

**Supplementary Information****The zero-carbon target for vehicle traffic in 2050: A pipe dream?**

Figure S1:

Visualization of the first zero-carbon year depending on unlimited and limited market growth due to missing scrapping

- ▲.....▲ Scenario 2: Forecasts based on actual data      ■ - - - - ■ Scenario 4: 100% EVs in 2050  
 ◆.....◆ Scenario 3: 100% carbon free power in 2050      ●.....● Scenario 5: 100% carbon free power and 100% EVs in 2050



Figure S1 (cont'd):

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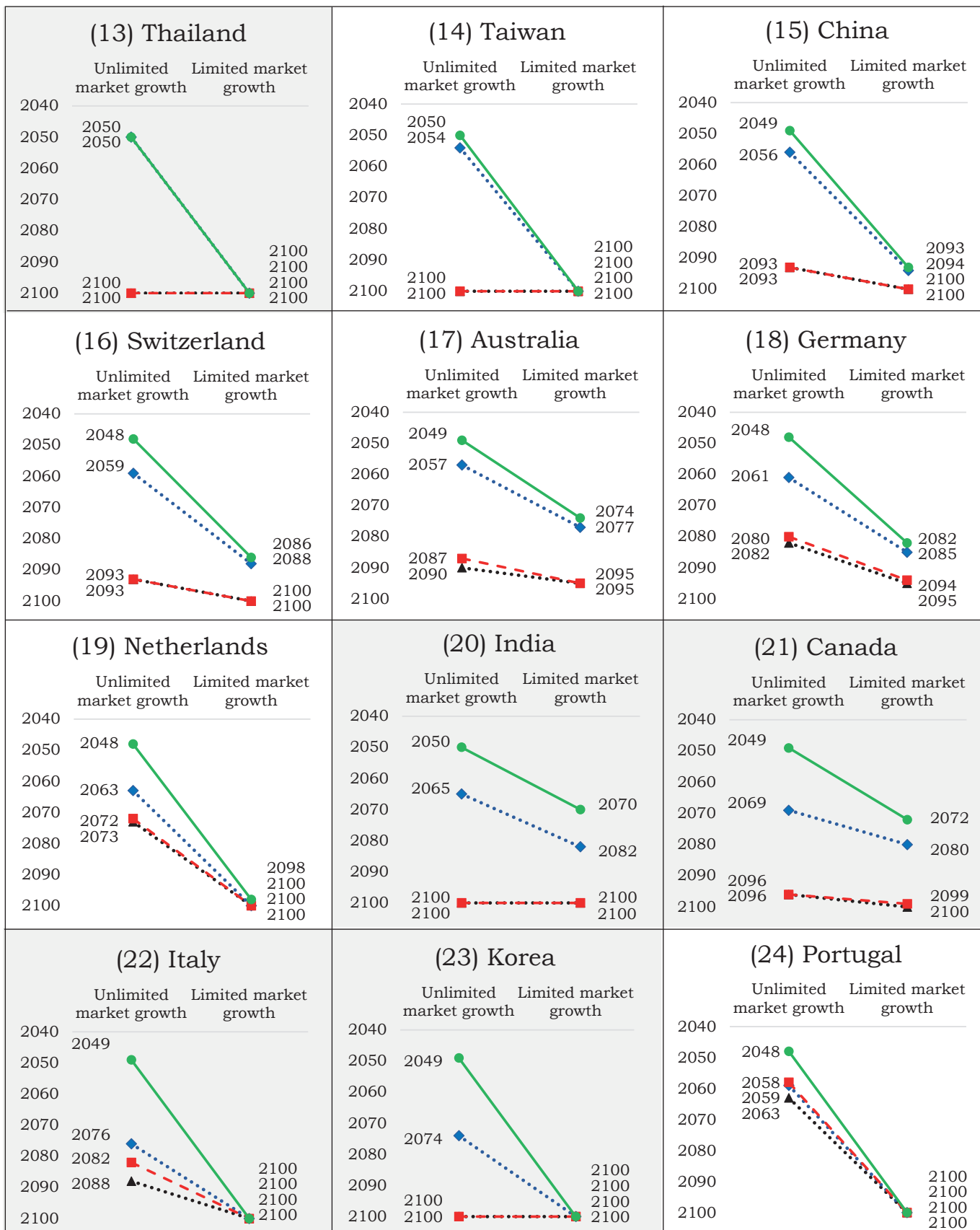
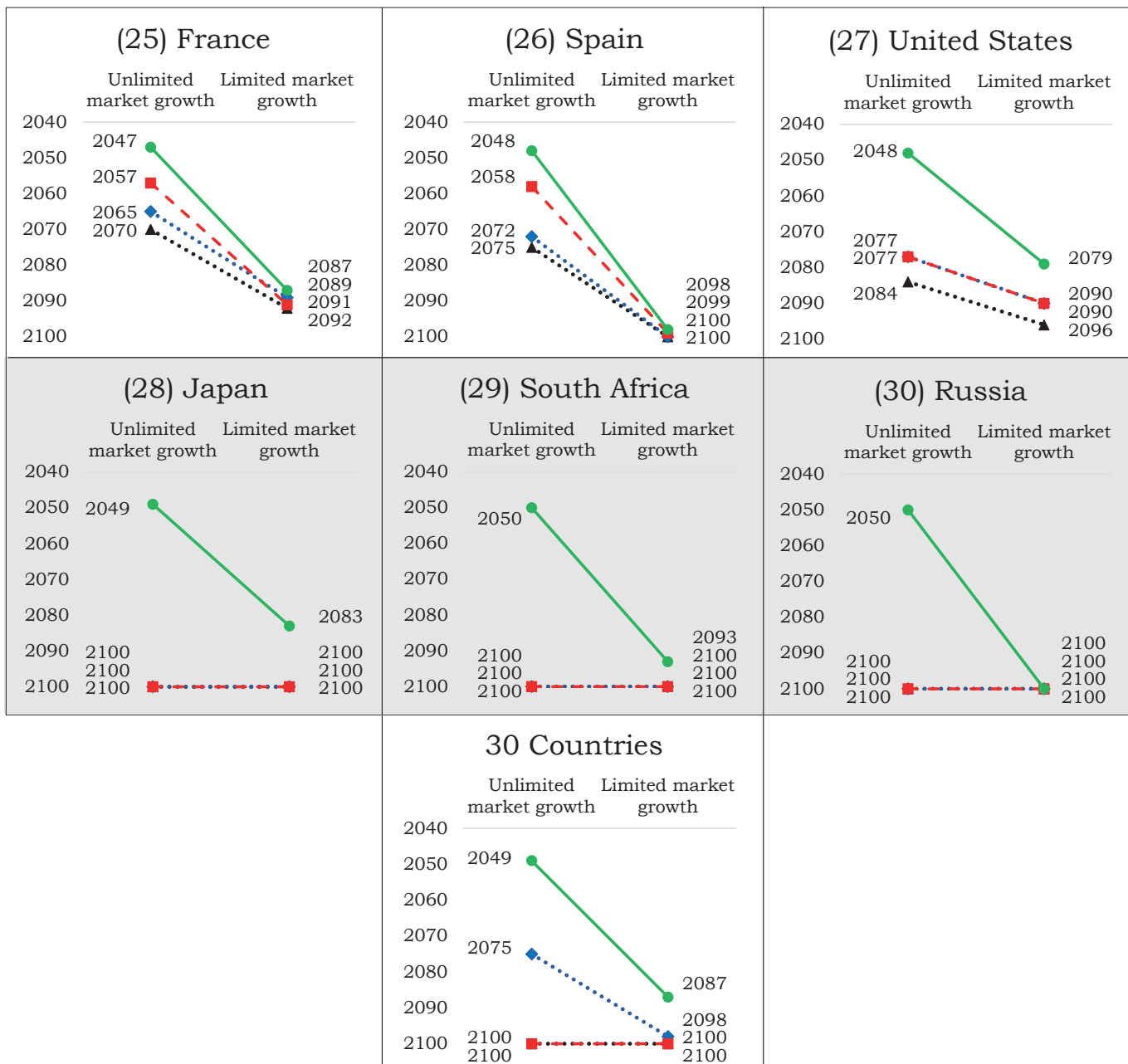


