verbal description of forecast trend from launch to present:
The question launched on 4/21/16 and quickly spiked downwards and then upward to about 50%. After hitting a relative max of 54% on 4/25/16, the percent steadily declined to 1% until 9/1/16. There was then a sharp increase in percent until 10/11/16 when the question finally hit 100% "Yes".



Question 6:
Will at least 400 employers participate as partners in the US Department of Energy's Workplace Charging Challenge in 2016?

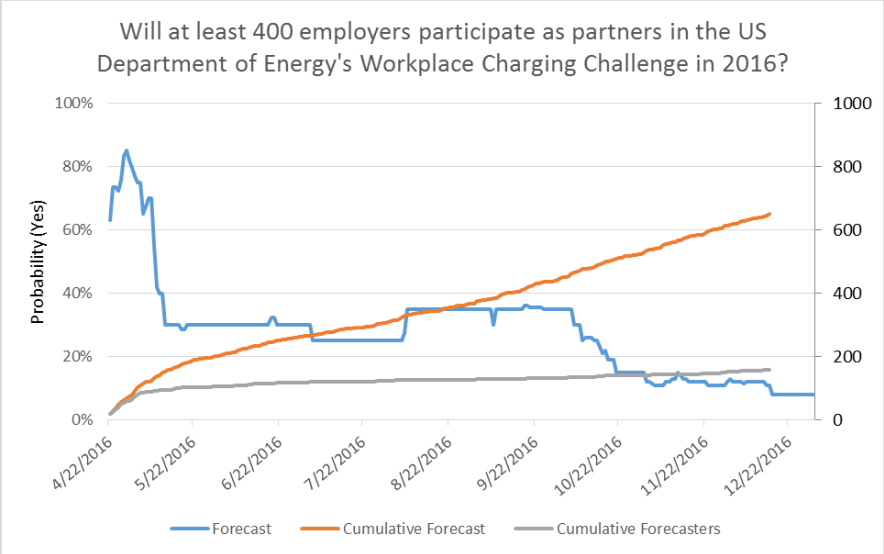
This question was voided on 16 December 2016 due to a change in how the Department of Energy (DoE) calculates the total number of Partners and in the way DoE data is presented at the links provided. These changes make the clarification issued on October 4th inconsistent with the way DoE counts affiliates.

Stats (# of forecasts, # of forecasters, resolved yet?):
159 Forecasters, 662 Forecasts, question voided on 12/16/16

Background Information
In 2012, the US Department of Energy (DOE) launched the Workplace Charging Challenge with the goal of installing electric vehicle charging stations in workplace parking lots of at least 500 employers by 2018 (Energy Department). In 2015, 260 organizations participated as partners. Learn more about Workplace Charging Challenge partners here. The question will be resolved using DOE data. Examples of progress reports from 2014 and 2015 can be found here: 2014 Report, 2015 Report. For more information on electric vehicle charging stations, see Alternative Fuels Data Center.

Clarification Released 10/4/2016: Subsidiaries of companies listed as "Partners" in DOE's workplace challenge do not count as separate partners. For example, the website currently lists Duke Energy, with Duke Energy Carolinas, Duke Energy Florida, Duke Energy Indiana, Duke Energy Kentucky, Duke Energy Ohio, and Duke Energy Progress listed in italics as subsidiaries. Duke Energy counts as one partner.

Verbal description of forecast trend from launch to present:
This question opened on 4/21/16 and the probability immediately went into the mid-80s. Towards the end of April, the probability steeply declined until hitting 30% on 5/12/16. The probability stayed within 5% of 30% until early October when it began to decline to the 8% point at which it was voided.



