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A CASE STUDY ON GERMANY'S AVIATION TAX USING THE SYNTHETIC CONTROL APPROACH

BY

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NO 18-16

DEPARTMENT OF ECONOMICS
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A CASE STUDY ON GERMANY'S AVIATION TAX USING THE SYNTHETIC CONTROL APPROACH

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HIGHLIGHTS

- We investigate the effects of Germany's AT on passenger numbers
- Counterfactual predictions of passenger numbers in the absence of AT are estimated using the synthetic control method
- Results indicate that AT has been associated with significantly decreased passenger numbers at most German airports, with exception of large hubs, and growth in passenger numbers at airports in bordering countries

Abstract:

The German Aviation Tax (AT) is a tax levied on departing passengers from German airports. The synthetic control method is used to generate counterfactual passenger numbers for German airports, and for airports outside Germany but near the German border. The results presented are consistent with cross-border substitution of passenger demand in response to AT. Most AT exempt airports near the borders have made sizable, significant, gains in passenger numbers since Germany introduced AT. Within Germany there appears to be a clear distinction in the impact on small/regional airports and that on larger hubs.

JEL Classification:

H26, H30, L93

Keywords: aviation taxes, passenger demand, synthetic control

1. Introduction

Aviation tax (AT) regimes in Europe receive considerable attention. Germany's AT was introduced on 1st January 2011 and remains payable on departures from all German airports at a cost of €7.47, €23.32, or €41.99 depending on the distance flown[1]. While often motivated as environmental taxes, common perception is that revenue raising is the key driver of ATs. Airports and airlines often spearhead campaigns for their abolition, citing adverse effects on demand, competitiveness and connectivity[2]. Germany's Economy Minister is reportedly swaying toward abolition for these reasons[3].

In this paper, we investigate the impact Germany's AT has had on passenger numbers using German airports and airports outside Germany but near the border (henceforth referred to as bordering airports). Specifically, we use the synthetic control method of Abadie et al. (2010) to construct counterfactual series for each airport of interest, representing passenger numbers under the alternative scenario that AT was never introduced. The impact of AT is then estimated as the gap between actual passenger numbers since 2011 and the synthetic numbers.

We estimate changes in passenger numbers that can be attributed to AT for German airports and for bordering airports outside of Germany. Airports are modelled separately to see whether the effects of the AT might differ across airport types. Results indicate more passengers used bordering airports after the introduction of German AT, while most German airports, with the exception of hubs, saw a negative impact of AT on passenger numbers.

Our main contribution is to the relatively scarce literature on the impact of aviation taxes on passenger numbers. A few case studies (Gordijn and Kolkman 2011, and Steverink and van Daalen 2011) assess the effects of the Dutch aviation tax, introduced in 2008[4]. Using the average passenger growth rate as comparison, Gordijn and Kolkman (2011) estimate that the introduction of the aviation tax can be associated with a 6.9% reduction in passenger numbers at Amsterdam Airport. Using a linear extrapolation of passenger numbers at different airports, they also estimate that approximately one million Dutch passengers started using bordering airports as a consequence of the tax. Their analysis is complicated by two main

[1] Listed in Annex 1 and 2 of the German Aviation Tax Act (2011).
[2] See Edinburgh Airport (2015).
[3] See DW "*German Air Passenger Tax Under Increased Fire*" August 2017.
[4] The Dutch AT was abolished a year later.

factors: the 2008/09 economic crisis coinciding with the taxation period and the short amount of time during which the tax was in place. Furthermore, it is unclear how reliable their counterfactual passenger number estimations are: linear extrapolations might not be accurate in the presence of shocks (or non-linear passenger trends) while using European passenger growth rates as counterfactuals might not capture region-specific differences in passenger trends.

Our empirical approach, which uses the synthetic control method to estimate counterfactual passenger numbers, can provide robust estimates of counterfactuals for a number of reasons. First, this method optimises the selection of comparison (control) airports so that counterfactual passenger numbers are based on the control airports most similar to treated airports in terms of passenger trends. Second, in the optimisation process, it uses covariates that control for regional and macroeconomic shocks to passenger numbers. To our knowledge, this paper is the first case study on aviation taxes that employs the synthetic control method. This approach is particularly suitable for our analysis as it allows us to construct reliable counterfactuals using aggregate level data[5].

Through our findings we also contribute to the literature on the determinants of air passenger demand and airport choice (see for example Graham 2000, Brons et al. 2002, Jankiewicz and Huderek-Glapska 2016, or Valdes 2015). Only a few studies (Pels et al. 2003, Steverink and van Daalen 2011) consider the impact aviation taxes have on the airport choices of passengers. These studies are however mostly theoretical in their approach. Our paper therefore contributes to the literature by providing empirical evidence that passengers[6] are highly responsive to the introduction of aviation taxes, and by finding some evidence (albeit only at the aggregate level[7]) that passengers change airport preferences in response to these taxes.

Furthermore, our analysis contributes to the literature on cross-border shopping (Joossens and Raw 1995, Nielsen 2001, Asplund et al. 2007). This strand of the tax policy literature focusses on the way tax differences across borders affect the preferences and choices of consumers. Our results contribute to the literature by finding evidence for a specific case of

[5] Indeed, according to Abadie et al. (2015) the most relevant application of the synthetic control method is for comparative case studies that use aggregate data. A diff-in-diff estimation, where control group selection is largely arbitrary, would be likely biased by the large structural differences between treated and control airports (these are in different countries and might be affected by different market forces).
[6] In the specific German case.
[7] Detailed micro-data on individual tax liabilities and flight ticket prices would be necessary to assess micro-level impacts of changing air taxes on airport choices. Data of this kind was not accessible for our study.

cross-border shopping: our results show that aviation tax differences across borders can have a noticeable impact on air passenger movements between the bordering countries. More specifically, we find that the introduction of the AT in Germany can be associated with a substantial increase in passengers at tax-free airports near the German border.

The remainder of the paper is organised as follows. Section 2 summarises the relevant policy background. Section 3 describes the data and outlines the empirical approach. Section 4 shows the results. Section 5 assesses the plausibility of our findings. Section 6 provides a discussion of our findings. Section 7 concludes.

2. Background

The German aviation tax (AT) was introduced on 1st January, 2011. The AT is charged after passengers departing from German airports. There are three different unit taxes charged based on distance flown: €7.47, €23.32, or €41.99[8] is charged for short, medium, and long-distance flights, respectively. According to forecasts by Berster et al. (2010), the number of passengers expected to belong to each tax category was (at the time of introduction) 62.3, 2.9, and 8.9 million, respectively.

This indicates that[9] roughly 84% of passengers can be expected to pay a unit tax of €7.47, 4% of passenger can be expected to pay €23.32, and 12% of passenger can be expected to pay €41.99. Consequently, passengers on short and long-distance flights will contribute to the vast majority of tax revenues from AT. The average passenger departing from a German airport faced a tax increase of €12.25[10].

Upon the introduction of the tax, some experts warned (see Steppler 2011) that the German AT was likely to have the same adverse effect on passenger numbers than the Dutch version of the tax introduced a few years earlier. The AT remains controversial to this day with frequent calls for its abolition by industry participants and policy makers[11].

[8] See Annex 1 and 2 of the German Aviation Tax Act 2010.
[9] Unfortunately no data is available to estimate these numbers for all of our sample years. The estimation above is based on 2008 data.
[10] This is the weighted average of the unit taxes considering the shares of passengers traveling under each distance band. We do not have data on prices and therefore do not know whether this tax change was passed on to passengers (and to what extent).
[11] See for example DW, *German Air Passenger Tax Under Increased Fire*, August, 2017.

3. Data and Identification Strategy

We assess the impact of the German AT on passenger numbers by estimating counterfactual series of passenger numbers for each treated airport – the counterfactual numbers correspond to a scenario where no aviation tax was introduced. The choice of 'treated' airports, for which we believe AT may have had an impact, are German international airports and bordering airports (located outside Germany but within two hours driving time[12]). The latter group allow us to investigate potential spill-over effects from AT. To assess why AT might have had a different impact at some airports in comparison to others, we estimate separate models for each airport. For treated airports, we compare actual (observed) passenger numbers to counterfactual ones after the introduction of AT to assess the impact of the tax.

To estimate counterfactual passenger numbers, we use the synthetic control method (Abadie et al. 2010). The synthetic control method constructs counterfactuals (also referred to as synthetic controls) using a weighted average of passenger numbers at 'control' airports. Control airports are airports where no changes in aviation taxes took place during our sample period[13]. The controls are chosen for their ability to predict passenger numbers at 'treated' airports in the pre-tax period. Furthermore, covariates are included in the estimation to control for variation arising from other factors that affect passenger numbers (regional and macroeconomic variables).

In summary, the counterfactual estimation is optimised based on: 1) the extent to which passenger trends in the pre-AT period are similar between treated and control airports and 2) the extent the process through which changes in covariates feed into changes in passenger numbers is similar for treated and control airports. For example, there is some process through which changes in purchasing power are reflected in changes in passenger numbers (in the pre-AT period) for a treated airport. For the counterfactual, our approach will use the control airports that are the best at reproducing this process during the pre-tax period. Our counterfactual will therefore incorporate, through the covariates, shocks[14] that affect passenger numbers.

[12] According to Google Maps.
[13] Information on aviation tax regimes is from EBAA, *A Snapshot of European Aviation Taxes*, September 2015.
[14] Shocks to passenger numbers that are not captured by the covariates could however bias our estimations, especially if they coincide with the AT period (see below).

The covariates included are: purchasing power per capita in euros at the NUTS2 regional level[15], to control for the impact of macroeconomic shocks; and lagged passenger numbers, to capture airport specific trends, where the chosen lags are selected based on the best fit between counterfactual and actual passenger numbers in the pre-tax period. Annual data on passenger numbers using each airport over the period 2003-2015 are from Eurostat[16].

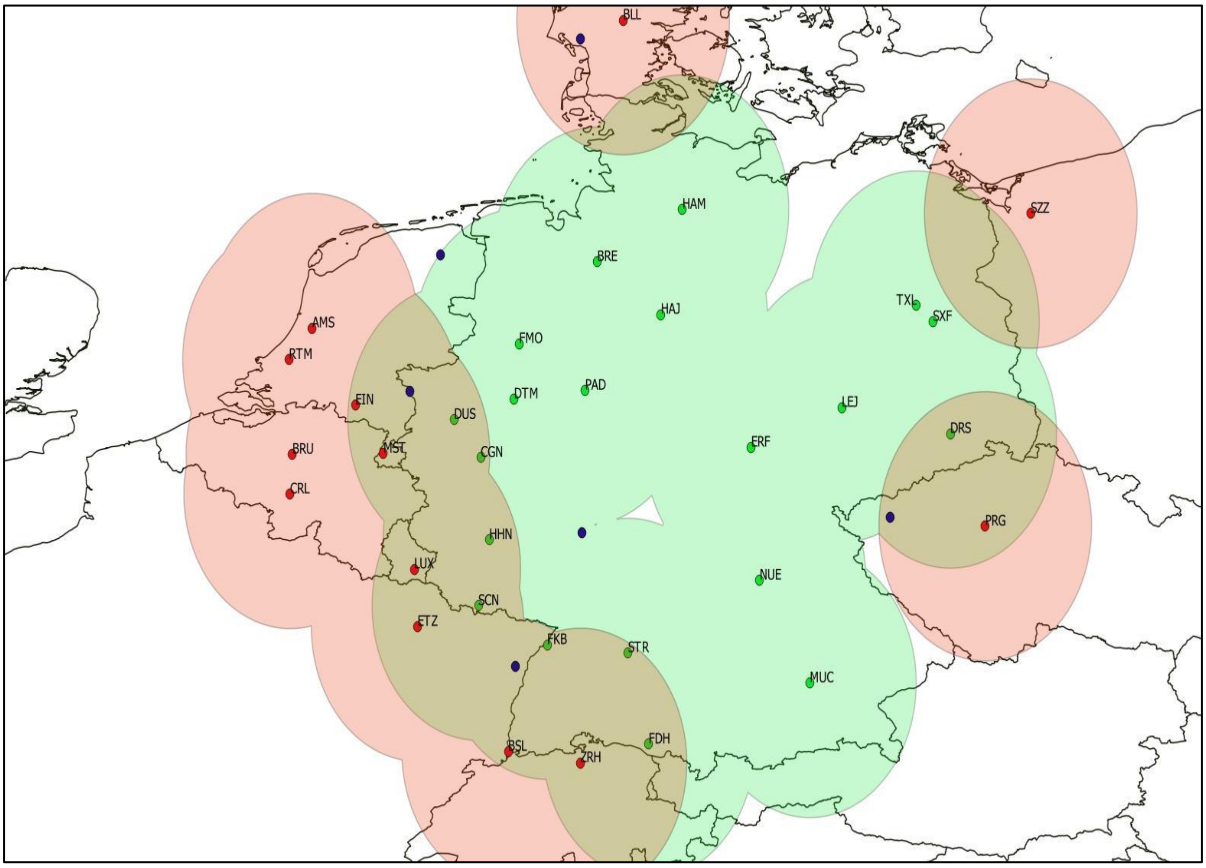
To avoid biased estimates, we need to make restrictions to our data. Austrian airports are excluded, since Austria also introduced an AT in 2011. The Netherlands introduced an AT in July 2008 but abolished it a year later. Rather than exclude all Dutch airports we first estimated series for their passenger numbers under the counterfactual assumption that they never introduced AT, then used these data in place of actual numbers going forward, with the aim of then isolating the impact of German AT on each Dutch airport[17]. As a check on the plausibility of these results the Appendix includes models for Dutch airports without the Dutch AT adjustment.

Furthermore, while we do control for macroeconomic/regional shocks and airport specific time trends through our covariates, a limitation of our approach is that we cannot control for idiosyncratic shocks affecting passenger numbers at treated airports. If these coincide with our treatment period, we could wrongly contribute their impact to the introduction of AT. For this reason, we exclude airports that we know to have undergone major capacity expansions or reductions in years corresponding to the AT period. For example, Frankfurt Airport is excluded due the expansion of their terminals in 2012, which increased the annual capacity of their terminal by 6 million passengers[18].

Treated airports are shown in Figure 1 along with an indication of catchment area, represented by a circle with a radius of 150km. Blue dots represent airports excluded due to data/model limitations or other post-intervention shocks to passenger numbers.

[15] Eurostat data.
[16] These data concern both departing, arriving and transfer passengers, which is a limitation since that the tax is charged on departing passengers.
[17] This procedure relies on the assumption that the temporary Dutch AT had no long-run effects.
[18] See Frankfurt Airport Press Release "*Frankfurt Airport Opens Pier A-Plus as Scheduled"* October 2012.

Figure 1. Map of Airports and Catchment Areas



Note: German airports and catchment areas are shown in green; bordering airports/catchment areas in red; and blue points with no label indicate airports excluded from estimation.

Criteria used in selecting control airports include: located in a country with no change in AT[19] over the period; but otherwise similar characteristics to the treated airports (Abadie et al. 2010). Chosen controls therefore vary across the treated airports (full details are provided in the Appendix, along with the selected weighted averages used in order to create the synthetic passenger number series). Following Billmeier and Nannicini (2013), two sets of estimates were constructed in each case: set A use control airports from countries surrounding Germany under the assumption that treated and control units are likely to face similar macroeconomic and regional shocks; while set B use a larger number of control airports from across the EEA. The preferred results are those from whichever set of estimates provides the best fit for the pre-tax period (as in Ormaechea et al. 2017).

[19] A list of ATs is provided by European Business Aviation Association.

4. Results

Full results of the synthetic control estimates are provided in the Appendix. Here we show results for two airports by way of examples. Figures 2 and 3 plot actual and counterfactual (synthetic) passenger numbers for Amsterdam and Nuremberg respectively. The impact associated with the introduction of AT corresponds to the vertical difference (gap) between the actual and counterfactual time trends after 2010. The imposition of AT in 2011 is associated with increased passenger numbers relative to the counterfactual in the case of Amsterdam, and decreased numbers in the case of Nuremberg.