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## S2. Comparison of the logistic and Gompertz growth functions regarding their ability to predict vehicle sales

To compare the performance of logistic and Gompertz growth in predicting EV sales, the mean absolute percentage error method (MAPE) was used. This is a safe and intuitive method for evaluating the applicability of prediction procedures (de Myttenaere et al., 2016; Meade and Islam, 1995). At the end of 2023, there had been 14 years of EV sales. Thus, it is possible to catch up on individual predictions at the end of each year. In order to achieve meaningful results, predictions should not have started before the end of 2014, when five annual results were available.

The predictions from the end of 2014 to the end of 2023 made by a Gompertz growth function were compared with the actual sales figures, and the absolute percentage deviations are added up and then divided by the number of observations. The same was done with a logistic growth function. This results in the *MAPE* value shown in Equation (1).

$$MAPE = \frac{\sum_{k=Year-of-Forecast+1}^{2023} \left| \frac{Actual_k - Forecast_k | depending on Year-of-Forecast}{Actual_k} \right|}{Number of Comparisons} \cdot 100 \quad (1)$$

The calculations were made using China as an example because it is the country with the largest absolute sales figures. In Table S2.1, the actual stock end of 2023 is 22,982,000 EVs in China. The Gompertz function predicts, at the end of 2014, an inventory of 22,388,000 EVs in 2023, and the logistic function predicts 385,929,000,000. Thus, the absolute percentage regarding the Gompertz function results are shown in Equations (2) and (3).

$$Absolute-Gompertz_{2023}\% = \left| \frac{22,982 - 22,388}{22,982} \right| = 2.6\% \quad (2)$$

and

$$Absolute-Logistic_{2023}\% = \left| \frac{22,982 - 385,929}{22,982} \right| = 1,579.3\% \quad (3)$$

These absolute values are inserted into Table S2.2.

**Table S2.1:** Gompertz and logistic functions' forecasts for China's EV stock

|      | According to the <b>Gompertz Growth function</b> , forecast end of the year ... |        |        |        |        |        |        |        |        |  | China actual |
|------|---------------------------------------------------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--|--------------|
|      | 2014                                                                            | 2015   | 2016   | 2017   | 2018   | 2019   | 2020   | 2021   | 2022   |  | 2023 (thsd.) |
| 2010 |                                                                                 |        |        |        |        |        |        |        |        |  | 1            |
| 2011 |                                                                                 |        |        |        |        |        |        |        |        |  | 5            |
| 2012 |                                                                                 |        |        |        |        |        |        |        |        |  | 16           |
| 2013 |                                                                                 |        |        |        |        |        |        |        |        |  | 29           |
| 2014 |                                                                                 |        |        |        |        |        |        |        |        |  | 92           |
| 2015 | 225                                                                             |        |        |        |        |        |        |        |        |  | 281          |
| 2016 | 509                                                                             | 723    |        |        |        |        |        |        |        |  | 652          |
| 2017 | 1,058                                                                           | 1,659  | 1,420  |        |        |        |        |        |        |  | 1,299        |
| 2018 | 2,039                                                                           | 3,438  | 2,826  | 2,499  |        |        |        |        |        |  | 2,460        |
| 2019 | 3,673                                                                           | 6,513  | 5,202  | 4,466  | 4,374  |        |        |        |        |  | 3,668        |
| 2020 | 6,227                                                                           | 11,407 | 8,936  | 7,507  | 7,318  | 5,962  |        |        |        |  | 4,998        |
| 2021 | 9,999                                                                           | 18,647 | 14,440 | 11,948 | 11,605 | 9,064  | 7,579  |        |        |  | 8,398        |
| 2022 | 15,293                                                                          | 28,695 | 22,100 | 18,108 | 17,544 | 13,269 | 10,735 | 11,894 |        |  | 14,576       |
| 2023 | 22,388                                                                          | 41,878 | 32,234 | 26,269 | 25,408 | 18,768 | 14,793 | 16,688 | 20,669 |  | 22,982       |