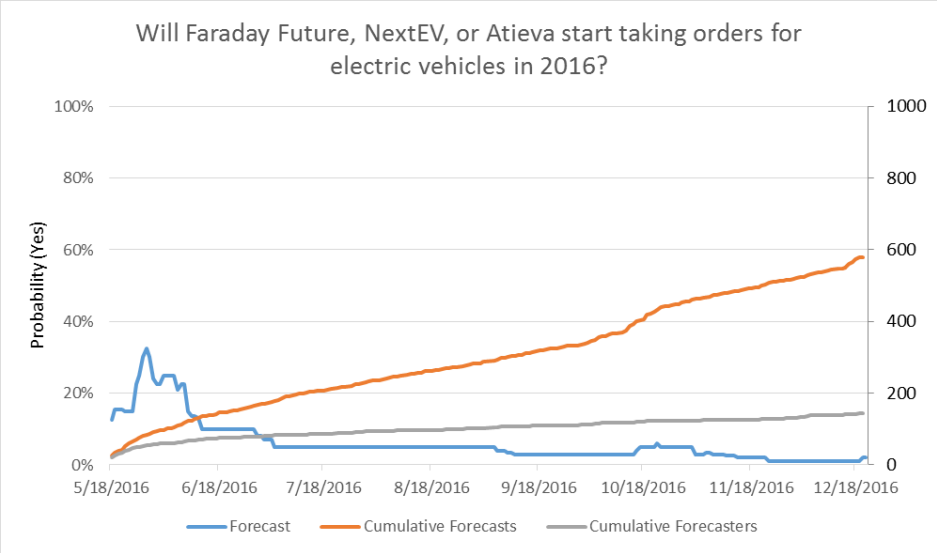
Question 7:
Will Faraday Future, NextEV, or Atieva start taking orders for electric vehicles in 2016?

This question was closed as "Yes" with an end date of 14 December, 2016. Lucid Motors, formerly Atieva (Electrek), began taking orders in December 2016 (Lucid Motors, The Verge, Inside EVs).

Stats (# of forecasts, # of forecasters, resolved yet?):
145 Forecasters, 586 Forecasts, closed Dec 14, 2016 with 100% Yes

Background Information
Faraday Future, NextEV and Atieva are challenging Tesla with new high-end battery-powered electric vehicles. These companies are backed by Chinese technology entrepreneurs or carmakers, have bold visions, have raised significant capital, and are being led by many former Tesla and other Silicon Valley executives (Fortune, Electrek, Green Car Reports).

Verbal description of forecast trend from launch to present:
This question opened on 5/17/16 and fluctuated from around 25% to 15%, and then up to 30% within about 2 weeks. After hitting 30%, the probability began a slow decline over the next couple months until it hit 1% on 11/23/16. On 12/14/16, the % "Yes" spiked to 100% as the questions was closed (Lucid Motors, formerly Atieva, began taking orders in December).



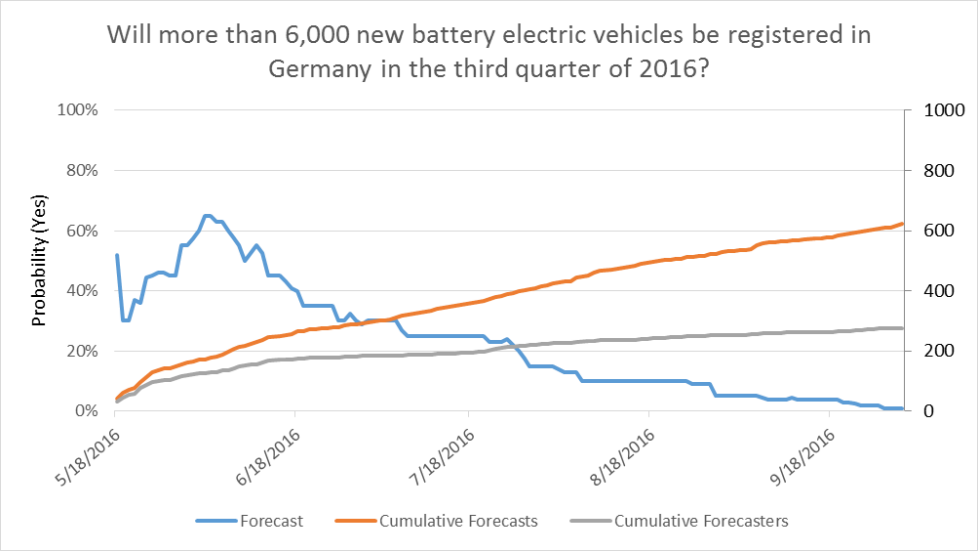
Question 8:
Will more than 6,000 new battery electric vehicles be registered in Germany in the third quarter of 2016?

This question was closed on "No," with an end date of 30 September 2016. Kraftfahrt-Bundqesamt, the source for the best-selling-cars report mentioned below, reported 3,321 new battery electric vehicles were registered in the third quarter (Kraftfahrt-Bundqesamt).