Figure 2: Examples of Synthetic Control Estimates

Amsterdam *Nuremberg*

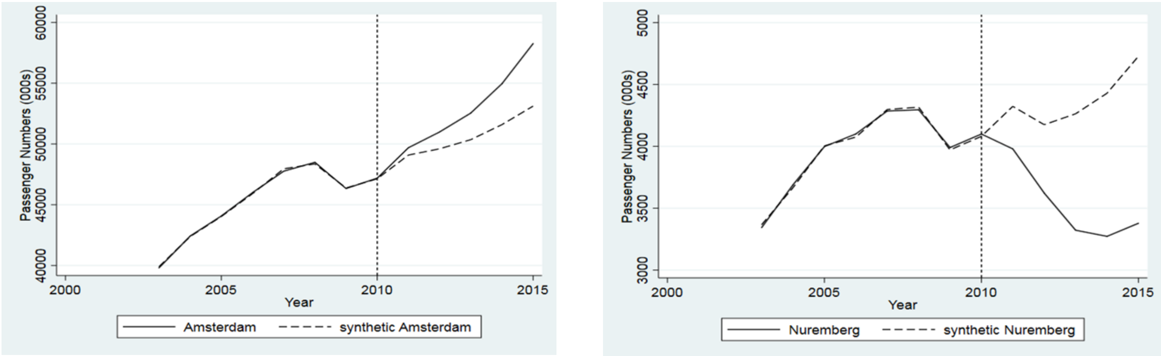
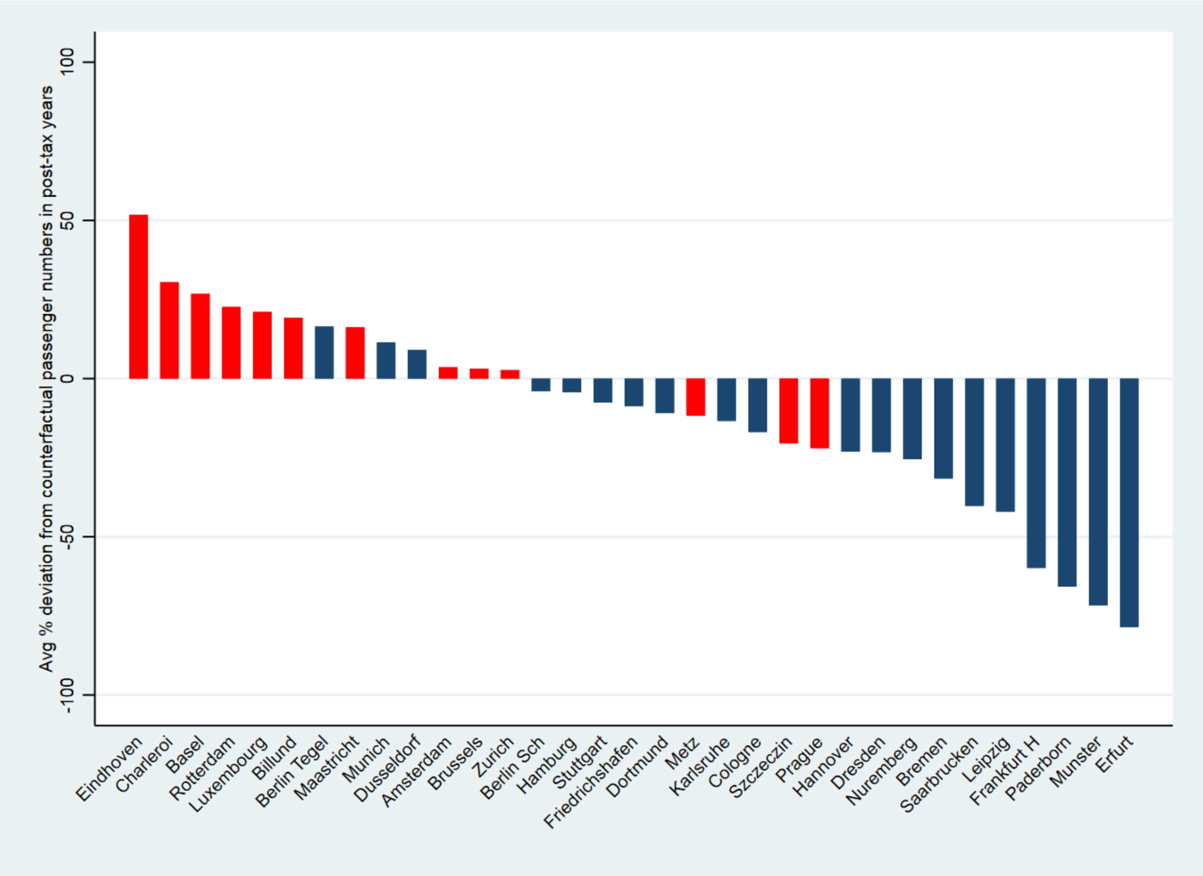


Figure 3 summarises the full set of results for the treated airports, by plotting the post-tax percentage deviations of actual passenger numbers as compared to the counterfactual. The plotted figure is the average over the post-tax sample, 2011-2015, in each case.

Figure 3. Post-Tax Deviations from Counterfactual Passenger Numbers (Treated Airports)



Bordering airports are marked red.

Most German airports appear on the right of the figure, indicating estimated passenger losses since AT's introduction. Most bordering airports, shown in red, made gains. A small number of German airports, notably Berlin Tegel, Dusseldorf and Munich saw gains in passenger numbers relative to the no tax counterfactual.

Aggregating the results shown in Figure 3 for German airports provides us with an estimate of 7.3 million passengers lost compared to the counterfactual scenario under the assumption of no AT. This is less than 1% of total passenger numbers at these airports during the post-tax period so indicates rather a small effect on aggregate passenger demand.

5. On the Plausibility of the Findings

To check the plausibility of our findings we: provide information on pre-tax fit of models; explore the sensitivity of results to the choice of control airports; and provide information on the significance of our estimates based on placebo tests.

The fit of synthetic control models in the pre-tax period is measured using Root Mean Squared Prediction Errors (RMSPE) - constructed from the squared difference between actual and counterfactual passenger numbers for each pre-tax year, averaged across the available pre-tax years. The normalised RMSPE adjusts for airport size so is expressed as a % of that airport's passenger numbers in 2010; a figure in excess of 5% is indicative of poor fit and signals that estimates of the impact of AT must then be treated with caution.

The check on the sensitivity of results considers whether estimated impacts of AT are affected by the inclusion/exclusion of particular airports in the set of controls. Similar estimated impacts are indicative of robustness.

Inference on significance of estimated effects comes from placebo tests, following Abadie et al. (2010). First the AT treatment is assigned to each control airport and impacts estimated. Since no AT was actually introduced for these airports we expect any estimated impacts to be small and random. Essentially, we have confidence in our results for treated airports if their estimated post-tax gaps are large relative to those generated in the placebo tests.

We use RMSPE ratios to construct p-values. RMSPE ratios are measured as the post-tax gap (between actual and counterfactual passenger numbers) divided by the pre-tax gap. These ratios indicate the extent to which post-tax gaps are large in comparison to the pre-tax fit of our counterfactuals. Each p-value then indicates the likelihood that a randomly selected RMSPE ratio from the sample of placebo tests is larger than that of the given treated airport. It is simply the number of RMSPE ratios from the placebo group that exceed the ratio for the treated airport, and divided by the number of control airports in the group. For example, if the treated airport's RMSPE ratio is larger than the ratio for all of its control airports (say there are 50 of them), the p-value is going to be equal to 0/50 = 0.

Significance can be interpreted as indicating AT was associated with a greater than random effect on passenger numbers for specific airports. Lack of significance also has a clear implication: that passenger numbers at the given treated airport were not significantly affected by AT. Recall though that these inferences must be predicated on well-fitting models that are reasonably robust to the choice of controls. Table 1 summarises our findings. Most of our airport estimates are based on well-fitting synthetic control models and are robust.

In Table 1, airport results marked bold are based on ill-fitting synthetic control models (or estimates that lack robustness). The small number of airports falling under this category tend to be regional airports, with low annual passenger numbers. It is possible that passenger number changes at these airports are too idiosyncratic[20] to be modelled appropriately.

[20] Since these airports serve very few airlines and destinations, a single airline changing routes or schedules might have a substantial impact on passenger numbers.

Table 1. Summary of Robustness/Inference Measures:

Airports	**Pre-estimation error (% of passengers)**	**Sample Robustness Check**	**RMSPE Ratio**	**p-value**
Berlin Schonefeld	2.55	N/A	2.85	0.167
Berlin Tegel	3.73	✓	20.71	0.000***
Bremen	2.96	✓	12.91	0.021**
Cologne	1.12	✓	22.81	0.000***
Dortmund	3.21	✓	7.35	0.170
Dresden	3.05	✓	10.76	0.000***
Dusseldorf	0.94	✓	11.39	0.000***
Erfurt	**22.1**	✓	**2.98**	**0.381**
Frankfurt Hahn	3.29	✓	10.37	0.085*
Friedrichshafen	2.49	✓	2.30	0.523
Hamburg	1.68	✓	4.65	0.563
Hannover	3.26	✓	6.10	0.191
Karlsruhe	**7.86**	✓	**1.91**	**0.766**
Leipzig	2.08	✓	14.35	0.000***
Munich	0.37	✓	27.06	0.000***
Munster	0.62	✓	52.24	0.000***
Nuremberg	0.48	✓	264.8	0.000***
Paderborn	**8.84**	N/A	**6.65**	**0.176**
Stuttgart	2.04	✓	4.48	0.563
Amsterdam	0.12	✓	22.13	0.000***
Basel	3.98	✓	10.95	0.063*
Billund	2.16	✓	7.60	0.170
Brussels	1.78	✓	3.84	0.600
Charleroi	**6.59**	✓	**4.49**	**0.333**
Eindhoven	0.00	✓	169.09	0.000***
Luxembourg	3.08	✓	13.19	0.021**
Maastricht	**25.8**	✓	**2.70**	**0.381**
Metz	**8.32**	✓	**4.95**	**0.143**
Prague	1.54	N/A	10.76	0.133
Rotterdam	**9.02**	✓	**5.14**	**0.300**
Saarbrucken	**10.07**	✓	**6.24**	**0.143**
Szczecin	**16.02**	×	**1.52**	**0.714**
Zurich	3.27	✓	1.21	0.714

Results marked bold are based on ill-fitting synthetic control models. N/A indicates that the Stata algorithm (synth) used to calculate synthetic controls was not able to estimate one of the sample models.

***Significant at 1% level, **5%, *10%

6. Discussion

The findings set out above are consistent with the likely behavioural responses of agents to increases in AT.

a) That bordering airports are estimated to have benefited from AT is consistent with passengers switching to alternative airports to avoid ticket prices that incorporate AT. Such effects will be strongest when German and non-German airport catchment areas overlap (see Figure 1).

b) Behavioural responses of airlines may have intensified such effects. Indeed, even assuming full pass-on of taxes into ticket prices, the average tax increase of €12.25 from the tax does not warrant the magnitude of the response seen for some airports[21]. It is possible however, that the response of airlines, especially low-cost ones, have exacerbated the impact of AT. Anecdotal evidence from the Dutch and German AT cases point to some airlines having responded to an anticipated drop in demand by relocating their services to airports outside the AT area. Such responses ought to be strongest among budget airlines, since they are less tied to hubs and able to relocate quickly (see Thelle and la Cour Sonne 2017). Of course, the elimination of some destinations from regional airports forces travellers to shift their custom elsewhere. Our estimates are consistent with these explanations: smaller, regional airports (predominantly serving low-cost airlines) lost proportionately more passengers after the AT introduction. In fact, nearly all airports on the right end of Figure 3 - airports with the largest losses in passenger numbers from AT - fall under this category.

c) Estimates for hubs airports within Germany show either no significant effects (Hamburg) or positive and significant impacts of AT (Berlin Tegel, Dusseldorf, and Munich). Greater resilience of passenger numbers at hubs in the face of AT is consistent with a lower price elasticity of demand. This is likely to be associated with a greater proportion of passengers flying on business trips, see Hess and Polak (2005), greater proportion of untaxed transfer passengers, fewer offerings from budget airlines, less opportunities to substitute to non-taxed routes, and a greater attachment of non-budget airlines to particular hubs (so less likelihood of a supply side response). It is also possible that hubs within Germany gain from substitution away from budget

[21] Some airports have lost over 50% of their passengers. It is unlikely for there to be such a large demand side response given the size of the tax increase.

airlines induced by the latter's reduction in offerings from German regional airports and from substitution induced by the relatively larger proportionate change in budget airline's ticket prices, since the AT due varies only by distance, not by service level.

7. Conclusions

The synthetic control approach has provided estimates of the effects of German AT on passenger numbers using German airports and airports outside Germany but near the border. Estimates indicate that AT has significantly reduced passenger numbers, relative to the counterfactual of zero AT, for many German airports, though passenger numbers tended to hold up at and even grow somewhat at some hub airports. At the same time, most bordering airports gained passenger numbers. These findings are consistent with likely and mutually reinforcing behavioural responses of passengers and airlines to AT and the induced changes in the relative prices of airline services. Future research is needed to disentangle these behavioural responses.

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APPENDIX

Contents

Table 1. Synthetic Control Weights and RMSPE – Smallest Airport Group

Control weights and RMSPE	**ERF**	**FDH**	**SCN**	**MST**	**ETZ**	**SZZ**
RMPSE	**67.41**	**14.21**	**42.02**	**58.62**	**19.40**	**43.98**
Aarhus	**0**	**0.347**	**0.047**	**0.075**	**0**	**0**
Alexandropoulos	**0**	**0**	**0**	**0**	**0**	**0**
Antwerp	**0**	**0**	**0**	**0.646**	**0**	**0**
Bastia	**0**	**0**	**0.088**	**0**	**0**	**0**
Beziers	**0**	**0**	**0.592**	**0**	**0**	**0.5**
Brno	**0**	**0.176**	**0**	**0**	**0**	**0.5**
Chambery	**0**	**0**	**0**	**0**	**0**	**0**
Chios	**0**	**0**	**0**	**0**	**0**	**0**
Coruna	**0**	**0**	**0**	**0**	**0**	**0**
Jerez	**0**	**0.103**	**0**	**0**	**0.029**	**0**
Kalamata	**0.692**	**0**	**0.176**	**0**	**0.784**	**0**
Karpathos	**0**	**0**	**0**	**0**	**0**	**0**
Karup	**0**	**0**	**0**	**0.218**	**0**	**0**
Kavala	**0**	**0**	**0**	**0**	**0**	**0**
Kefallinia	**0**	**0**	**0**	**0**	**0**	**0**
La Rochelle	**0**	**0**	**0**	**0**	**0**	**0**
Nimes	**0**	**0.204**	**0.005**	**0**	**0**	**0**
Ostrava	**0**	**0.223**	**0**	**0**	**0**	**0**
Preveza	**0**	**0**	**0**	**0**	**0**	**0**
Samos	**0**	**0**	**0**	**0**	**0**	**0**
Skiathos	**0**	**0**	**0**	**0**	**0**	**0**
Zakintos	**0.308**	**0.165**	**0.272**	**0.062**	**0.186**	**0**
Zaragoza	**0**	**0.005**	**0.218**	**0**	**0**	**0**

Table 2. Synthetic Control Weights and RMSPE – Small Airports (Sample B[1])

Control weights and RMSPE	BRE	DTM	HHN	HAJ	FKB	FMO	NUE	BLL	BSL	EIN	LUX	RTM	PAD	CRL
RMPSE	78.79	56.33	114.5	166.2	91.51	8.02	19.69	54.27	168.7	0.001	49.77	83.91	86.45	341.5
Aalborg	0	0	0	0	0	0	0	0	0	0.473	0	0.179	0	0
Almeria	0	0	0	0.295	0	0.180	0	0	0	0.001	0	0	0	0
Asturias	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Bastia	0.517	0	0	0	0	0	0	0.542	0	0.001	0.699	0	0	0.34
Biarritz	0	0	0	0	0	0.153	0	0	0	0.001	0	0	0	0
Bilbao	0	0	0	0	0	0	0.198	0	0	0	0	0	0	0
Bordeaux	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bratislava	0	0.223	0	0	0	0	0	0	0.098	0.001	0	0	0	0
Burgas	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0
Chania	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Coruna	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Faro	0	0	0.005	0	0	0	0	0	0	0	0	0	0	0.005
Gdansk	0	0	0.218	0	0	0	0	0	0.384	0.009	0	0	0	0.218
Girona	0	0	0	0	0	0	0.041	0.115	0	0	0	0	0	0
Goteborg	0	0	0	0.705	0	0	0.274	0	0	0	0	0	0	0
Granada	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Heraklion	0	0	0.176	0	0	0	0.214	0	0	0	0	0	0	0.176
Ibiza	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jerez	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Kerkira	0	0	0	0	0	0.428	0	0	0	0	0.203	0.193	0	0
Kos	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Larnaka	0.003	0	0	0	0	0	0.136	0.172	0	0	0.098	0	0	0
Lille	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Ljubljana	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Malmo	0	0	0	0	0	0.093	0	0	0	0.001	0	0	0.282	0
Menorca	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Murcia	0	0.093	0	0	0	0	0	0	0	0.224	0	0	0	0
Nantes	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Pafos	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Porto	0.407	0	0	0	0	0	0	0	0	0	0	0	0	0.529
Reus	0	0	0	0	0	0	0.137	0	0	0.003	0	0	0	0
Riga	0	0	0.077	0	0	0	0	0	0.219	0.085	0	0	0	0.13
Rodos	0	0	0.325	0	0	0	0	0	0	0	0	0	0	0
Santander	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Santiago	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Santorini	0	0	0	0	0	0	0	0	0	0.003	0	0	0	0
Sevilla	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Sofia	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Stockholm B	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Tallin	0	0.489	0	0	0	0	0	0	0	0.005	0	0	0	0
Thessaloniki	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Timisoara	0	0	0	0	0.713	0	0	0	0	0.136	0	0	0	0
Valencia	0	0.088	0.199	0	0	0	0	0	0.299	0	0	0	0	0
Varna	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Vigo	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
Vilnius	0	0.110	0	0	0	0.02	0	0.171	0	0.033	0	0	0	0
Wroclaw	0.073	0	0	0	0.287	0	0	0	0	0.001	0	0	0	0
Zakintos	0	0	0	0	0	0.125	0	0	0	0.001	0	0.628	0.718	0

[1] Airports included are the ones from the two samples (Sample A and B) that had better fits. Synthetic control models with worse fits are not included for brevity's sake.