|      | According to the <b>Logistic Growth function</b> , forecast end of the year ... |         |         |         |        |        |        |        |        |  | China actual |
|------|---------------------------------------------------------------------------------|---------|---------|---------|--------|--------|--------|--------|--------|--|--------------|
|      | 2014                                                                            | 2015    | 2016    | 2017    | 2018   | 2019   | 2020   | 2021   | 2022   |  | 2023 (thsd.) |
| 2010 |                                                                                 |         |         |         |        |        |        |        |        |  | 1            |
| 2011 |                                                                                 |         |         |         |        |        |        |        |        |  | 5            |
| 2012 |                                                                                 |         |         |         |        |        |        |        |        |  | 16           |
| 2013 |                                                                                 |         |         |         |        |        |        |        |        |  | 29           |
| 2014 |                                                                                 |         |         |         |        |        |        |        |        |  | 92           |
| 2015 | 257                                                                             |         |         |         |        |        |        |        |        |  | 281          |
| 2016 | 724                                                                             | 847     |         |         |        |        |        |        |        |  | 652          |
| 2017 | 2,035                                                                           | 2,552   | 1,634   |         |        |        |        |        |        |  | 1,299        |
| 2018 | 5,699                                                                           | 7,645   | 4,061   | 2,827   |        |        |        |        |        |  | 2,460        |
| 2019 | 15,788                                                                          | 22,532  | 10,032  | 6,070   | 4,936  |        |        |        |        |  | 3,668        |
| 2020 | 42,505                                                                          | 63,410  | 24,436  | 12,955  | 9,775  | 6,577  |        |        |        |  | 4,998        |
| 2021 | 106,479                                                                         | 158,778 | 57,574  | 27,303  | 19,211 | 11,359 | 8,251  |        |        |  | 8,398        |
| 2022 | 228,680                                                                         | 316,231 | 126,148 | 56,075  | 37,198 | 19,507 | 12,931 | 13,196 |        |  | 14,576       |
| 2023 | 385,929                                                                         | 470,790 | 241,402 | 109,573 | 70,068 | 33,183 | 20,178 | 20,705 | 23,371 |  | 22,982       |

**Table S2.2:** Mean absolute percentage errors (MAPE)

| <b>Gompertz Growth function</b> absolute errors in % |        |        |        |        |        |       |       |       |       | China actual        |
|------------------------------------------------------|--------|--------|--------|--------|--------|-------|-------|-------|-------|---------------------|
|                                                      | 2014   | 2015   | 2016   | 2017   | 2018   | 2019  | 2020  | 2021  | 2022  | 2023 (thsd.)        |
| 2010                                                 |        |        |        |        |        |       |       |       |       | 1                   |
| 2011                                                 |        |        |        |        |        |       |       |       |       | 5                   |
| 2012                                                 |        |        |        |        |        |       |       |       |       | 16                  |
| 2013                                                 |        |        |        |        |        |       |       |       |       | 29                  |
| 2014                                                 |        |        |        |        |        |       |       |       |       | 92                  |
| 2015                                                 | 19.8%  |        |        |        |        |       |       |       |       | 281                 |
| 2016                                                 | 21.9%  | 10.9%  |        |        |        |       |       |       |       | 652                 |
| 2017                                                 | 18.6%  | 27.7%  | 9.3%   |        |        |       |       |       |       | 1,299               |
| 2018                                                 | 17.1%  | 39.8%  | 14.9%  | 1.6%   |        |       |       |       |       | 2,460               |
| 2019                                                 | 0.1%   | 77.6%  | 41.8%  | 21.8%  | 19.3%  |       |       |       |       | 3,668               |
| 2020                                                 | 24.6%  | 128.2% | 78.8%  | 50.2%  | 46.4%  | 19.3% |       |       |       | 4,998               |
| 2021                                                 | 19.1%  | 122.0% | 71.9%  | 42.3%  | 38.2%  | 7.9%  | 9.8%  |       |       | 8,398               |
| 2022                                                 | 4.9%   | 96.9%  | 51.6%  | 24.2%  | 20.4%  | 9.0%  | 26.4% | 18.4% |       | 14,576              |
| 2023                                                 | 2.6%   | 82.2%  | 40.3%  | 14.3%  | 10.6%  | 18.3% | 35.6% | 27.4% | 10.1% | 22,982              |
| Sum                                                  | 128.7% | 585.3% | 308.6% | 154.4% | 134.7% | 54.5% | 71.7% | 45.8% | 10.1% | <b>MAPE = 33.2%</b> |