Stats (# of forecasts, # of forecasters, resolved yet?):
278 Forecasters, 630 Forecasts, Closed on September 30, 2016 with the answer "No"

Background Information
Germany is launching a 1 billion euro rebate scheme to incentivize the sale of electric vehicles (Reuters). Question will be resolved using the totals from the "Electric" columns for the three months in Q3, July, August, and September at best-selling-cars.com. Registrations of hybrid electric vehicles and plug-in-vehicles will not count. Third quarter registrations in 2015 were 2,722, and include both German (e.g. BMW i3; VW e-Golf) and non-German (e.g. Nissan Leaf; Tesla Model X) models. Question will be suspended on 30 September 2016 and resolved when September's data is released. The new subsidy program, which gives purchasers a discount of 3000-4000 euros for select vehicles, is scheduled to start as early as May 2016. The German government is perceived as wanting to support the German auto companies, which are very important to the German economy, and to draw attention away from the diesel engine scandal of Volkswagen by emphasizing the country's commitment to "green" technologies. The tax is controversial with some economists, who oppose subsidizing private purchases, and with environmentalists, who see negative impact from a boost in electricity consumption at a time when Germany's ban on nuclear power plants has made its electricity generation more coal-based. For more information see: The Guardian, Bloomberg, Forbes, The Wall Street Journal.

Verbal description of forecast trend from launch to present:
When this question opened, the probability started off around 40% and slowly moved up to a max of 65% in early June. Then, the probability began to decline, hitting 31% at the end of July, 10% in mid August, 4% in mid September and finally 1% by the end of September.



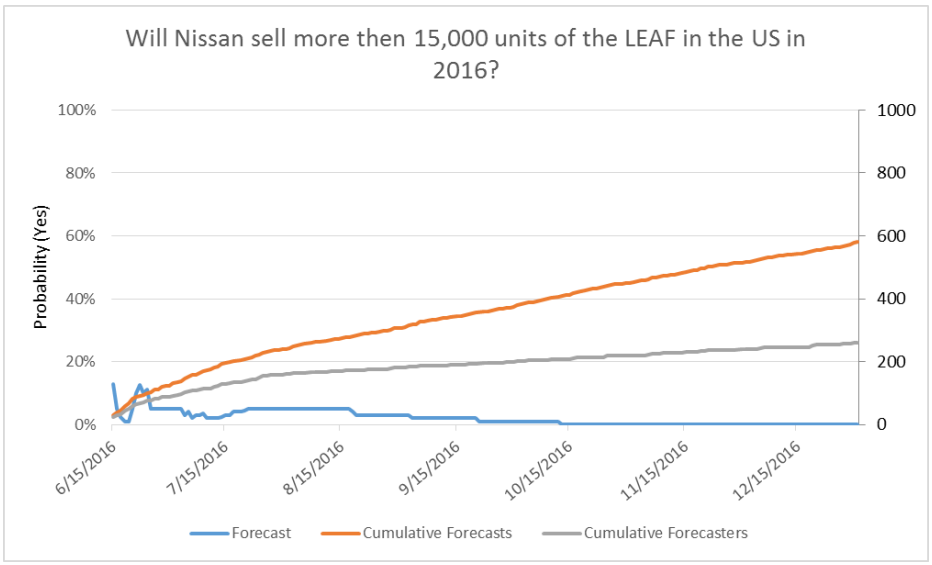
Question 9:
Will Nissan sell more than 15,000 units of the LEAF in the US in 2016?

This question closed as "no" with an end date of 31 December 2016. Sales of the Leaf were 14,006 for 2016 (Nissan).

Stats (# of forecasts, # of forecasters, resolved yet?):
265 Forecasters, 595 Forecasts, closed on Dec 31, 2016 with 0% “Yes”

Background Information
Nissan LEAF is the world’s all-time best selling battery-powered electric car, with global sales of over 200,000 units since its launch in 2010 (Nissan). More than 30,000 LEAFS were sold in the US during 2014, up from 22,610 in 2013. However, there was a sharp decline in 2015 with total sales in the US amounting to only 17,269. The newly-released 2016 LEAF has an upgraded 30 kWh battery option which will yield an estimated 107-mile range, a 27% improvement over the 24 kWh option offered in the previous model (Car and Driver). During the first quarter of this year, 2,931 units of LEAF were sold in the US.

Verbal description of forecast trend from launch to present:
This question opened on 6/14/16 at about 16%. Since then, the probability has declined, hitting 5% on 7/21/16, 1% on 9/23/16, and 0% on 10/14/16. The probability stayed at 0% “Yes” until the question closed.