Table 3. Synthetic Control Weights and RMSPE – Medium Sized Airports (Sample B)

Control weights and RMSPE	**TXL**	**CGN**	**DUS**	**HAM**	**STR**	**PRG**	**BRU**
RMPSE	**562.11**	**111.03**	**179.28**	**218.69**	**189.87**	**177.54**	**301.8**
Alicante	**0**	**0.001**	**0**	**0**	**0**	**0**	**0**
Athens	**0**	**0.001**	**0**	**0.071**	**0**	**0**	**0**
Budapest	**0**	**0.394**	**0**	**0**	**0.391**	**0.637**	**0**
Copenhagen	**0**	**0.001**	**0**	**0**	**0**	**0**	**0**
Geneva	**0.151**	**0.001**	**0.012**	**0**	**0**	**0.363**	**0.146**
Helsinki	**0**	**0.210**	**0**	**0.726**	**0**	**0**	**0**
Lisboa	**0.423**	**0.002**	**0.653**	**0.192**	**0**	**0**	**0**
Lyon	**0.317**	**0.001**	**0**	**0**	**0**	**0**	**0.301**
Malaga	**0**	**0.227**	**0**	**0**	**0.438**	**0**	**0**
Marseille	**0**	**0.041**	**0**	**0**	**0**	**0**	**0**
Nice	**0**	**0.001**	**0**	**0**	**0**	**0**	**0.108**
Orly	**0.11**	**0.027**	**0.335**	**0**	**0**	**0**	**0.445**
Palma	**0**	**0.001**	**0**	**0**	**0**	**0**	**0**
Stockholm M	**0**	**0.001**	**0**	**0**	**0**	**0**	**0**
Toulouse	**0**	**0.091**	**0**	**0.011**	**0.171**	**0**	**0**

Table 4. Synthetic Control Weights and RMSPE – Large Airports (Sample B)

Control weights and RMSPE	**MUNICH (MUC)**	**AMSTERDAM (AMS)**	**ZURICH (ZRH)**
RMPSE	**130.15**	**54.32**	**747.5**
Barcelona	**0**	**0.207**	**0**
Copenhagen	**0**	**0.213**	**0**
Geneva	**0.573**	**0**	**0.769**
London H	**0**	**0.228**	**0**
Madrid	**0.261**	**0**	**0**
Orly	**0**	**0**	**0.202**
Palma	**0**	**0**	**0**
Paris CDG	**0.166**	**0.352**	**0.028**
Stockholm	**0**	**0**	**0**

Table 5. Synthetic Control Weights and RMSPE – Airports selected from Sample A

Control weights and RMSPE	**BERLIN-S (SXF)**	**DRESDEN**	**LEIPZIG**
RMPSE	**186.72**	**57.52**	**59.29**
Aalborg	**0**	**0.437**	**0**
Bastia	**0**	**0**	**0.017**
Bordeaux	**0**	**0.441**	**0**
Gdansk	**0.118**	**0**	**0**
Lyon	**0.47**	**0**	**0**
Marseille	**0.412**	**0**	**0.280**
Montpellier	**0**	**0.122**	**0.213**
Nantes	**0**	**0**	**0.057**
Toulouse	**0**	**0**	**0**
Wroclaw	**0**	**0**	**0.433**

Table 6. RMSPE Ratios - Control Airports (Sample A):

Airport	RMSPE Ratio
Aalborg	0.77
Aarhus	2.18
Bastia	1.01
Bordeaux	1.02
Copenhagen	1.8
Gdansk	4.66
Lyon	2.38
Marseille	2.41
Montpellier	0.89
Nice	2.1
Nantes	4.3
Orly	0.83
Prague	1.32
Toulouse	1.32
Vienna	1.56
Wroclaw	1.44

Table 7. RMPSE Ratios - Control Airports (Sample B):

Table 7.1. Small Airports Group

Airport	RMSPE Ratio
Aalborg	4.33
Almeria	4.11
Asturias	2.14
Bastia	0.43
Biarritz	10.55
Bilbao	4.07
Bordeaux	2.38
Bratislava	11.32
Burgas	8.23
Chania	2.1
Coruna	4.3
Faro	0.83
Gdansk	1.34
Girona	5.37
Goteborg	1.56
Granada	1.44
Heraklion	3.73
Ibiza	6.11
Jerez	2.34
Kerkira	9.68
Kos	5.34
Larnaka	6.37
Lille	3.59
Ljubljana	1.02
Malmo	2.92
Menorca	3.30
Murcia	2.44
Nantes	6.11
Pafos	4.67
Porto	6.16
Reus	3.00
Riga	20.28

Rodos	5.89
Santander	11.06
Santiago	4.87
Santorini	4.54
Sevilla	4.25
Sofia	0.22
Stockholm	8.91
Tallin	1.88
Thessaloniki	7.69
Timisiora	6.94
Valencia	3.58
Vigo	4.00
Vilnius	1.92
Wroclaw	5.83
Zakintos	1.80

Table 7.2. Medium Sized Airport Group

Alicante	6.17
Athens	15.86
Budapest	7.01
Copenhagen	3.55
Geneva	6.45
Helsinki	11.42
Lisboa	3.32
Lyon	5.86
Malaga	1.07
Marseille	5.50
Nice	1.25
Orly	Could not be estimated
Palma	8.47
Stockholm Main	10.76
Toulouse	1.68

Table 7.3. Large Airports Group

Barcelona	6.72
Copenhagen	4.29
Geneva	Could not be estimated
London H	4.90
Madrid	1.59
Orly	14.93
Palma	Could not be estimated
Paris CDG	5.26
Stockholm Main	1.14

Table 8. Airport Codes

Airport	Code
Amsterdam	AMS
Basel	BSL
Berlin Schonefeld	SXF
Berlin Tegel	TXL
Billund	BLL
Bremen	BRE
Brussels	BRU
Charleroi	CRL
Cologne	CGN
Dortmund	DTM
Dresden	DRS
Dusseldorf	DUS
Eindhoven	EIN
Erfurt	ERF
Frankfurt Hahn	HHN
Frankfurt Main	FRA
Friedrichshafen	FDH
Hamburg	HAM
Hannover	HAJ
Karlsruhe	FKB
Leipzig	LEJ
Luxembourg	LUX
Maastricht	MST
Metz	ETZ
Munich	MUC
Munster	FMO
Nuremberg	NUE
Paderborn	PAD
Prague	PRG

