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# Has the popularity of battery electric vehicles in Norway affected total new car sales? A synthetic control method study

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## ABSTRACT

Battery electric vehicles (BEVs) have gained popularity in Norway, chiefly due to generous tax incentives. Using the synthetic control method, we study if BEVs' popularity has complemented or substituted for conventional new car sales. Comparing Norway with weighed control units from a donor pool of 16 other European countries between 1990 and 2018 as a counterfactual, we find that conventional new car sales since 2011 have fallen steeply in the country. Analyses also indicate that total new car sales have decreased since 2011. We conclude that BEVs substitute for conventional cars and probably even subtract total new car sales. An implication is that tax revenue loss from BEVs is probably higher than previously estimated, and the fleet of cars in Norway is probably older than in the absence of BEVs' generous tax incentives.

## KEYWORDS

Synthetic control method; battery electric vehicles; Norway; substitution effect; subtraction effect

## JEL CLASSIFICATION

B41; C50

## I. Introduction



Battery electric vehicles (BEVs) have gained popularity in Norway, chiefly due to generous tax incentives. Figure 1 illustrates the trend, and we observe that per capita new car sales of BEVs have taken off since 2011 as compared to conventional new car sales (the difference between the blue and orange line).<sup>1</sup> But have BEVs complemented or substituted for conventional car sales in Norway? By using the synthetic control method, we study this research question. It estimates the magnitude of a unit exposed to an intervention by constructing weighted control units, unexposed to intervention, as a counterfactual (Abadie, Diamond, and Hainmueller 2010). The method has been used in numerous studies (e.g. Abadie, Diamond, and Hainmueller 2015; Billmeier and Nannicini 2013), and we apply it to compare Norway – where BEVs have been exposed to generous tax incentives – with weighed control units from a donor pool of 16 other European countries between 1990 and 2018.<sup>2</sup> Granted, BEVs in other European countries than Norway have been exposed to tax incentives, but to

a lesser extent and their relative sales are low (5.39% in the Netherlands in 2018, 2.19% in Denmark in 2015, 2.01% in Sweden in 2018, and all other estimates outside of Norway between 1990 and 2018 are below 2%).<sup>3</sup>

Besides being of academic interest, our study also has an economic interest because due to generous tax incentives concerning BEVs in Norway, and high taxation of conventional cars, BEVs' popularity represents tax revenue loss, but we have no reasonable estimates of the amount. BEVs can be any vehicle that uses all power from batteries, but they are electric cars in our study. Conventional cars include internal combustion vehicles and hybrid vehicles (hydrogen cars are practically absent in Norway).

## II. Methods

Per capita conventional new car sales in Norway in year  $t$  are  $C_{1t} = \alpha_{1t}B_{1t} + C_{1t}^N$ .  $\alpha_{1t}B_{1t}$  is the effect that the new car sales of BEVs have had on conventional new car sales in Norway in year  $t$ , and  $C_{1t}^N$

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<sup>1</sup>To estimate per capita new car sales of BEVs, we divide new car sales of BEVs (source: the European Alternative Fuels Observation) by the midyear estimate of total population (source: the World Bank). To estimate per capita conventional new car sales, we first take a difference between total new passenger car sales (source: the European Automobile Manufacturers Association) and new car sales of BEVs. Next, we divide the difference by the midyear estimate of the total population.

<sup>2</sup>The 16 European countries are EU member states from before the extension to Eastern Europe (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the UK), plus Switzerland.

<sup>3</sup>For all countries, we estimate (per capita) new car sales of BEVs and conventional new car sales as we do for Norway (see Footnote 1).