Will Nissan sell more then 15,000 units of the LEAF in the US in 2016?
Probability (Yes)
100%
80%
60%
40%
20%
0%
1000
800
600
400
200
0
6/15/2016
7/15/2016
8/15/2016
9/15/2016
10/15/2016
11/15/2016
12/15/2016
Forecast
Cumulative Forecasts
Cumulative Forecasters

Analysis of Autonomous Vehicle (AV) Questions

The four questions launched in connection with expanding the Challenge to "Disruptions from Vehicle Innovations" all concern autonomous vehicles. These questions focused on the major players (i.e., Google, Tesla, Uber) advancing the technology and on the relevant state-level policy in the short-run. The specific topics were selected based on the news reported in the popular and trade media, as well as the ease of resolving the question using publicly available data sources.

Three of the four questions on Tesla, Uber and state-level policy were resolved in ways that suggested significant progress in autonomous vehicles in a short timeframe. The answer to the fourth question about Google announcing the public testing of its fully autonomous vehicles in a US city before 2017 while turned out to be a "no," Google did announce on April 25' 2017 its first public testing program for residents in Phoenix, Arizona. Hence, progress in autonomous vehicles in the short-run has been swift with all major players making significant advances and with policymakers starting to allow autonomous vehicles to operate on public roads.

In terms of the forecasting trend, with the exception of the question about Uber, the consensus forecast immediately following the launch of the question was substantially different from that during the intermediate and the later time-periods suggesting the existence of a highly uncertain environment around autonomous vehicles.

Initially, forecasters considered the question of whether Google will announce the public testing of its autonomous vehicles in a US city before 2017 through multiple lenses. Some viewed it as a relatively likely outcome because Google is lagging behind Uber and Ford in terms of public testing, it was aggressively hiring for the AV project, and the fact that California passed a law to allow for public testing of autonomous vehicles on some state roads. Others viewed it as a relatively unlikely outcome in the short-run because of greater scrutiny around autonomous vehicles with respect to public safety coupled with a number of minor accidents involving Google's AVs, as well as the recent churn within Google's AV project organization. Over the next two months, the optimism faded away as forecasters felt that the timeframe was too short for Google to initiate public testing before 2017, and that it was more likely to announce public testing in 2017.

Regarding when will Tesla release a software update that adds off-ramp capabilities to its Autopilot system, forecasters initially felt that such an update will likely happen in 2017 but not in 2016. While forecasters acknowledged Tesla's aggressiveness in terms of introducing autonomous features in its existing fleet of cars, they felt that adding an off-ramp capability is technically challenging and its introduction may be further slowed by NTSB's ongoing investigation of accidents involving Tesla cars being driven in autonomous modes. However, after Tesla CEO Elon Musk announced in his blog post on Sep 11 that Tesla's next Autopilot software update 8.0 will be rolled out in a week or two and that it will include an off-ramp capability, forecasters quickly adjusted their forecasts.

A similar forecasting pattern also emerged with respect to the question of whether any US state will enact legislation that allows autonomous vehicles to operate on its public roads between 12 August 2016 and the end of 2016. Initially, the forecasting community raised several concerns

about getting a legislation passed within such a short window and that too during the period of Presidential election. Many forecasters did note the different bills related to autonomous vehicles that are being considered in several states, and some of them even shared detailed analysis of the expected timing that those bills will be passed. On Aug 29, California Assembly Bill No. 1592 allowing autonomous vehicles to operate on some state roads was passed in the senate, and was sent to the Governor for approval. This news was swiftly captured by the forecasters and led to the consensus probability increasing significantly over the next three weeks.

Finally, the forecasting community predicted that it is unlikely that an Uber self-driving car with a member of the public as a passenger will be involved in an auto accident while driving autonomously between 14 October 2016 and 1 January 2017. The comments from the forecasters suggested that this expectation was based on the short timeframe for the question, the small number of such cars on the streets, and the steps that Uber took to ensure the safety of the cars. Several forecasters went great lengths in estimating the probability of an accident based on the available statistics on accidents. While there were some reports that an Uber vehicle was involved in an accident in October, there was no evidence that there was a passenger in the car or that the vehicle was in autonomous mode.