Rotterdam	RTM
Saarbrucken	SCN
Szczecin	SZZ
Stuttgart	STR
Zurich	ZRH

Synthetic Control Models – Sample B

Figure 1. Synthetic Control – Amsterdam Airport

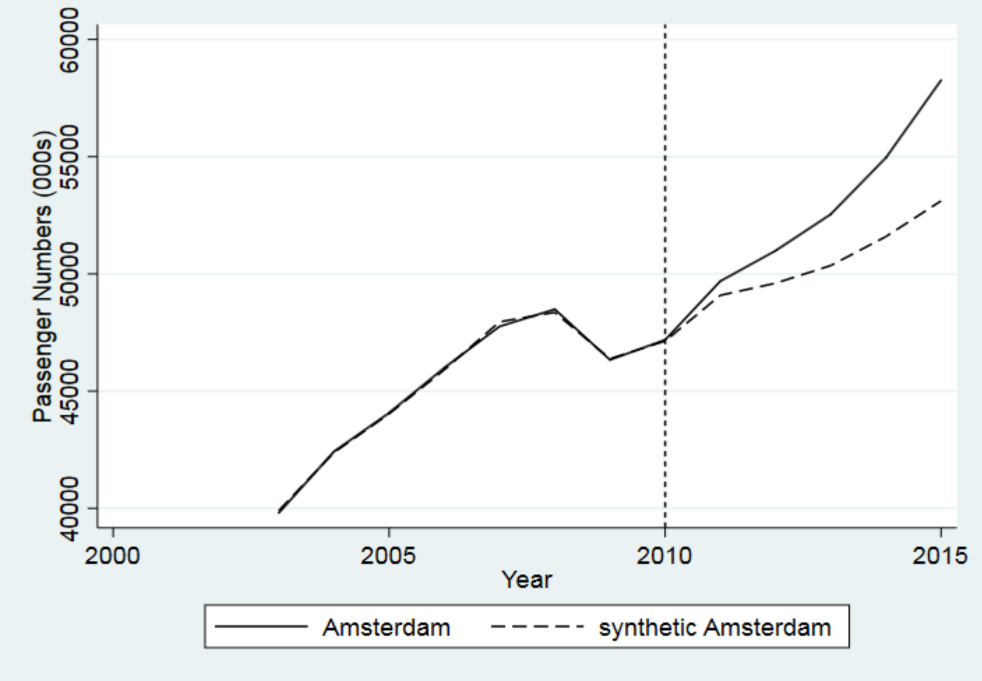


Figure 2. Synthetic Control – Basel Airport

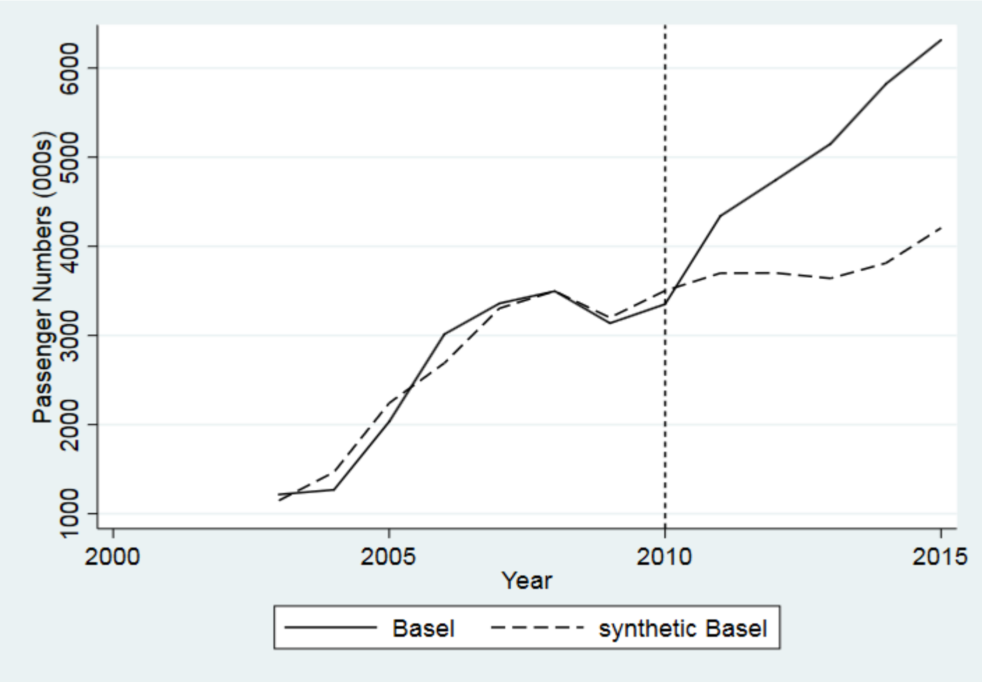


Figure 3. Synthetic Control – Berlin Tegel Airport

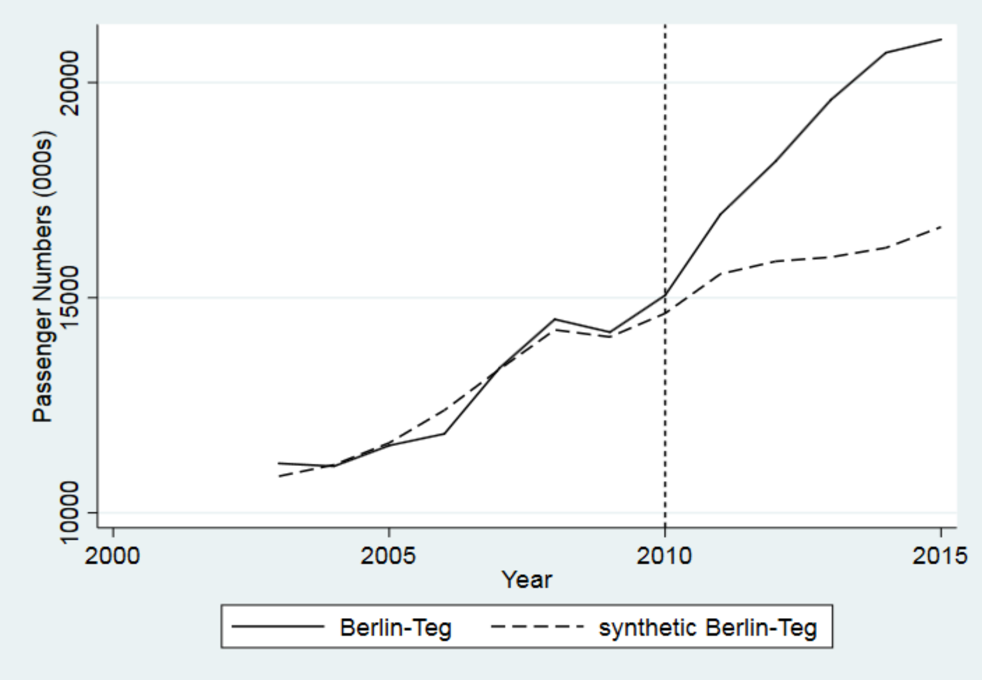


Figure 4. Synthetic Control – Billund Airport

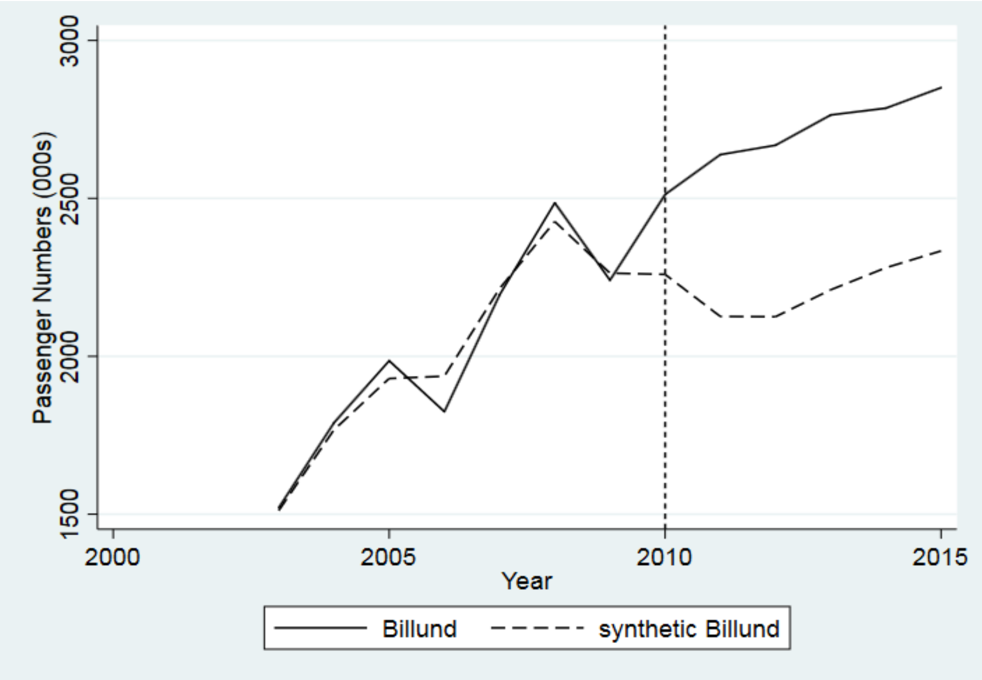


Figure 5. Synthetic Control – Bremen Airport

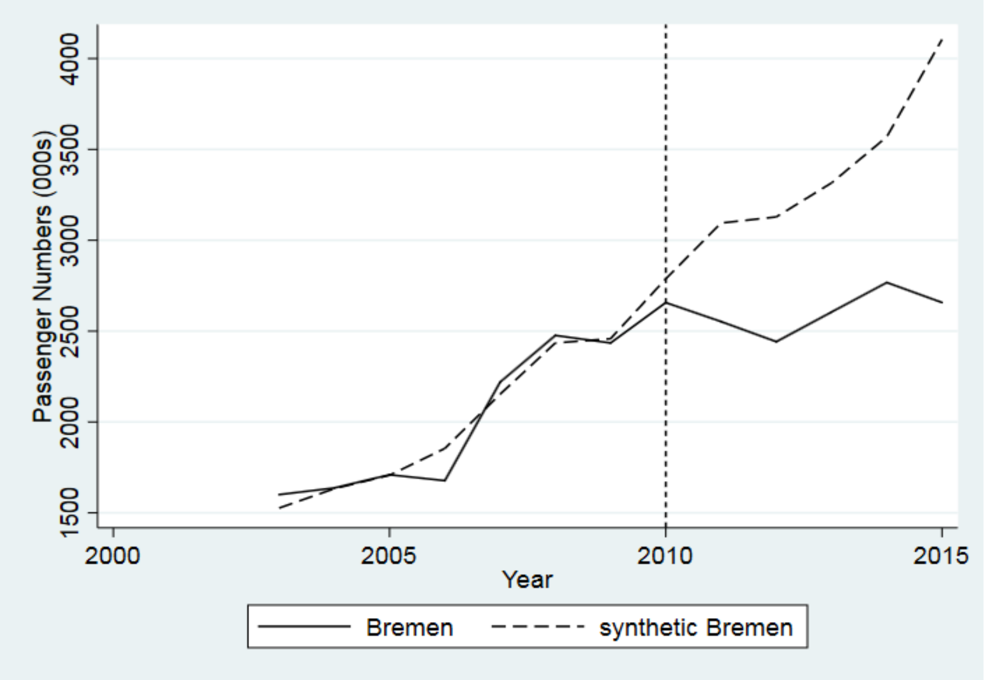


Figure 6. Synthetic Control – Charleroi Airport

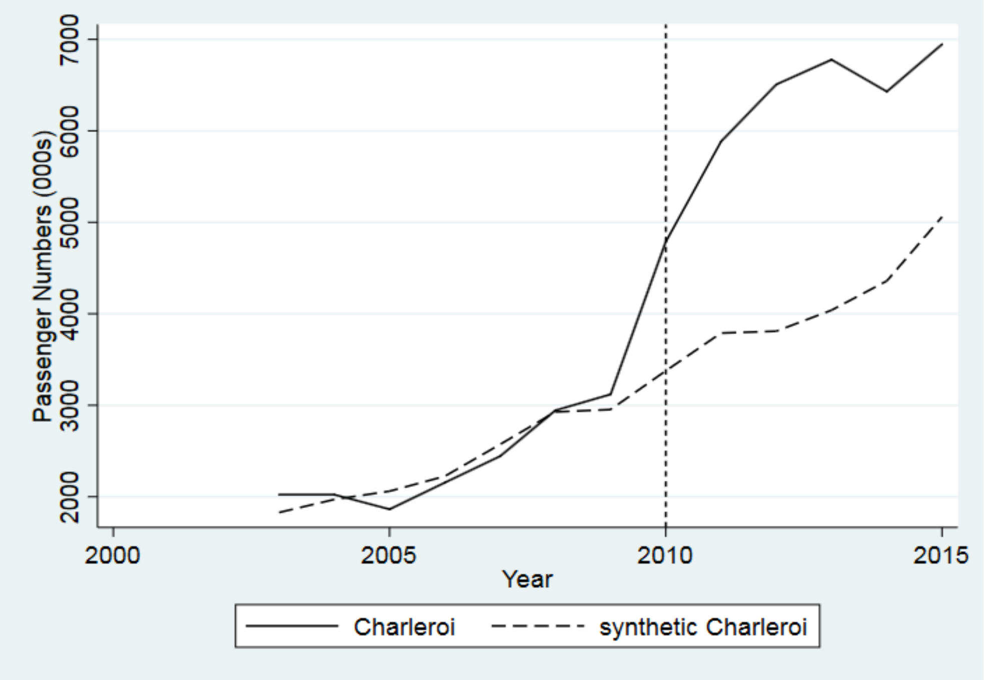


Figure 7. Synthetic Control – Cologne Airport

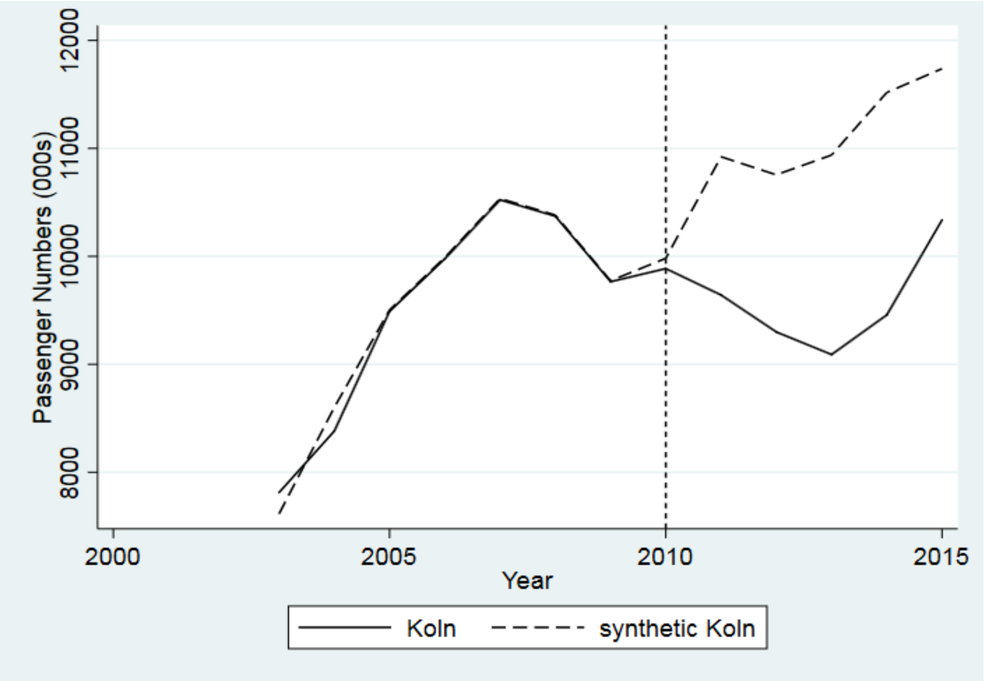