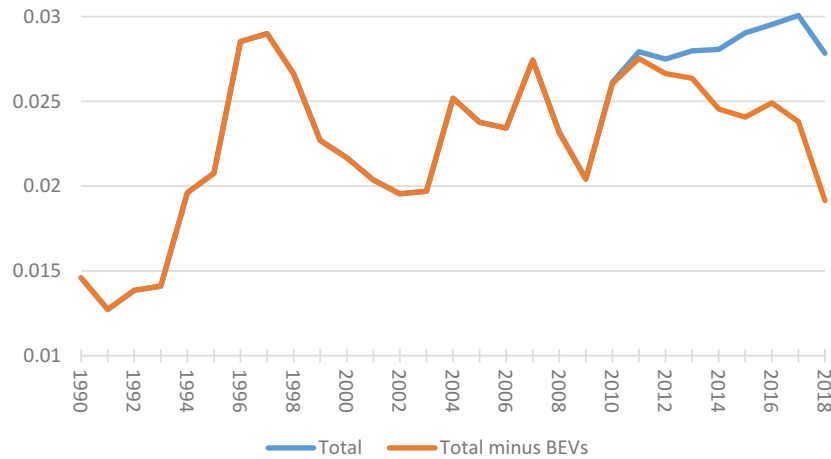


Figure 1. Total and total minus BEVs per capita new car sales in Norway.

is per capita conventional new car sales in year  $t$  in Norway in the absence of new car sales of BEVs. That is,  $C_{1t}^N$  is the counterfactual of per capita conventional new car sales in Norway if new car sales of BEVs were absent.

As the new car sales of BEVs took off in Norway in 2011 and were practically negligible before that, eventually finding that  $C_{1t} \approx C_{1t}^N$  when  $t = 2011-2018$ , shows that BEVs have complemented conventional new car sales (i.e.  $\alpha_{1t}B_{1t} \approx 0$  as the effect that BEVs have had on conventional new car sales in Norway in year  $t$  is practically absent). Eventually finding that  $C_{1t} < C_{1t}^N$  when  $t = 2011-2018$  shows that BEVs have substituted for conventional new car sales in Norway (i.e.  $\alpha_{1t}B_{1t} < 0$  as the effect that BEVs have had on conventional new car sales in Norway in year  $t$  is negative).

$\hat{C}_{1t}^N = \sum_{j \neq 1} w_j Y_{jt}$  where  $w_2, w_3, \dots, w_{17}$  represent optimal country weights from our donor pool of 16 other European countries (than Norway), and  $Y_{jt}$  is

a function of weighted country variables (outside of Norway), which we explain shortly. The best estimate of  $\hat{C}_{1t}^N$  is when it is as similar as possible with  $C_{1t}$  when  $t = 1990-2010$ , i.e. when the sales of BEVs in Norway were practically negligible (cf. Abadie, Diamond, and Hainmueller 2010).

To estimate  $\hat{C}_{1t}^N$ , we use average country variables reported in the left column of Table 1 ( $t = 1990-2010$ , except for the latter variable, which we explain in the following).<sup>4</sup> It is common, according to Kaul et al. (2015), to use ‘the entire pre-treatment path of the outcome variable as predictors’ (p. 1), which in our study would imply including per capita conventional new car sales each year between 1990 and 2010 as a country variable to estimate  $\hat{C}_{1t}^N$ . However, Kaul et al. warn against it, and following their recommendation, we include per capita conventional new car sales in 2010, i.e. the last year before the new car sales of BEVs took off in Norway, as an additional country variable.

Table 1. Actual and synthetic predictor means and weights concerning per capita conventional new car sales (total cars minus BEVs).

Variable	Weight (sum = 1)	Actual Norway	Synthetic Norway
Average change in national currency (%) vs. the USD, 1990-2010	.039	.997	.992
Average GDP per capita, PPP (constant 2011 int. \$), 1990-2010	.049	55,971	40,398
Average GDP per capita growth (%), 1990-2010	.001	1.90	1.35
Average unemployment (%), 1990-2010	.031	4.24	6.02
Average change in unemployment (percentage point), 1990-2010	.200	-.099	-.081
Average short-term interest rate, 1990-2010	.076	5.81	5.17
Per capita conventional new car sales, 2010	.603	.026	.027

RMSPE is .0031242, and donor countries are Denmark (unit weight is .985) and Greece (unit weight is .015).