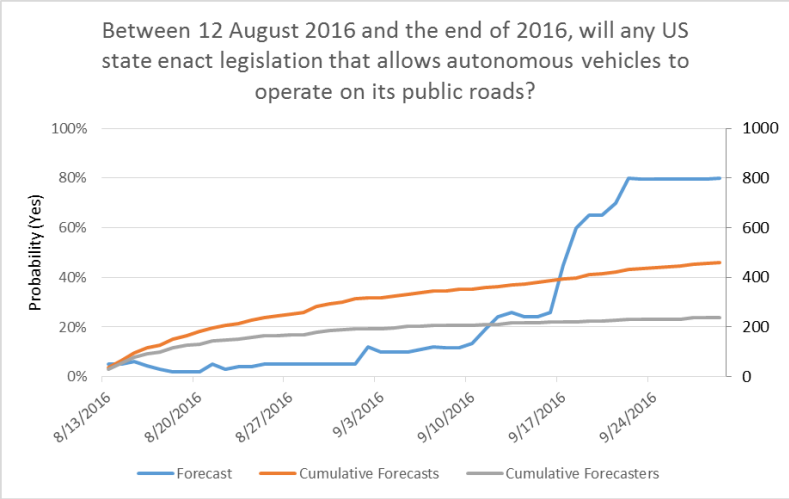
Question-by-question details follow for the four questions related to autonomous vehicles.

Question 10:
Between 12 August 2016 and the end of 2016, will any US state enact legislation that allows autonomous vehicles to operate on its public roads?

This question was closed as "yes" on September 29, 2016. On that day, California's governor signed a bill into law which permits the use of autonomous vehicles on some state roads (Road & Track, East County Today, California Legislative Information).

Background:
Most states neither explicitly allow nor explicitly ban the operation of autonomous vehicles on public roads, making such vehicles de facto legal (Washington Post). However, several states are considering legislation that would explicitly allow autonomous vehicles to operate on public roads (National Conference of State Legislatures, The Center for Internet and Society). Autonomous vehicles are those that can operate without the active control or monitoring of a human driver, at least under some conditions. This does not refer to cars with regular features such as adaptive cruise control, lane assist, crash avoidance, emergency braking, and other technology unless those features allow a driver to cede all control and monitoring. Any legislation enacted allowing autonomous vehicles on public roads will resolve the question as "yes," even if the legislation places restrictions on those autonomous vehicles (e.g., by limiting operation to certain roads or conditions, or only allowing operation for the purposes of research or testing).

Forecast trend:
The consensus probability for almost six weeks from the time this question was launched suggested a low likelihood that any US state would enact legislation autonomous vehicles to operate on its public roads. However, a flurry of news about a number of legislations being considered in different states dramatically shifted the consensus probability towards it being a probable event. Hence, the consensus forecasting trend for this question suggested that the outcome that was deemed somewhat unlikely during the first six weeks actually did take place. A closer inspection of comments by the forecasters suggests that the main source of uncertainty within the forecasting community was not that legislation would be passed but whether it would be passed within the designated timeframe in the question.

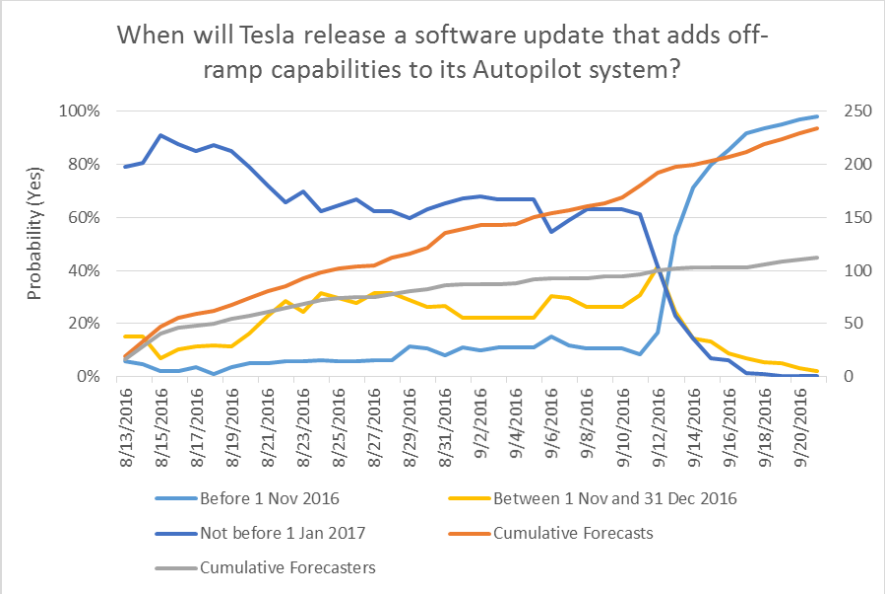


Question 11:
When will Tesla release a software update that adds off-ramp capabilities to its Autopilot system?