Figure 8. Synthetic Control – Dortmund

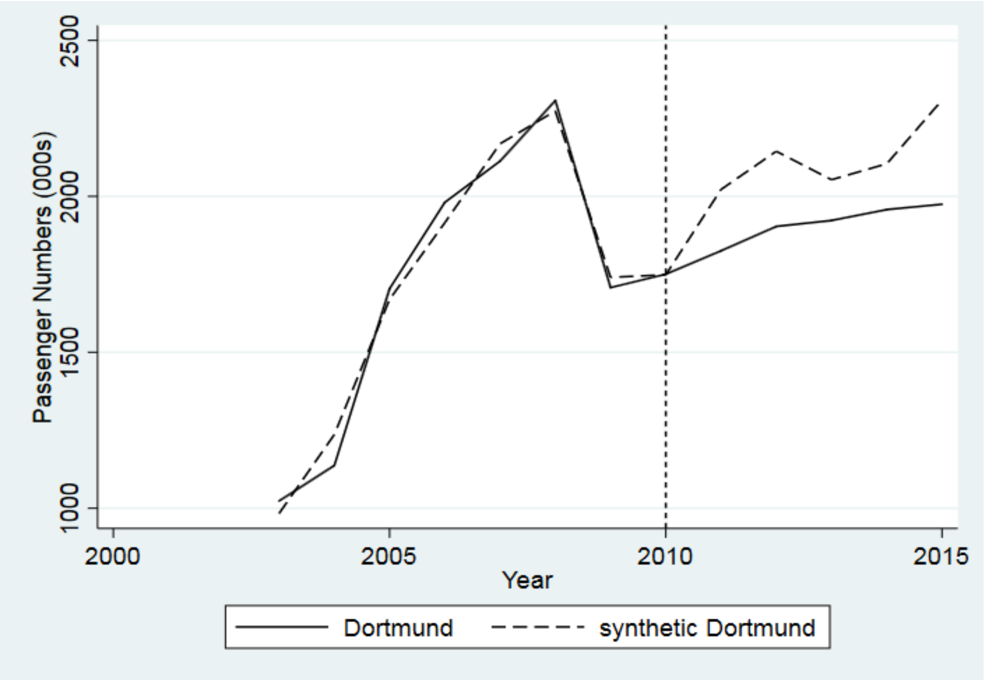


Figure 9. Synthetic Control - Dresden Airport

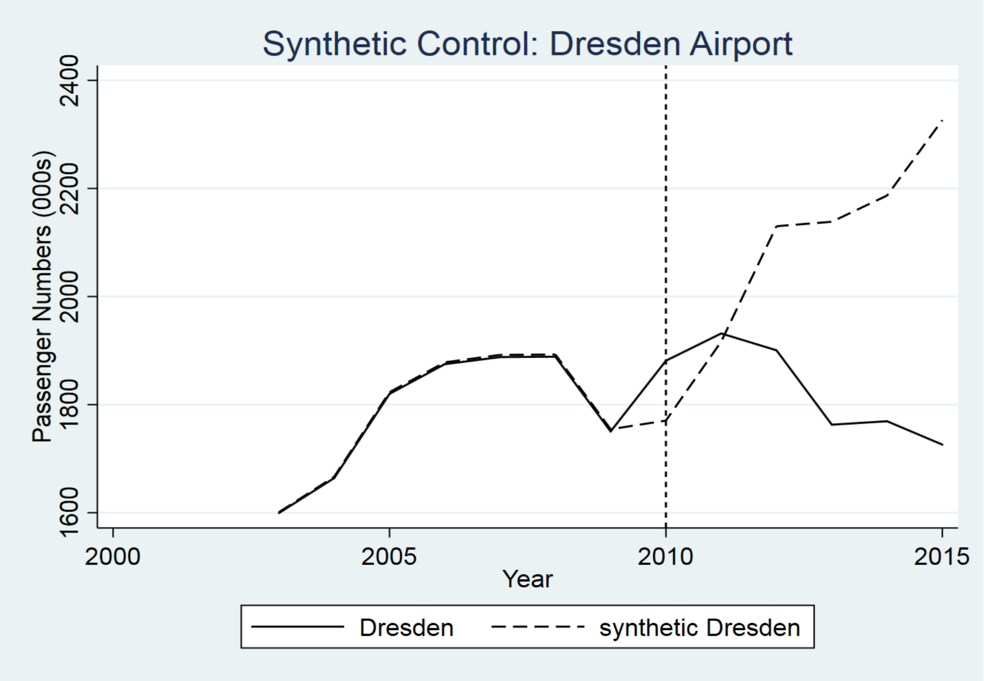


Figure 10. Synthetic Control – Dusseldorf Airport

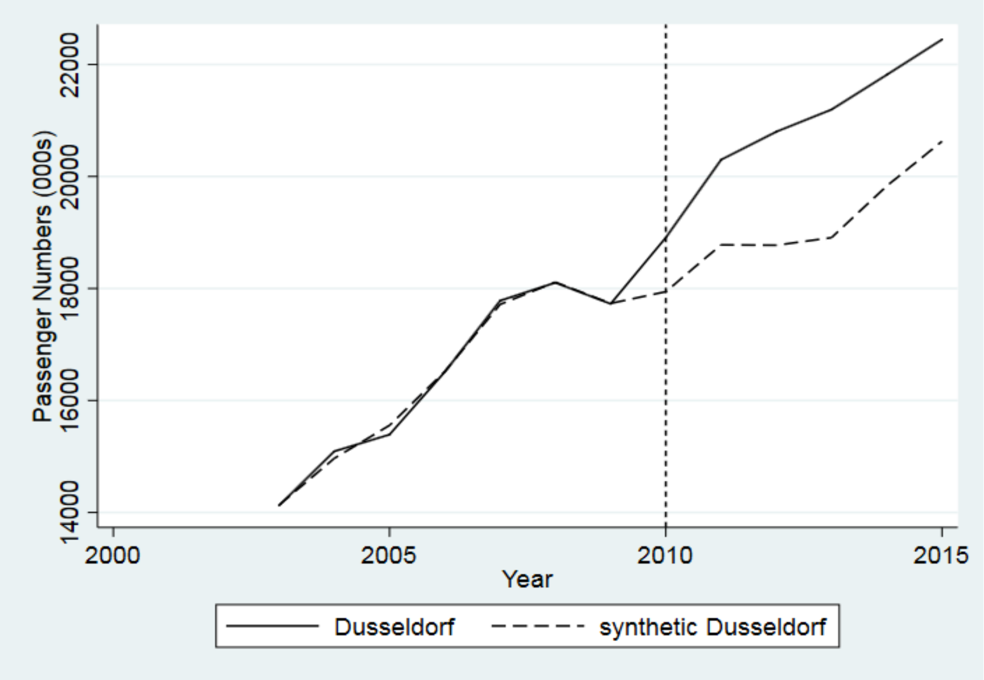


Figure 11. Synthetic Control – Eindhoven Airport

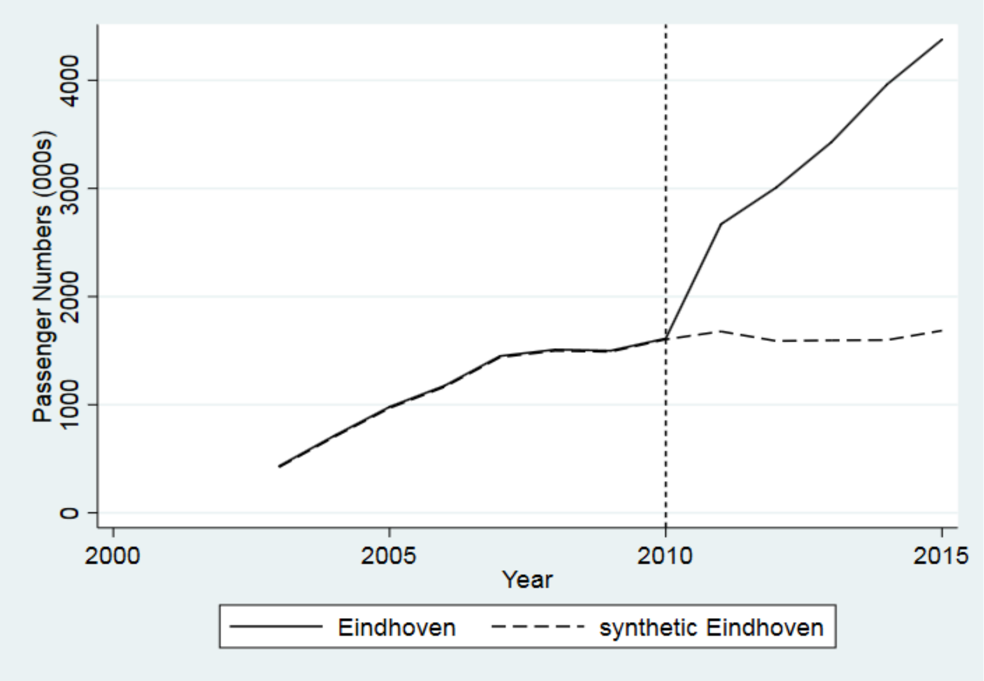


Figure 12. Synthetic Control – Erfurt Airport

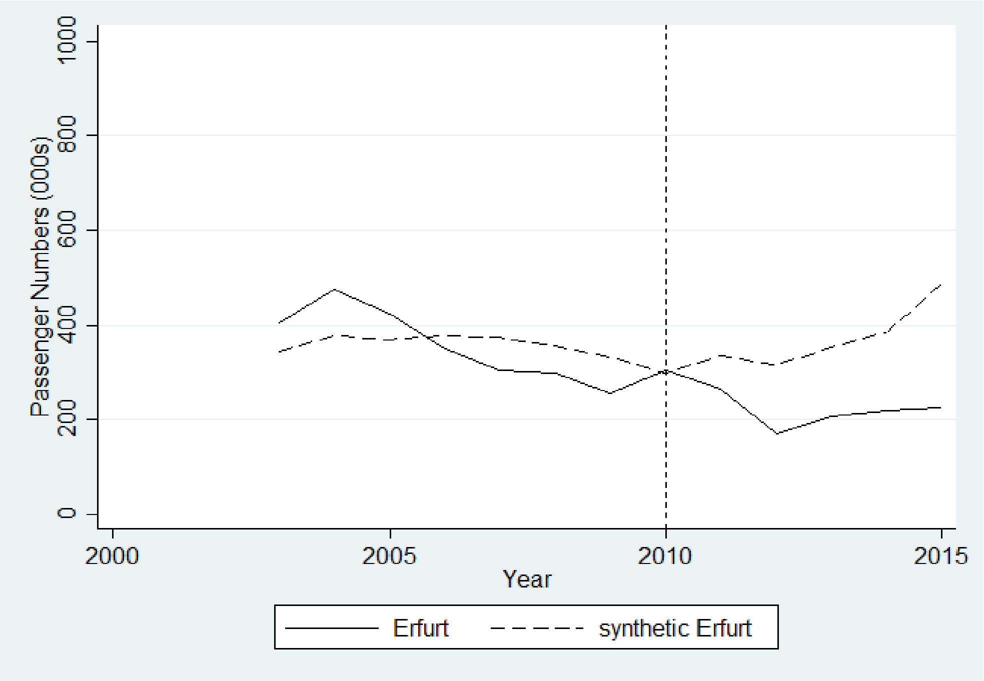


Figure 13. Synthetic Control – Frankfurt Hahn Airport

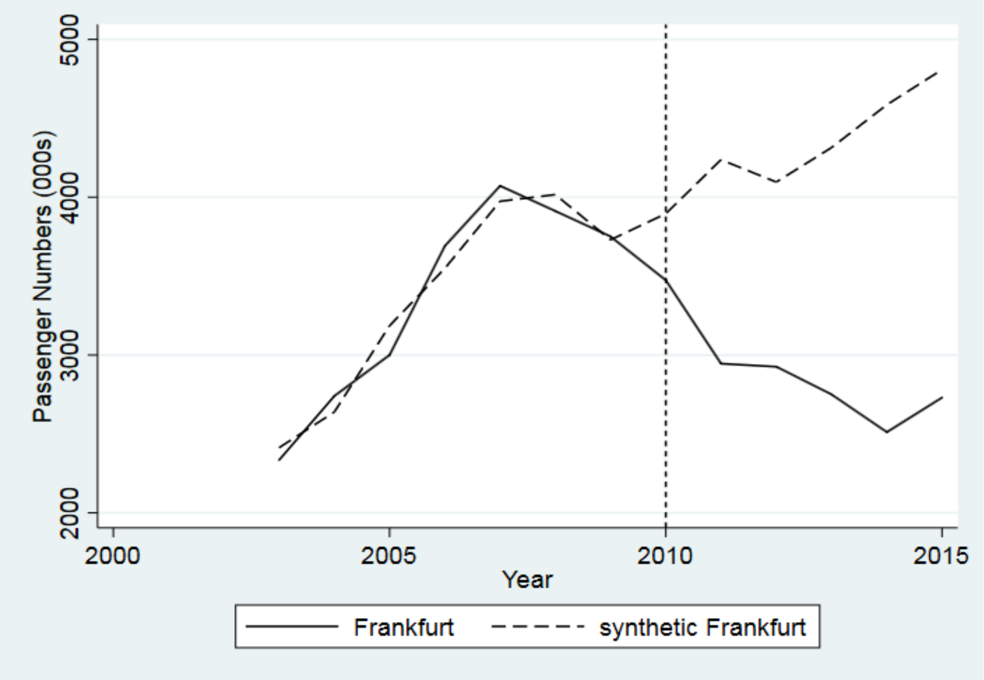


Figure 14. Synthetic Control – Friedrichshafen Airport

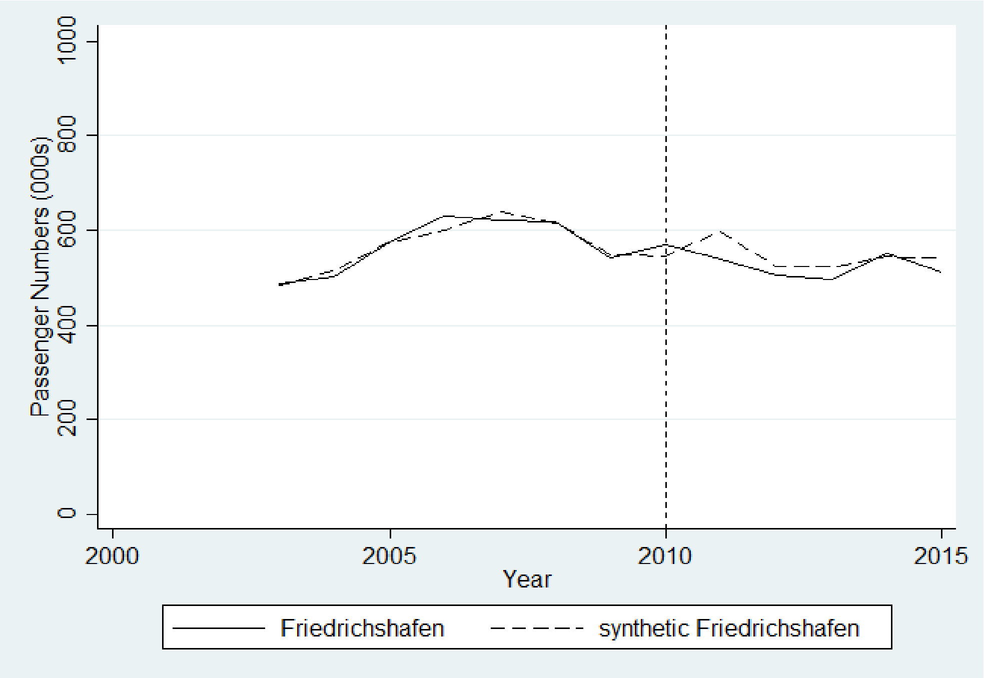


Figure 15. Synthetic Control – Hamburg Airport