<sup>4</sup>We estimate the average change in the national currency (%) vs. the USD as a ratio of the national currency to the USD in a given year divided by the ratio of the national currency to the USD in the preceding year. OECD is a source of the variable. Also, OECD is a source of the variables average GDP per capita, average GDP per capita growth, and average short-term interest rates. The ILO estimate by the World Bank is a source of the variables average unemployment and the average change in unemployment.

### III. Results

Figure 2 presents estimates by using `synth` and `synth_runner` (Abadie, Diamond, and Hainmueller 2014; Galiani and Quistorff 2017) in Stata 15 (2017). The first graph in the left column shows per capita conventional new car sales (total minus BEVs) in the 17 countries and reports Norway in bold. Per capita sales in Norway are relatively low, probably due to the high taxation of conventional cars. Hence, the fleet of cars in Norway is relatively old.

The second graph shows  $C_{1t}$  (the blue line labelled ‘Treated’) and  $\hat{C}_{1t}^N$  (the red line and labelled ‘Synthetic Control’).<sup>5</sup> Between 1990–2010  $C_{1t} \approx \hat{C}_{1t}^N$ , but  $C_{1t} < \hat{C}_{1t}^N$  from 2011. It shows that conventional new car sales since 2011 are lower than in the absence of sales of BEVs. Thus, since 2011, BEVs have substituted for new car sales in Norway. The third graph shows so-called placebo tests of relative deviations by carrying out similar estimates on each of the 17 countries, and we observe that Norway, in