This question was closed on answer option "a) Before 1 November 2016" with an end date of 21 September 2016. Tesla released its 8.0 software update on 21 September 2016 and that update included off ramp capabilities (CNET, Jalopnik, Autoweek, Business Insider).

Background:
Tesla's Autopilot system, released via an over-the-air (OTA) software update in October 2015, is a major advance towards self-driving technology providing drivers with semi-autonomous drive and parking capabilities (Tesla). However, a fatal crash in Florida in May 2016 when a Tesla was in Autopilot mode and two other crashes in Montana and Pennsylvania have prompted consumer advocates to call on Tesla to reconsider its approach towards self-driving technology and make significant changes to its Autopilot system. They are also advocating regulatory oversight over the launch of self-driving features to ensure consumer safety (Consumer Reports). Tesla insists on the safety of the Autopilot system and plans to introduce new features and enhancements (CBS SF Bay Area, CNN Money). A Tesla 8.0 software update is currently in beta, and is rumored to include a new Autopilot feature that allows the car to exit the highway onto an off-ramp after the driver activates the turn signal (electrek).

Forecast trend:
This question required forecasters to provide an estimated probability of Tesla releasing the software update with respect to three different time periods – (a) "Before 1 November 2016," (b) "Between 1 November 2016 and 31 December 2016, inclusive," (c) "Not before 1 January 2017." For almost a month after the question was launched, the consensus probability suggested that this update will probably not be released before 1 Jan, 2017. However, a flurry of news during the second week of September about Tesla releasing the software update drastically shifted the consensus probability towards the earliest time period.



Question 12:
Before 2017, will Google announce that it will conduct public testing of its fully autonomous vehicles in a US city?

This question was closed as "no."

Background:
Since 2014, Google has focused on developing a fully autonomous vehicle that can "operate safely and autonomously without requiring human intervention" and which "won't have a steering wheel, accelerator pedal, or brake pedal… because they don't need them" (Google Self-Driving Car Project, Google Official Blog, Google Plus). Public testing refers to testing that allows people from the general public to use Google's Cars. Uber's testing of its autonomous cars in Pittsburgh is an example of public testing (Bloomberg, NY Times). Google is currently testing its self-driving cars in Kirkland, WA, Mountain View, CA, Phoenix, AZ, and Austin, TX, but those tests are not open to the public.

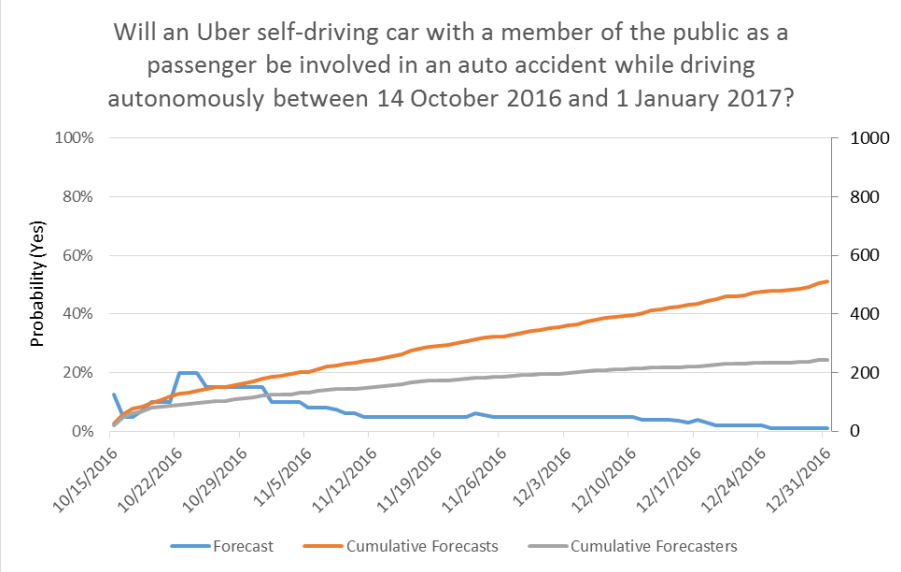
Forecast trend:
This question was launched on 9/16/16 and initially the consensus probability fluctuated between about 50% and about 30%, and then gradually decreased until the question was closed. After the initial volatility in forecasts over the first week, the forecasting consensus seems to suggest that Google will probably not announce a public testing of its fully autonomous vehicles in a US city before 2017, which turned out to be the case.