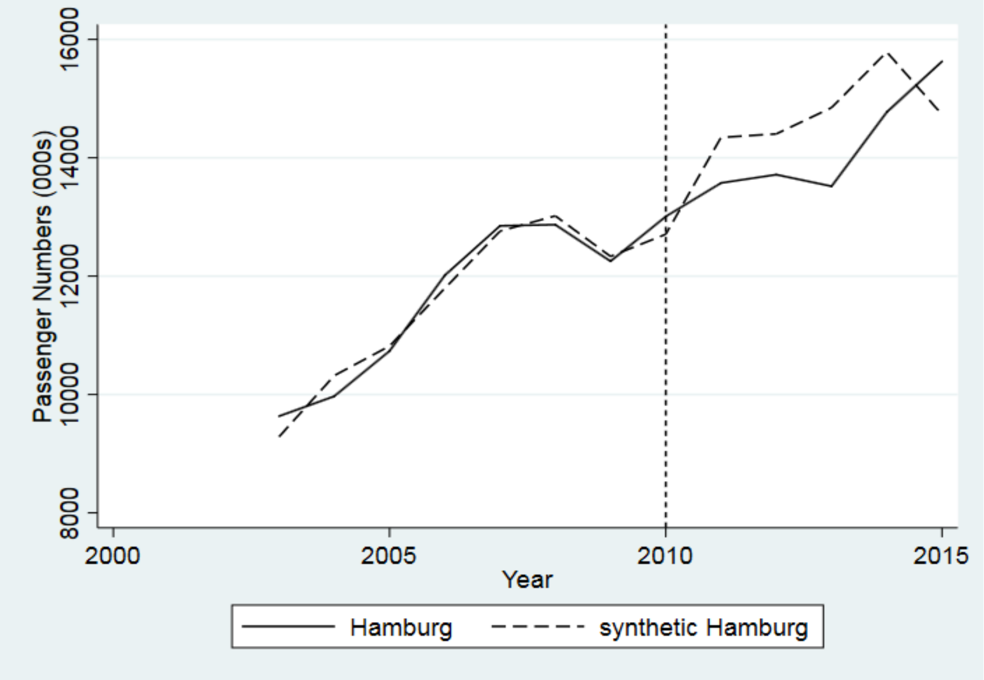


Figure 16. Synthetic Control – Hannover Airport

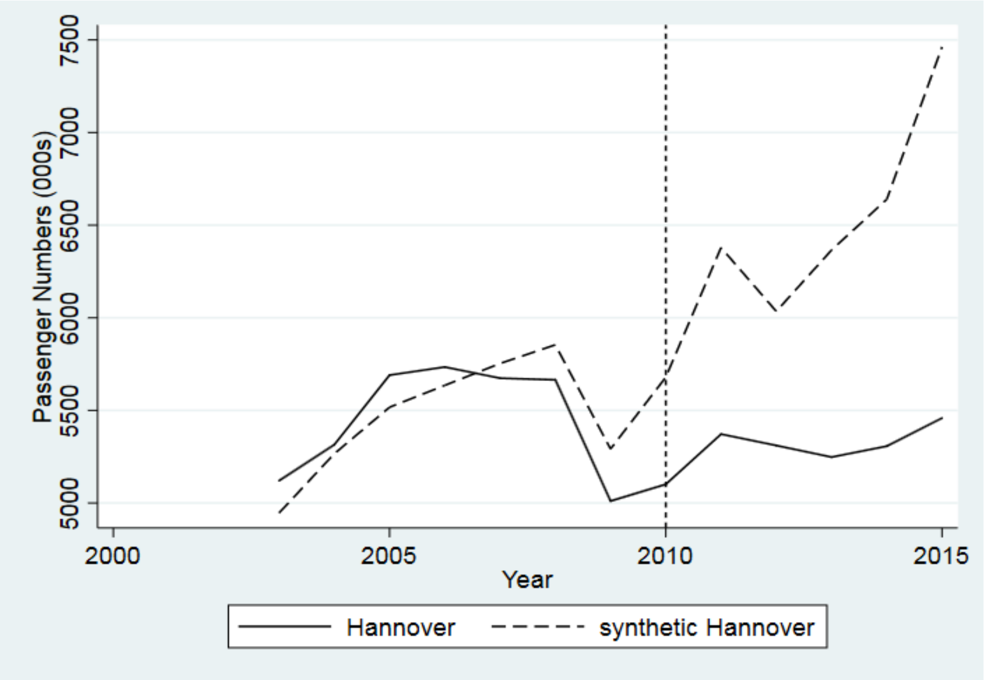


Figure 17. Synthetic Control – Karlsruhe Airport

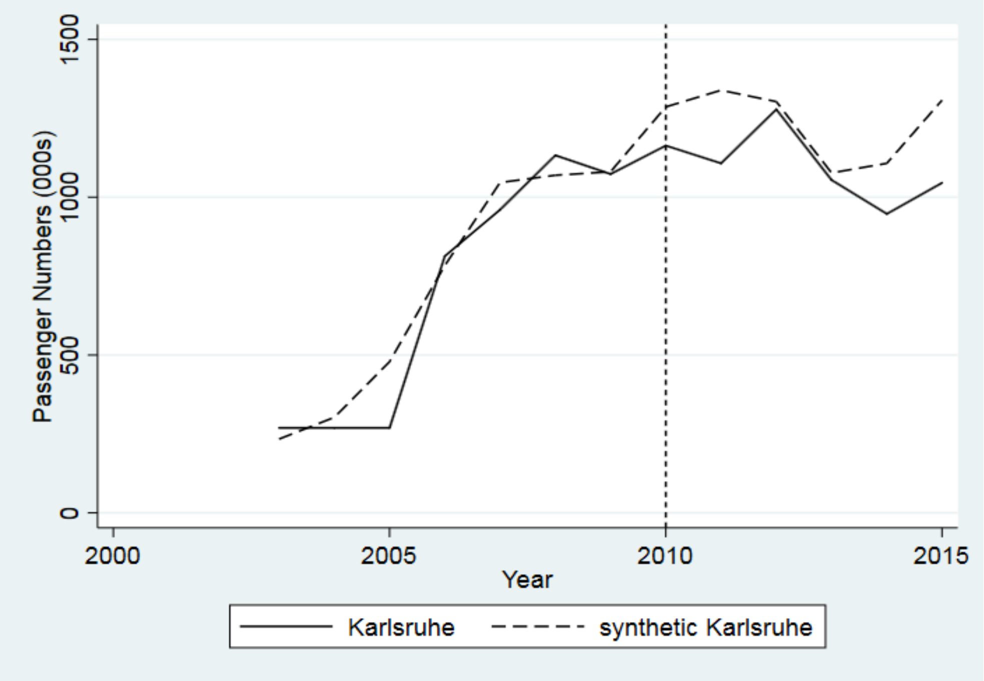


Figure 18. Synthetic Control – Leipzig Airport

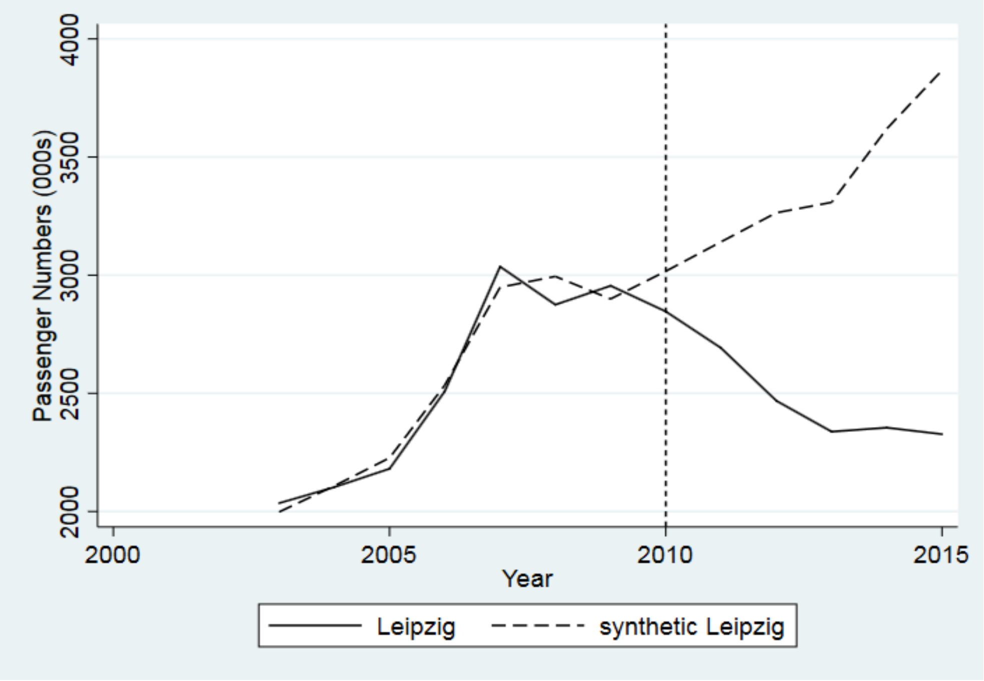


Figure 19. Synthetic Control – Luxembourg Airport

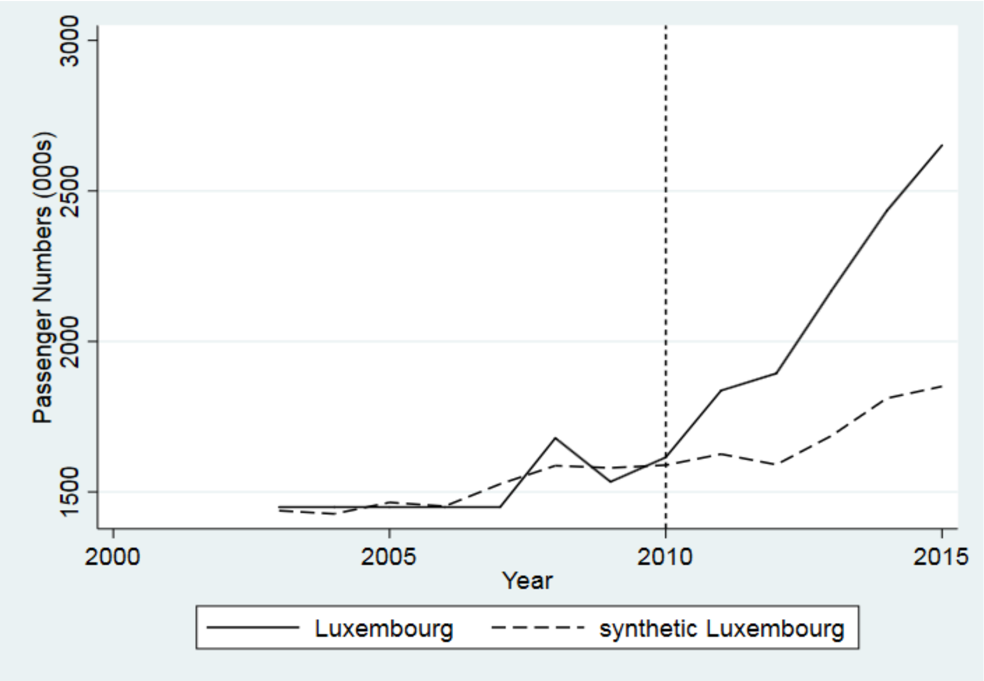


Figure 20. Synthetic Control – Maastricht Airport

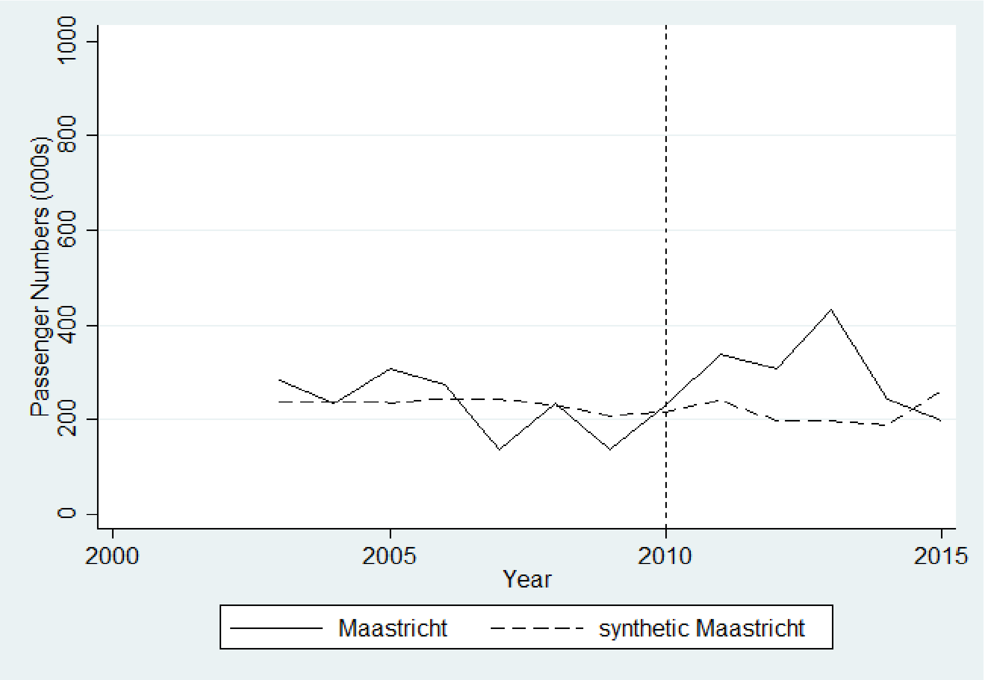


Figure 21. Synthetic Control – Metz Airport

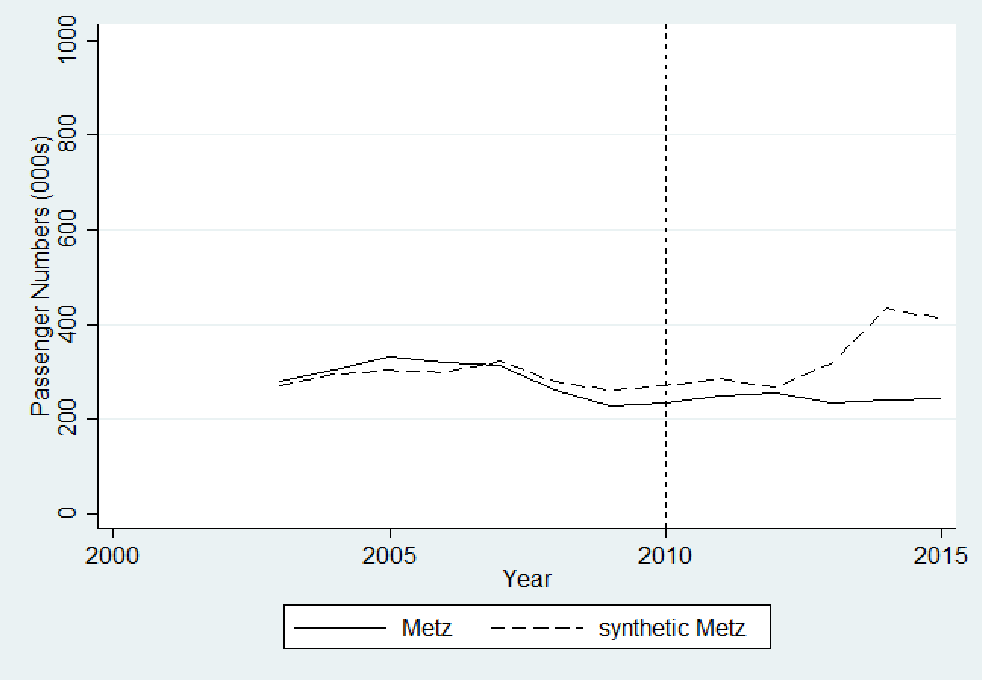


Figure 22. Synthetic Control – Munich Airport

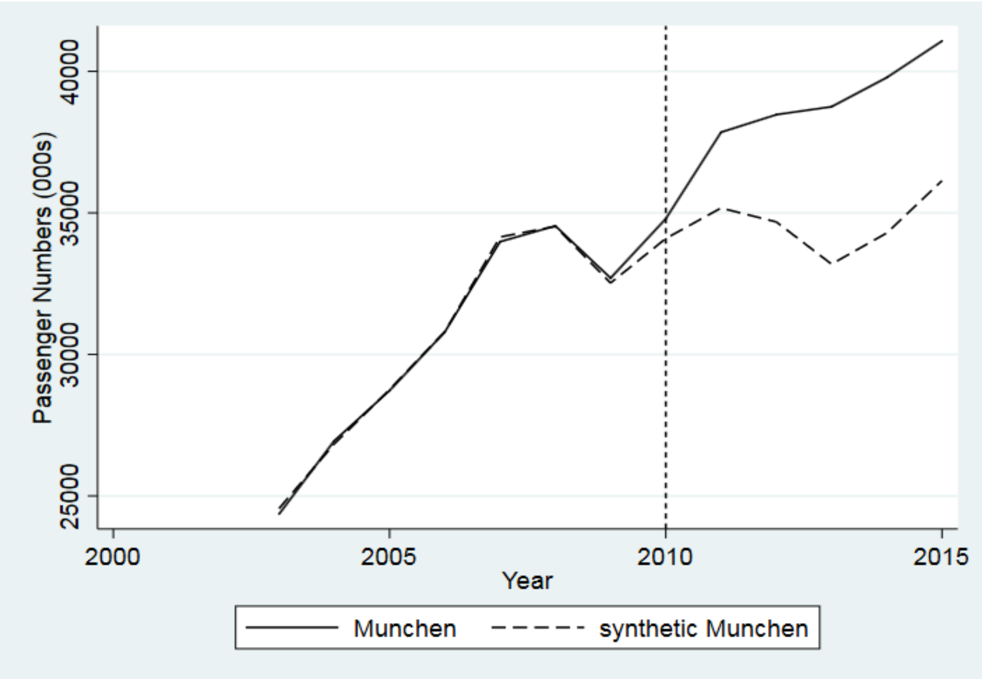


Figure 23. Synthetic Control – Munster Airport