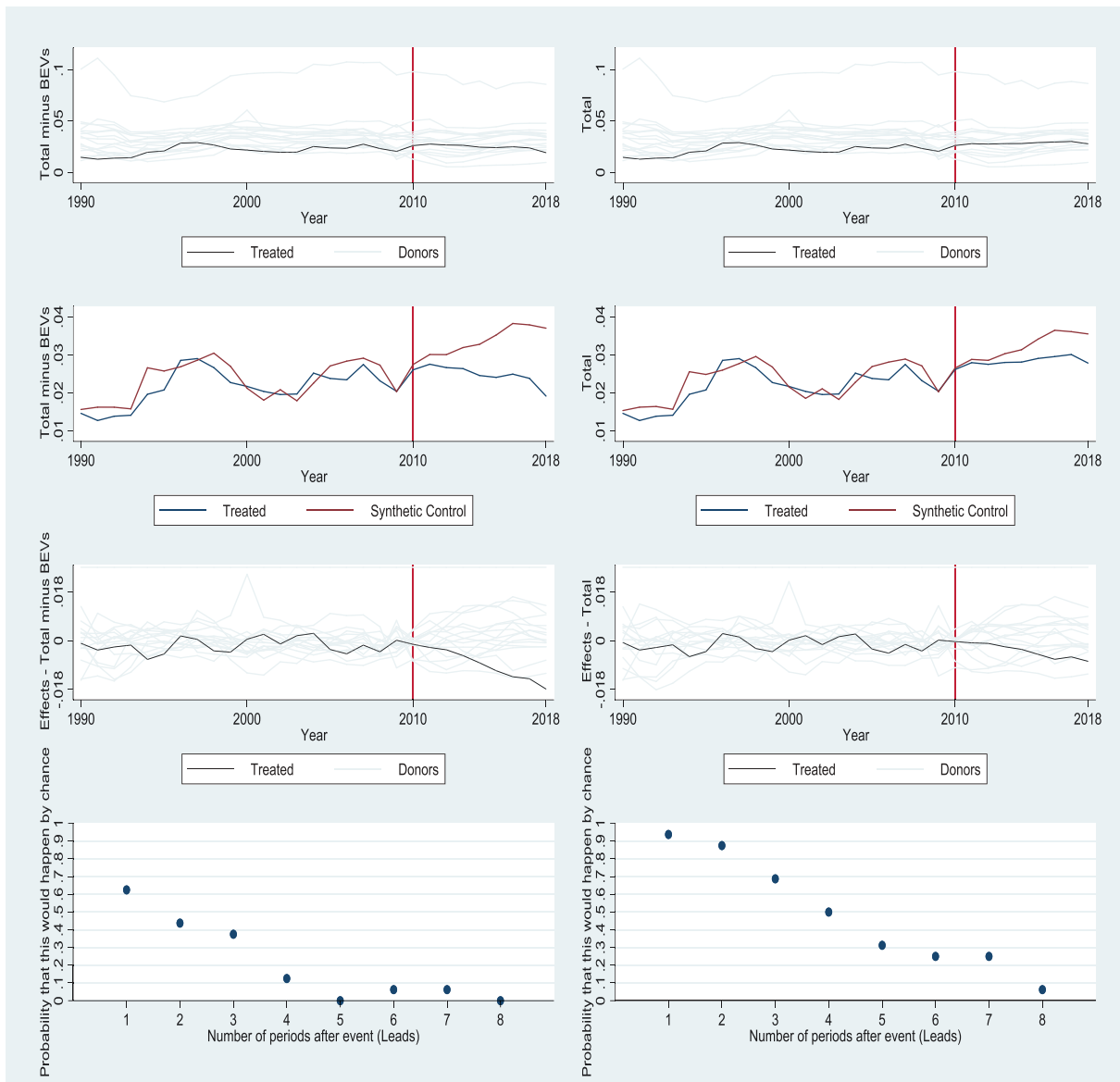


Figure 2. Synth and synth\_runner estimates.

<sup>5</sup>We use the nested option to optimize the model fit of  $\hat{C}_{1t}^N$  (Abadie, Diamond, and Hainmueller 2014), and Table 1 reports the weight of each country variable, the minimized root mean squared prediction error (RMSPE), and the unit weights of included donor countries (Denmark and Greece). Table 1 also shows variable estimates of Actual and Synthetic Norway, which deviate somewhat, but they are almost identical concerning the variable with the highest weight (per capita new car sales, 2010).

**Table 2.** Actual and synthetic predictor means and weights concerning per capita total new car sales (conventional cars plus BEVs).

Variable	Weight (sum = 1)	Actual Norway	Synthetic Norway
Average change in national currency (%) vs. the USD, 1990-2010	.035	.997	.994
Average GDP per capita, PPP (constant 2011 int. \$), 1990-2010	.018	55,971	39,447
Average GDP per capita growth (%), 1990-2010	.001	1.90	1.37
Average unemployment (%), 1990-2010	.018	4.24	6.25
Average change in unemployment (percentage point), 1990-2010	.031	-.099	-.059
Average short-term interest rate, 1990-2010	.027	5.81	5.25
Per capita conventional new car sales, 2010	.869	.026	.027

RMSPE is .002839, and donor countries are Denmark (unit weight is .922) and Greece (unit weight is .078).

bold, since 2011, has a relatively strong decrease in per capita conventional new car sales. Standard significance testing is not plausible when using the synthetic control method, but we instead report in the fourth graph standardized p-values, elaborated by Abadie, Diamond, and Hainmueller (2010). The graph shows that the p-value decreases and reaches roughly zero after five periods (in 2015).

So far, we have studied per capita sales of *conventional* cars (total cars minus BEVs), but in the right column of Figure 2 and in Table 2, we report similar estimates of per capita *total* car sales. We observe in the right column of Figure 2 that not only per capita conventional car sales have dropped in Norway, but also *total* car sales. Granted, the effect is less marked and robust as compared to conventional car sales, but according to the fourth graph, it approaches significance after eight periods (in 2018).

#### IV. Conclusion

Since 2011, BEVs substitute for and probably even subtract conventional new car sales in Norway. A possible reason for the subtraction is that in a period of transition, customers become uncertain concerning whether to choose conventional or new technology (Rosenkoph and Tushman 1994). For 2018, the tax revenue loss due to BEVs is reported to be 13.6 billion NOK.<sup>6</sup> However, since total new car sales probably would have been higher in the

absence of BEVs, the tax revenue loss is also probably much higher. A further implication is that the fleet of cars in Norway is probably older than in the absence of BEVs' generous tax incentives.

#### Disclosure statement

No potential conflict of interest was reported by the authors.

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