Question 13:
Will an Uber self-driving car with a member of the public as a passenger be involved in an auto accident while driving autonomously between 14 October 2016 and 1 January 2017?

This question was closed as "no" with an end date of 31 December 2016. Although there were some reports that Uber vehicle was involved in an accident in October (WTAE Pittsburgh), there was no evidence that there was a passenger in the car or that the vehicle was in autonomous mode. There are no indications of other accidents.

Background:
In the first public test of self-driving cars in the US, Uber recently launched a program where the public can hail and ride in one of the company's autonomous vehicles (Uber, NY Times). Each car has two Uber employees seated in the front seats who can take control when needed (NPR, Scientific American). However, concerns remain about the safety of these cars at this initial stage of development, especially in light of the recent accidents involving a Tesla Model S (The Verge), and a Google self-driving car (Quartz). For this question to resolve as "yes", an Uber self-driving car must physically contact another vehicle or object while driving autonomously. Malfunctions that do not result in an accident would not be sufficient to resolve the question (e.g. Quartz).

Forecast trend:
The consensus forecasting pattern represented in general a high level of optimism around Uber's self-driving car not getting involved in an accident during the initial months of testing. Indeed, the optimism gradually grew over time, and that's how the question was finally resolved.



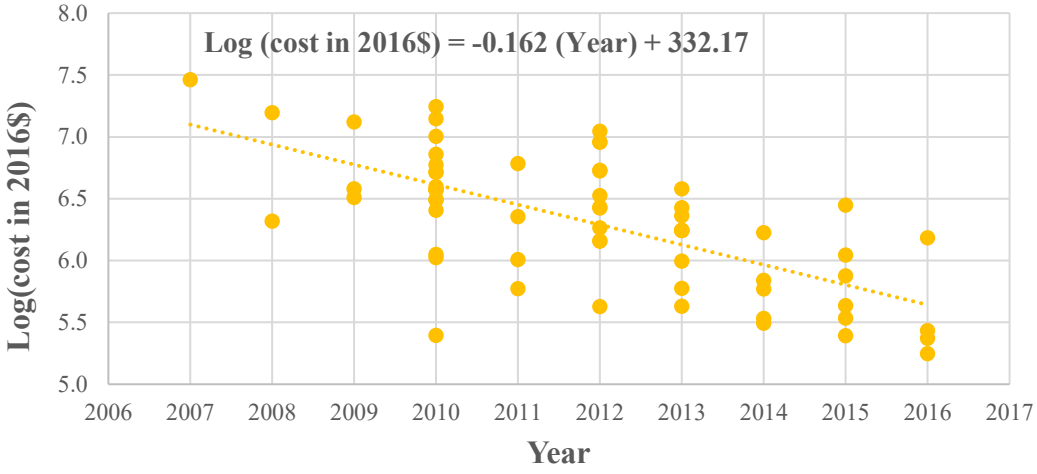
EV Technology Improvement (Battery cost)

One key factor affecting consumer acceptance of electric vehicles is the high cost of lithium-ion (Li-ion) batteries so we were very keen on having a question about the improvement trend in the cost of batteries used in EVs. However, coming up with a question on this topic presented several challenges. First, EV manufacturers and their battery suppliers typically do not disclose battery costs in a systematic manner over time. Second, EV manufacturers such as Nissan and Tesla have pursued vastly different approaches in terms of the performance and driving range of their EVs, which makes any comparative assessment of the battery costs across the different manufacturers difficult. Finally, there is no industry-wide benchmark of the cost of batteries used in EVs, and the expected improvement trend. We were able to address these challenges by drawing on an article published in *Nature Climate Change* (Nykvist and Nilsson, 2015).[2] Authors collected 53 unique cost-estimates for Li-ion battery packs from other academic articles, industry reports, news items with statements of cost-estimates from industry participants between 2007 and 2014. Based on the trend line of these cost estimates, they reported a 14% annual decline in the cost of battery packs between 2007 and 2014, and the industry-wide average cost of battery packs in 2014 as US $410 per kWh. If this trend holds through 2016, the industry-wide average cost would be about $300 per kWh, which formed the basis of the question on battery costs.