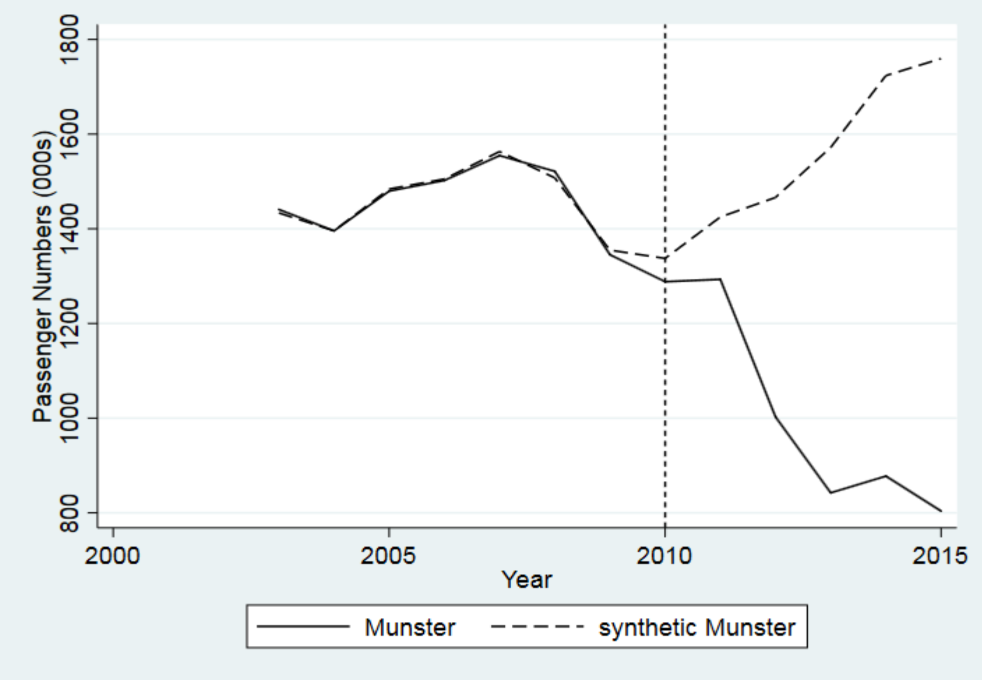


Figure 24. Synthetic Control – Nuremberg Airport

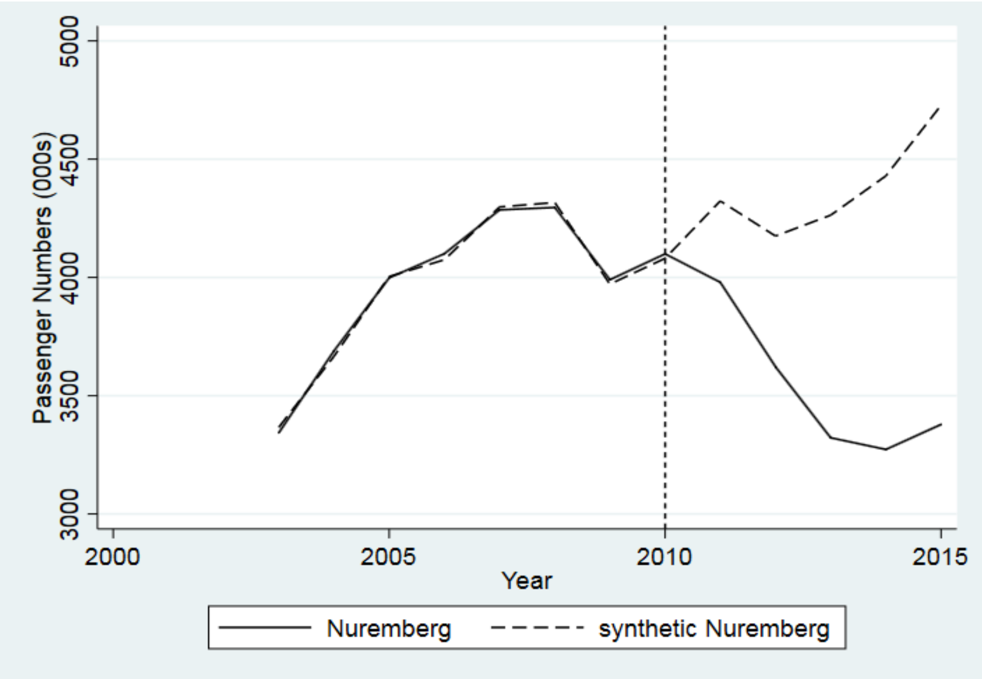


Figure 25. Synthetic Control – Paderborn Airport

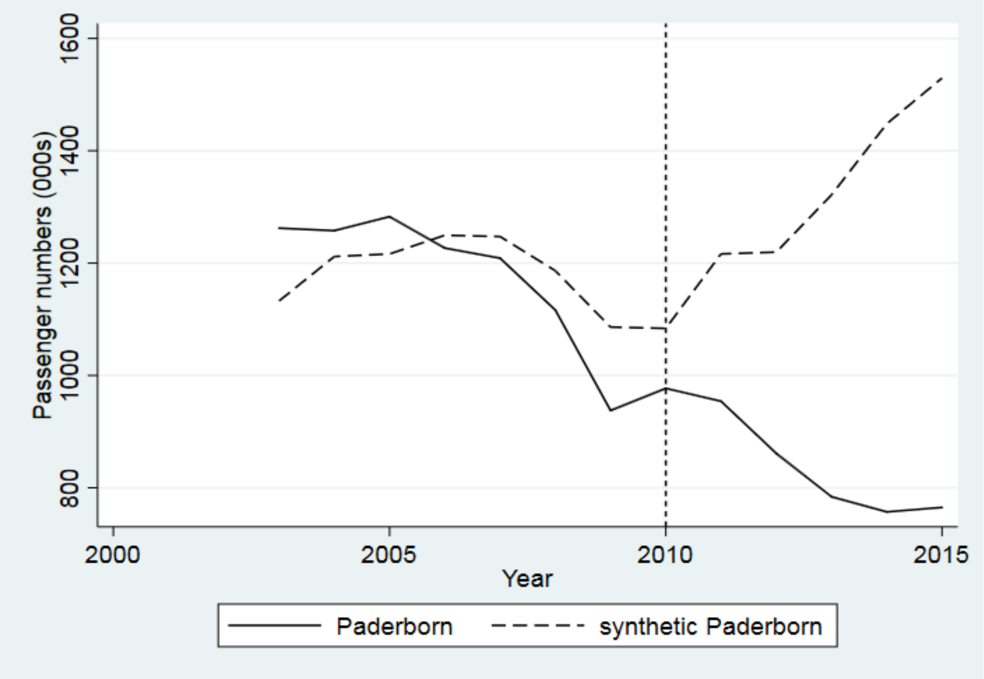


Figure 26. Synthetic Control – Prague Airport

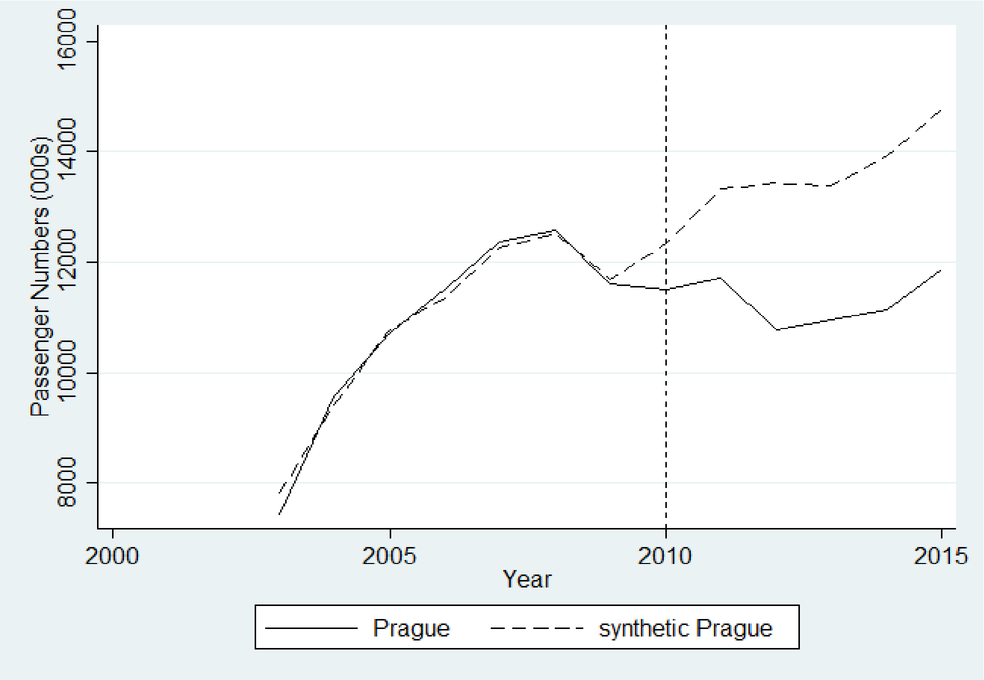


Figure 27. Synthetic Control – Rotterdam Airport

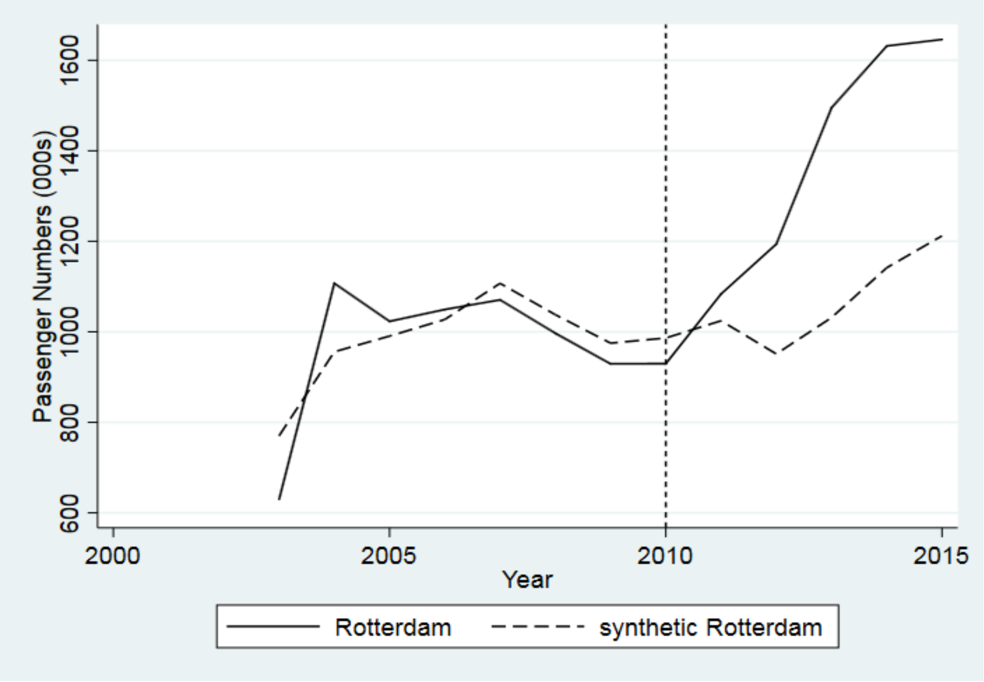


Figure 28. Synthetic Control – Saarbrucken Airport

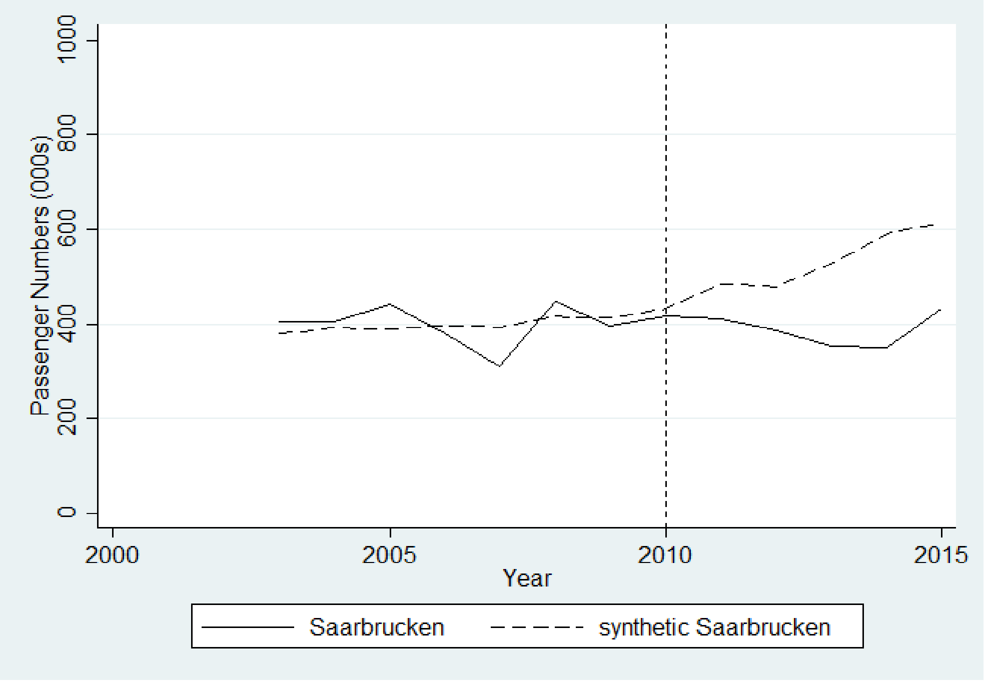


Figure 29. Synthetic Control – Stuttgart Airport

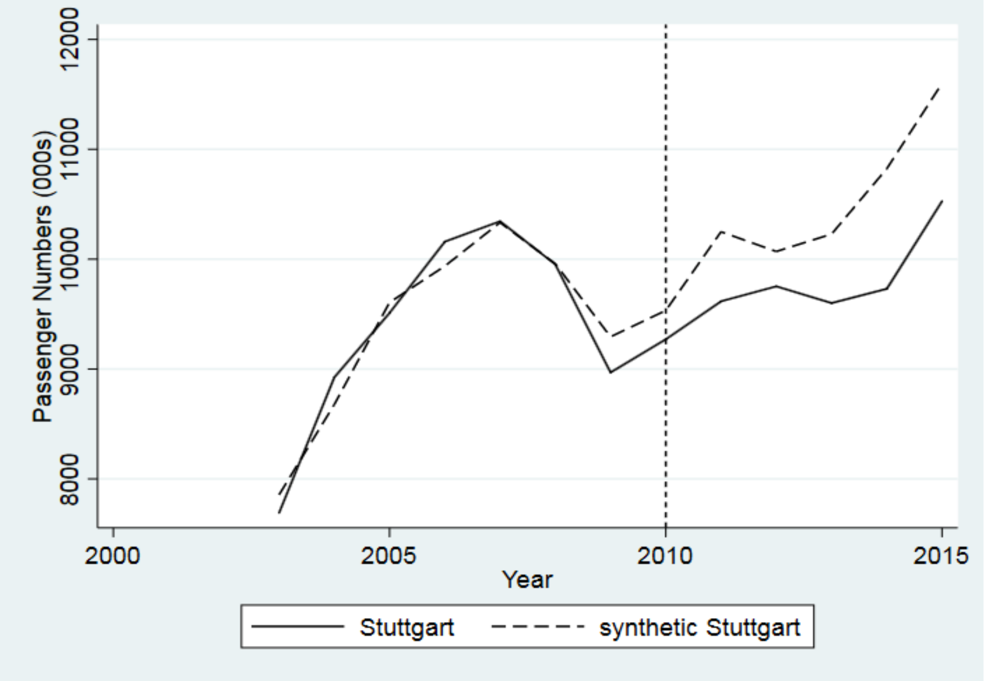


Figure 30. Synthetic Control – Szczecin Airport

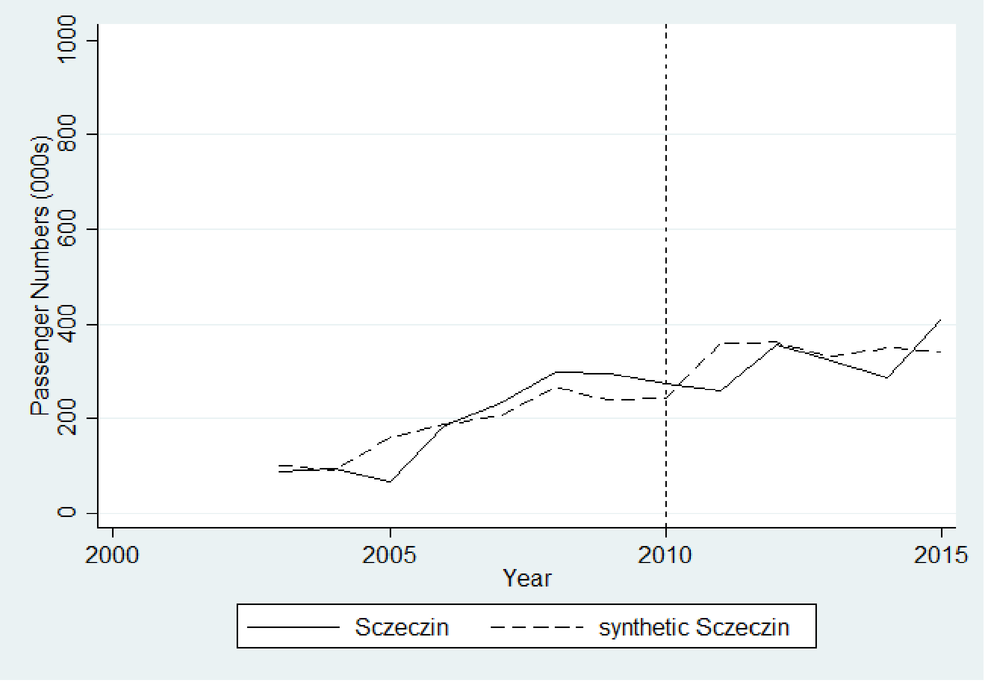
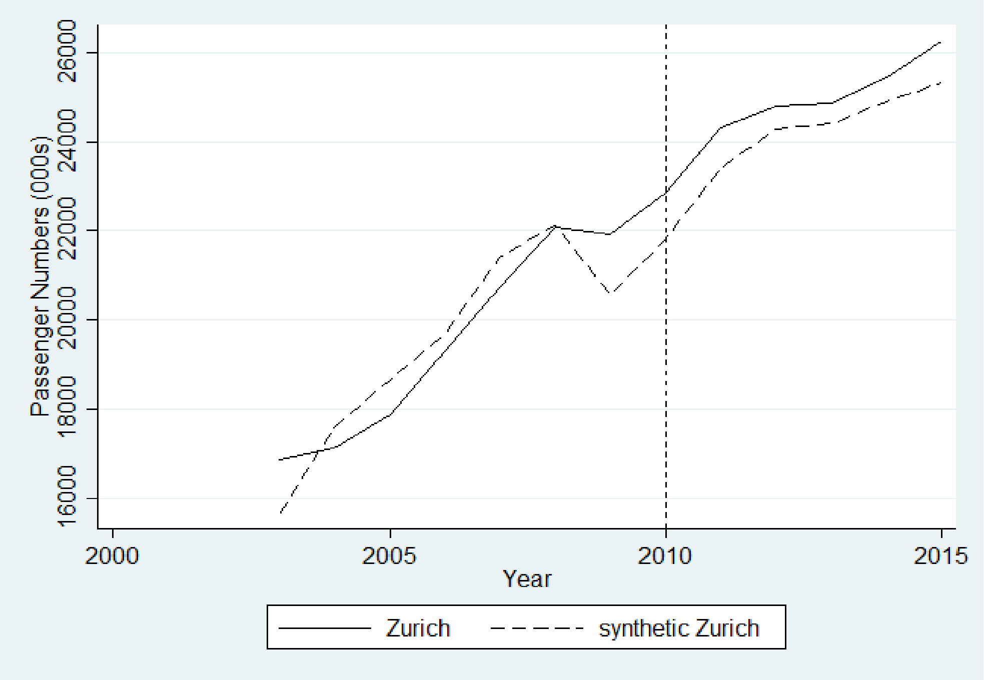