| <b>Logistic Growth function</b> absolute errors in % |         |         |         |         |        |        |       |       |      | China actual         |
|------------------------------------------------------|---------|---------|---------|---------|--------|--------|-------|-------|------|----------------------|
|                                                      | 2014    | 2015    | 2016    | 2017    | 2018   | 2019   | 2020  | 2021  | 2022 | 2023 (thsd.)         |
| 2010                                                 |         |         |         |         |        |        |       |       |      | 1                    |
| 2011                                                 |         |         |         |         |        |        |       |       |      | 5                    |
| 2012                                                 |         |         |         |         |        |        |       |       |      | 16                   |
| 2013                                                 |         |         |         |         |        |        |       |       |      | 29                   |
| 2014                                                 |         |         |         |         |        |        |       |       |      | 92                   |
| 2015                                                 | 8.5%    |         |         |         |        |        |       |       |      | 281                  |
| 2016                                                 | 11.1%   | 30.0%   |         |         |        |        |       |       |      | 652                  |
| 2017                                                 | 56.6%   | 96.4%   | 25.8%   |         |        |        |       |       |      | 1,299                |
| 2018                                                 | 131.7%  | 210.8%  | 65.1%   | 14.9%   |        |        |       |       |      | 2,460                |
| 2019                                                 | 330.5%  | 514.3%  | 173.5%  | 65.5%   | 34.6%  |        |       |       |      | 3,668                |
| 2020                                                 | 750.4%  | 1168.6% | 388.9%  | 159.2%  | 95.6%  | 31.6%  |       |       |      | 4,998                |
| 2021                                                 | 1167.8% | 1790.6% | 585.5%  | 225.1%  | 128.7% | 35.3%  | 1.8%  |       |      | 8,398                |
| 2022                                                 | 1468.8% | 2069.5% | 765.4%  | 284.7%  | 155.2% | 33.8%  | 11.3% | 9.5%  |      | 14,576               |
| 2023                                                 | 1579.3% | 1948.5% | 950.4%  | 376.8%  | 204.9% | 44.4%  | 12.2% | 9.9%  | 1.7% | 22,982               |
| Sum                                                  | 5504.7% | 7828.6% | 2954.6% | 1126.2% | 619.0% | 145.1% | 25.2% | 19.4% | 1.7% | <b>MAPE = 405.0%</b> |

Although the predictions in the short term are more accurate using logistic growth, in the medium and long term with the logistic method, the forecast error becomes so large that the Gompertz growth function is superior.

**References**

- de Myttenaere, A., Golden, B., Le Grand, B. & Rossi, F., 2016. Mean absolute percentage error for regression models. *Neurocomputing* 192, 38–48.
- Meade, N. & Islam, T., 1995. Forecasting with growth curves: An empirical comparison. *Int. J. Forecast.* 11, 199–215.