As background information to the question, we provided forecasters with an open-access version of the Nykvist and Nilsson (2015) article. We also referred them to a blog post where we offered a simplified account of the method used in the article, and mentioned that we will replicate the methodology from the article with the recent cost-estimates for 2014, 2015 and 2016 to resolve the question. After the question was closed, we identified 11 new cost estimates for the years 2014-2016. We performed the trend analysis based on 64 unique cost-estimates between 2007 and 2016 (53 estimates from the original article and 11 new estimates for the years 2014-2016). Based on the trend line below, there was a 16% annual decline in the cost of battery packs between 2007 and 2016, and the industry-wide average cost of battery packs in 2016 was US $282 per kWh. We shared the details of the methodology including the raw data that used to generate the trend with the forecasters through a follow-on blog post. While creating and resolving this question entailed significantly more effort than the other questions, it was satisfying to see that the forecasting community was satisfied with the resolution and that we were able to come up with an approach for using forecasting tournaments to predict industry-

[2] Nykvist, B., & Nilsson, M. Rapidly falling costs of battery packs for electric vehicles. *Nature Climate Change*, *5*(4), 329-332.

level technological progress.



EV Sales

Since an important goal of the challenge was to explore the market adoption of EVs, we considered a variety of questions to uncover the adoption pattern of EVs. Many of the questions focused on sales targets for the leading EV manufacturers (Tesla, Nissan), or on sales in geographical markets that are large and where the governments are incentivizing the adoption of EVs (China, Germany). We also included a question on Toyota, the largest auto manufacturer in the world in 2015 by number of vehicles sold. Instead of battery-powered EVs, Toyota has pursued an alternative approach towards low emission vehicles that are powered by fuel-cells. In some cases, the sales targets in the questions were based on targets mentioned by focal actors (e.g., Tesla, Chinese Government), and in other cases, they were estimated based on historical trends or on optimistic scenarios of growth. We were clear that sales figures include leases, and refer to both individual and business customers. All of these questions were well received by the forecasters, and were resolved through publicly available data sources.

Finally, we included a question focusing on new firms that were founded to manufacture high-end battery-powered electric vehicles (i.e., Faraday Future, NextEV and Atieva). Since these firms were in the early stage of development, the subject of the question was not around sales but rather around taking orders in the short-term. The resolution of this question would provide important information regarding the general momentum behind electric vehicles and the viability of the new start-ups in an industry that is controlled by large established players. Clearly, taking orders is not a proxy for sales and one could imagine many scenarios where taking orders (with or without a deposit that can be refunded) would simply be a marketing ploy or a way to generate some revenues with no market launch or sales in sight. However, taking orders has been a fairly standard practice for electric vehicle start-ups in this industry. Often, such a public announcement is accompanied by estimates of delivery to be in the following two years as has been the case for Tesla's introduction of Model S, Model X, and more recently, Model 3. Note that scaling up the manufacturing of a brand new electric vehicle is a multi-year undertaking costing hundreds of millions in investments, and there is a significant downside for a new start-up if orders do not translate into deliveries within the expected timeframe. Therefore, while

taking orders is not a proxy for sales, given the economics and the established practices of companies in this sector, it provides a useful indicator of progress towards electric vehicle commercialization by new breed of start-ups. Some forecasters expressed uncertainty about what "taking orders" meant and Atieva, the firm that started taking orders in December' 2016, changed its name to Lucid Motors, causing some confusion.

EV and AV Policy and Deployment

The questions on policy were selected based on their relevance, and were in general well received by the forecasters. The one exception was the question on the number of employers participating as partners in the US Department of Energy's Workplace Charging Challenge. Several forecasters raised questions about whether a subsidiary of a firm is counted as an additional partner or not. Based on our initial finding that the count in the DoE report exactly matched the count of partners on their website excluding subsidiaries, we issued a clarification on Oct 4 that subsidiaries are not included. However, after hearing back from DoE regarding how a partner is counted, we learnt that DoE is counting some subsidiaries as partners but not others, depending on how those companies apply for the challenge. Moreover, exactly which subsidiaries will count can't be determined based on public information. We also learnt that the list of partners at the DoE website that we shared with the forecasters is an accurate list of all current partners, but that some partners listed on that site are in fact not considered partners by the DoE and will be removed, and others are yet to be added with a substantial delay. Given these inconsistencies and especially our clarification that subsidiaries would not count, we decided that the best path forward was to void this question by closing it, not issuing scores, and explaining our reasoning to the forecasters.

The three questions on AVs focused on short-term developments for each of the three firms leading the charge on AVs – Google, Tesla, Uber. The wording of question for Google created some confusion regarding what we meant by "public testing" which was later clarified.