Figure 31. Synthetic Control – Zurich Airport



Synthetic Control Models – Sample A

Figure 32. Synthetic Control – Amsterdam Airport

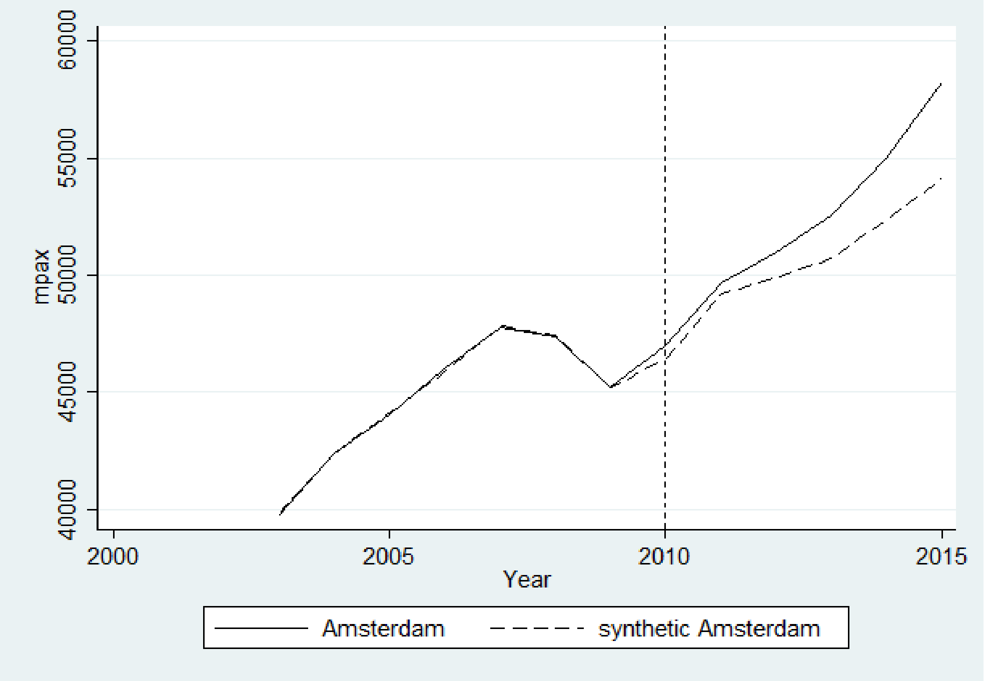


Figure 33. Synthetic Control – Basel Airport

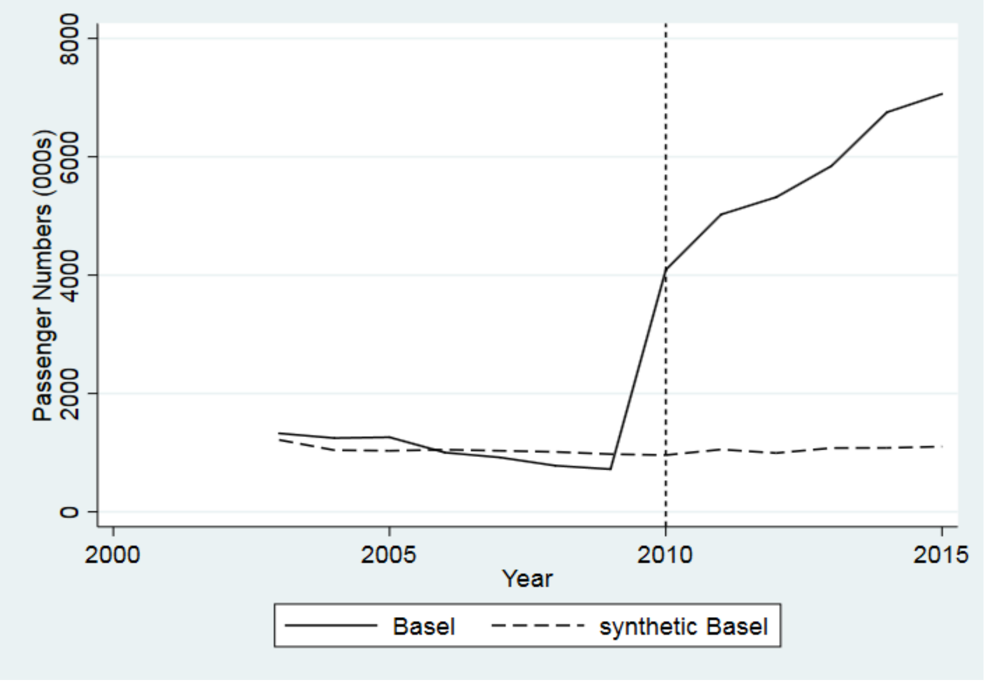


Figure 34. Synthetic Control – Billund Airport

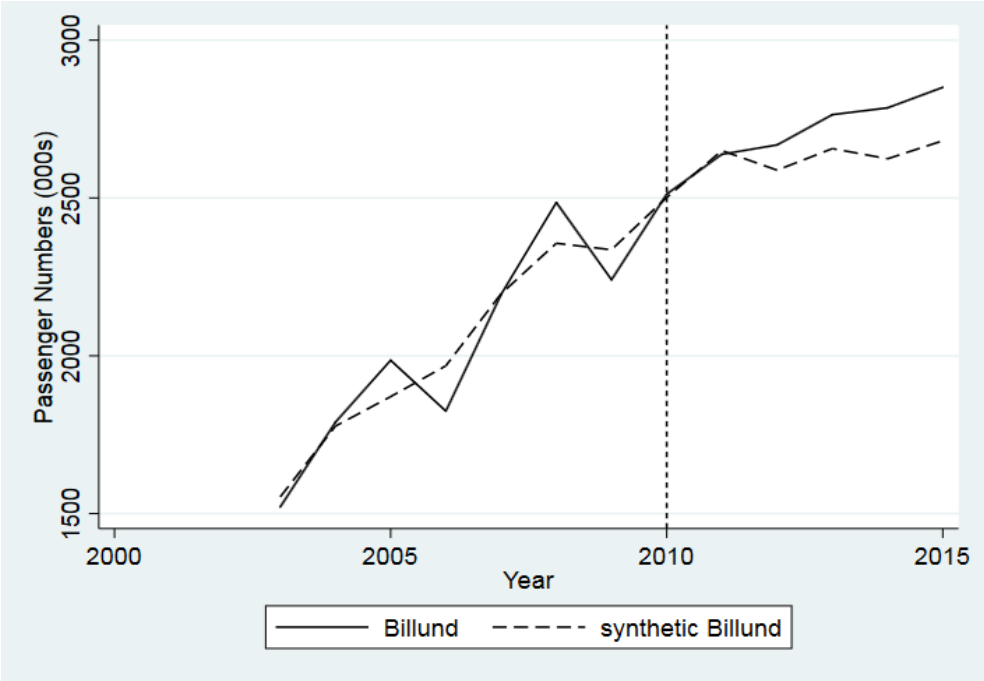


Figure 35. Synthetic Control – Bremen Airport

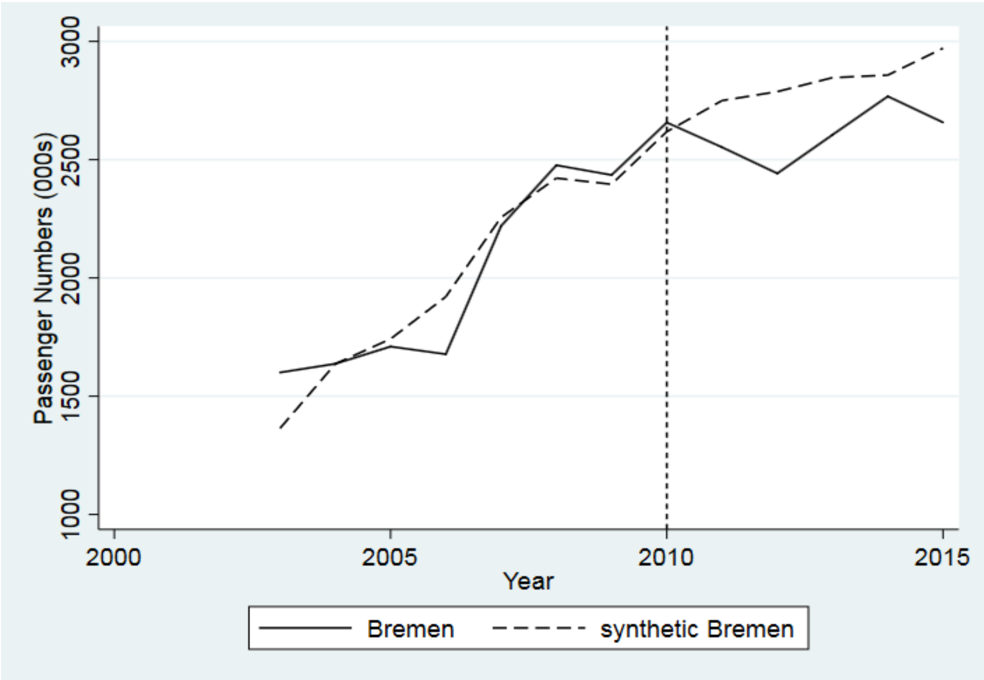


Figure 36. Synthetic Control – Brussels Airport

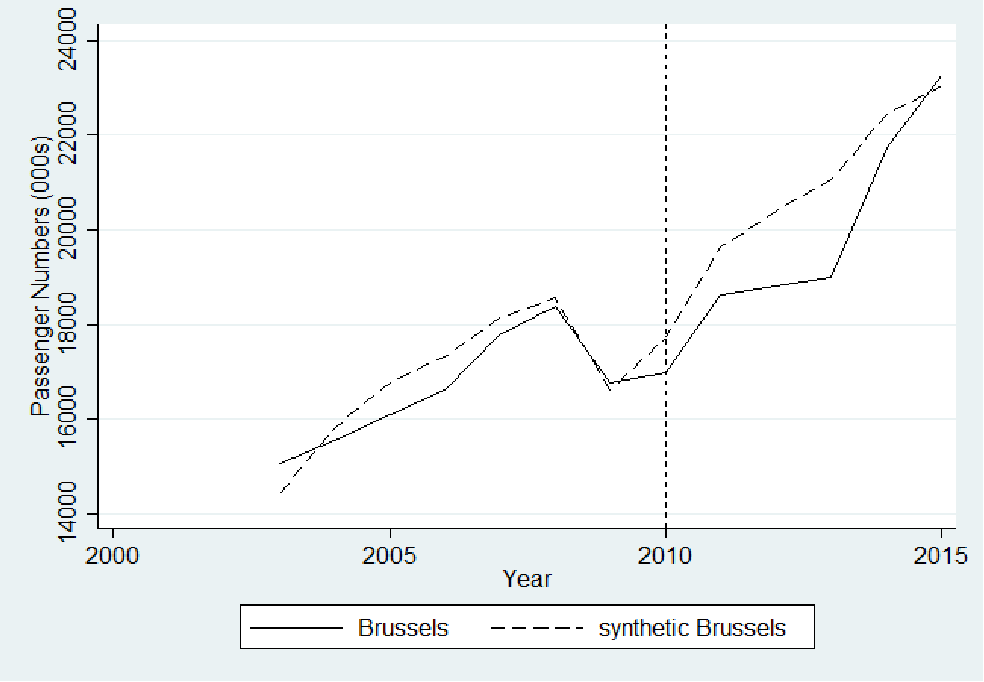


Figure 37. Synthetic Control – Berlin Schonefeld

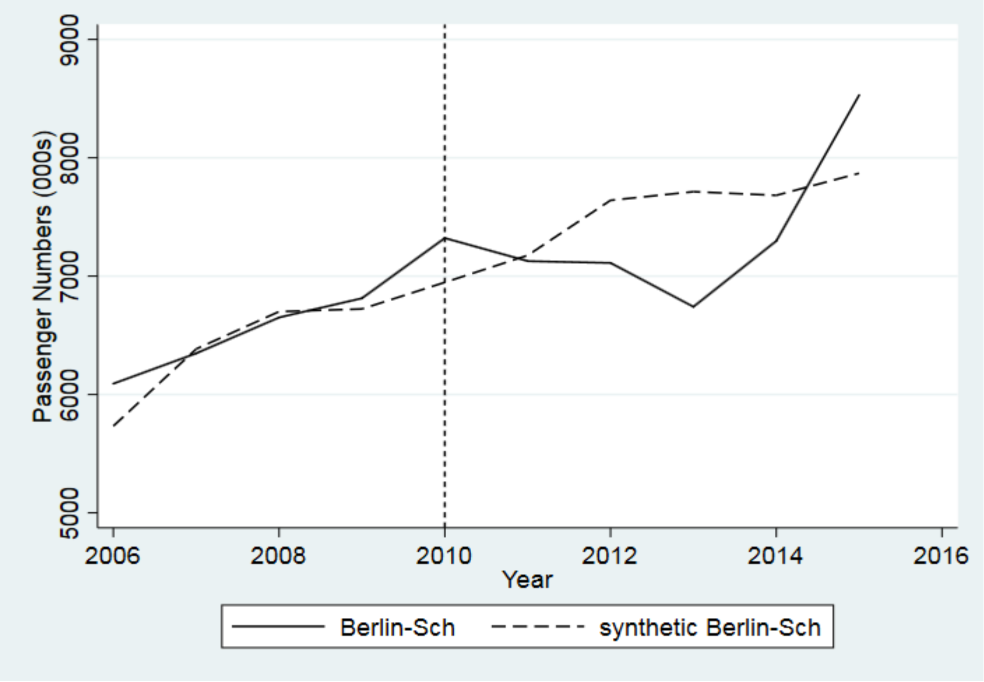


Figure 38. Synthetic Control – Berlin Tegel Airport

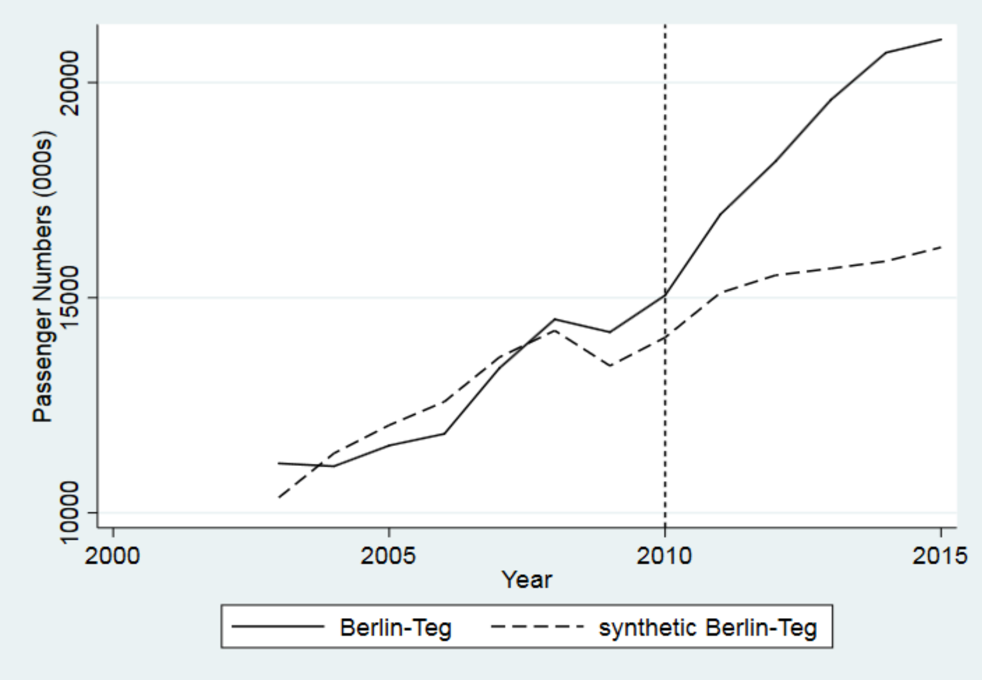


Figure 39. Synthetic Control – Charleroi Airport

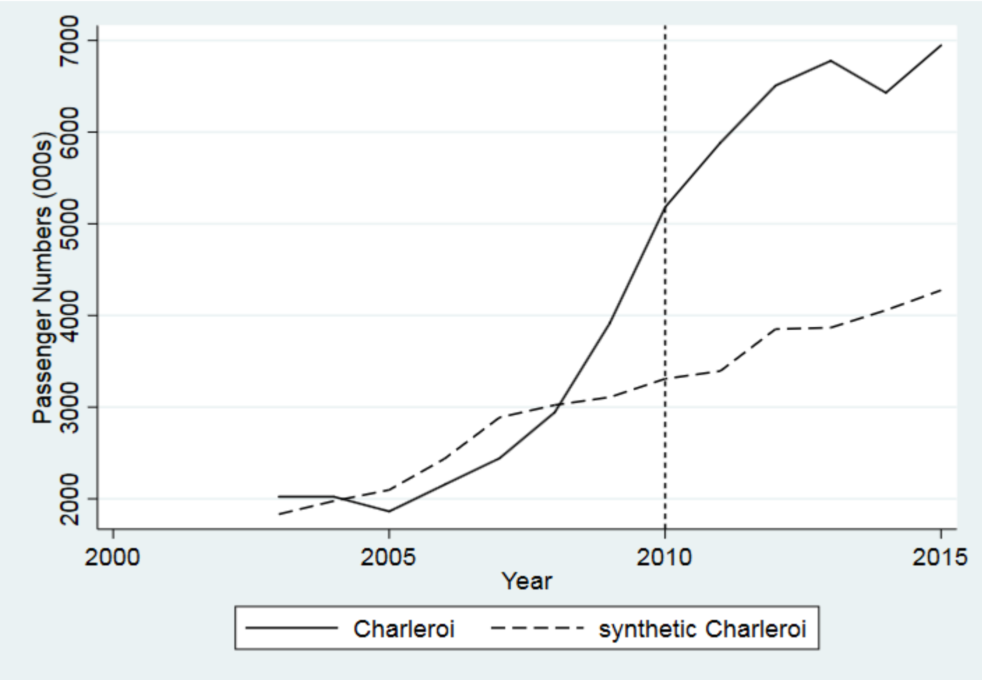


Figure 40. Synthetic Control – Cologne Airport

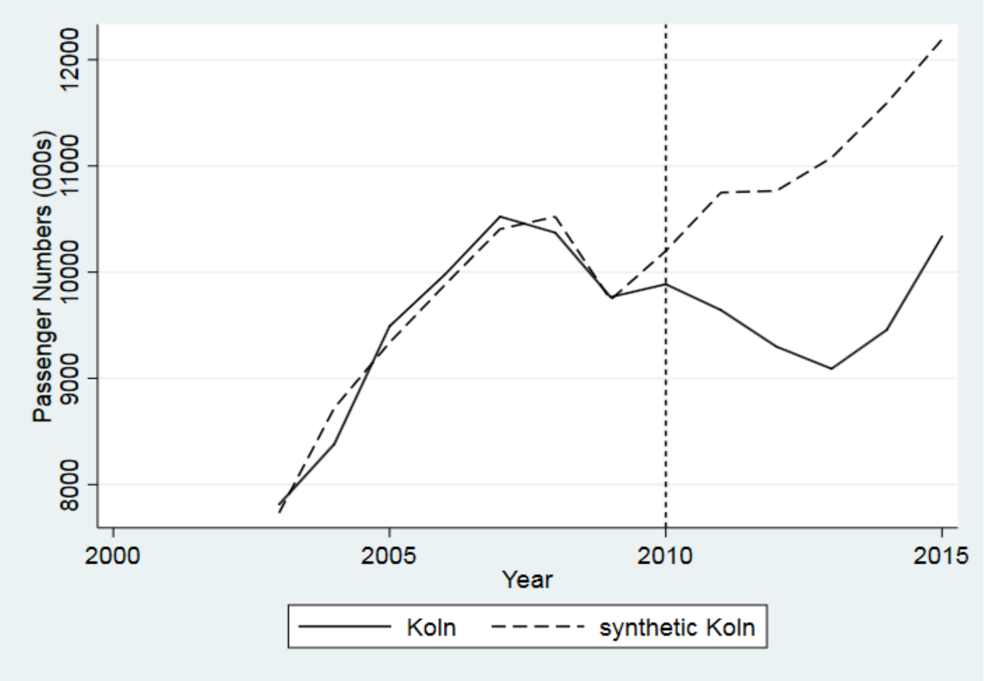


Figure 41. Synthetic Control – Dortmund Airport

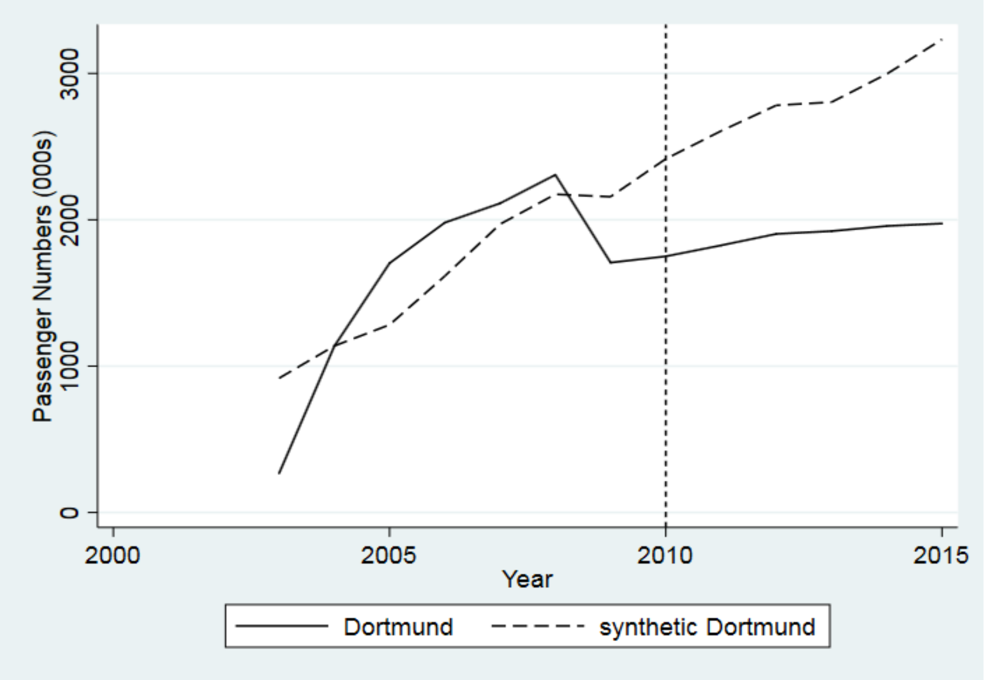


Figure 42. Synthetic Control – Dusseldorf Airport

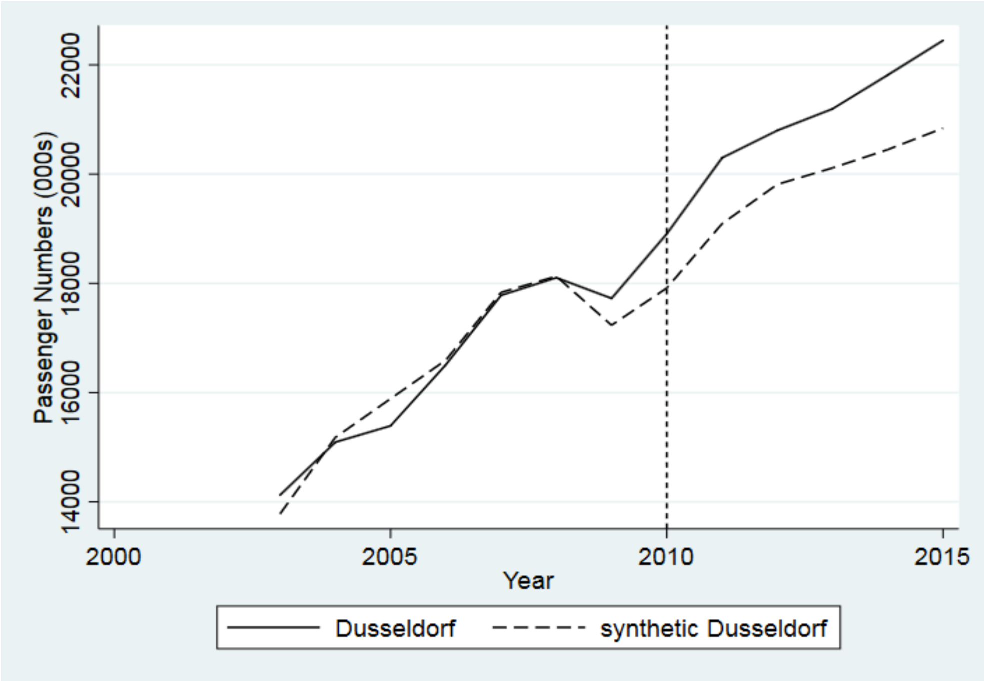


Figure 43. Synthetic Control – Dresden Airport

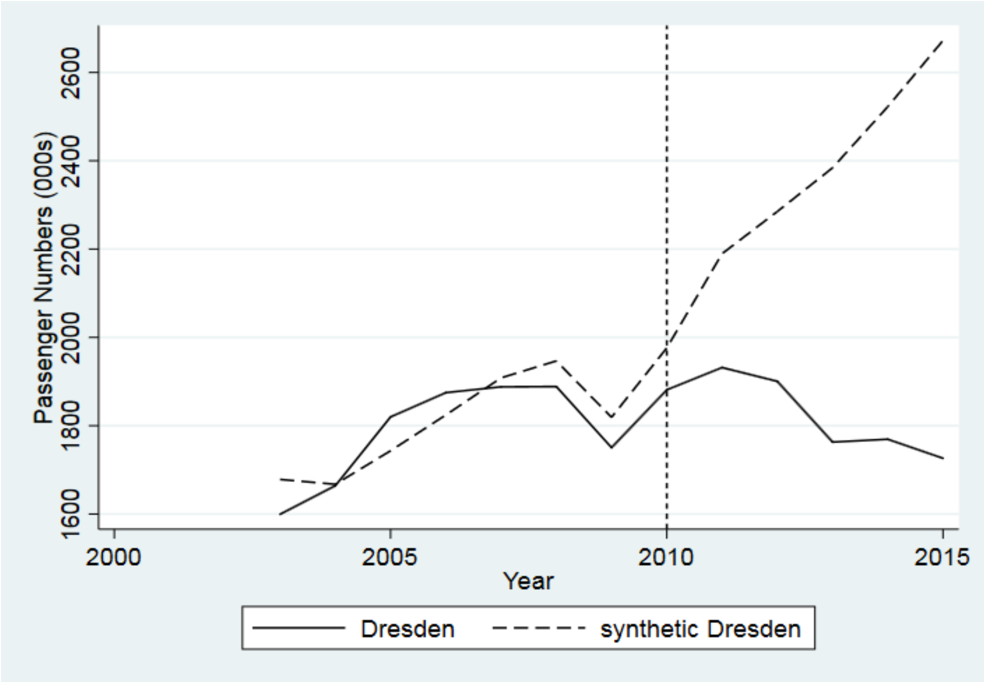


Figure 44. Synthetic Control – Eindhoven Airport

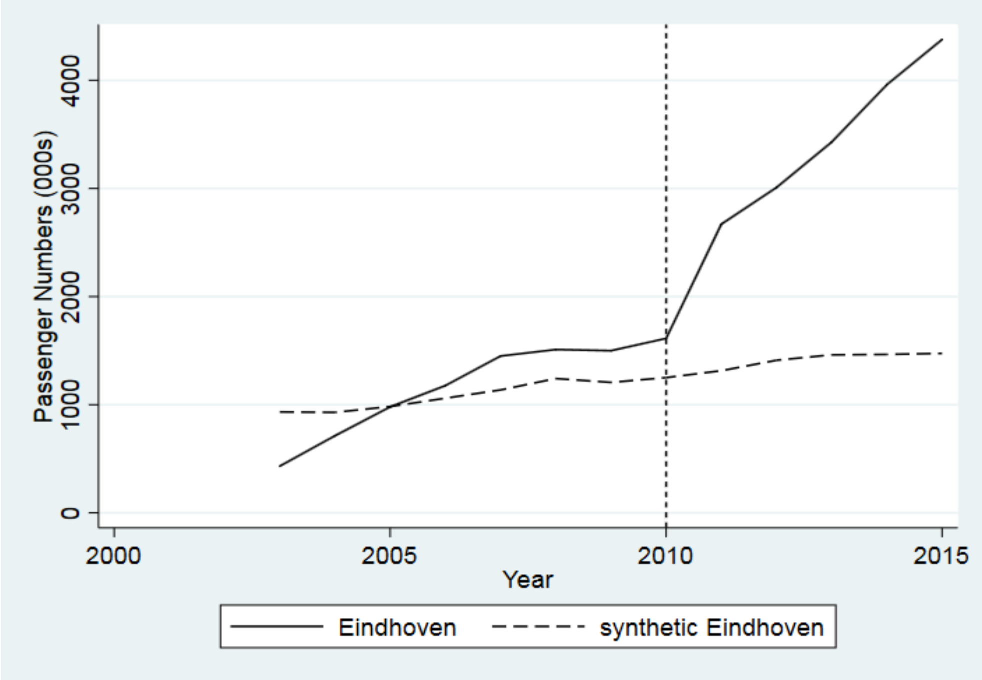


Figure 45. Synthetic Control – Erfurt Airport

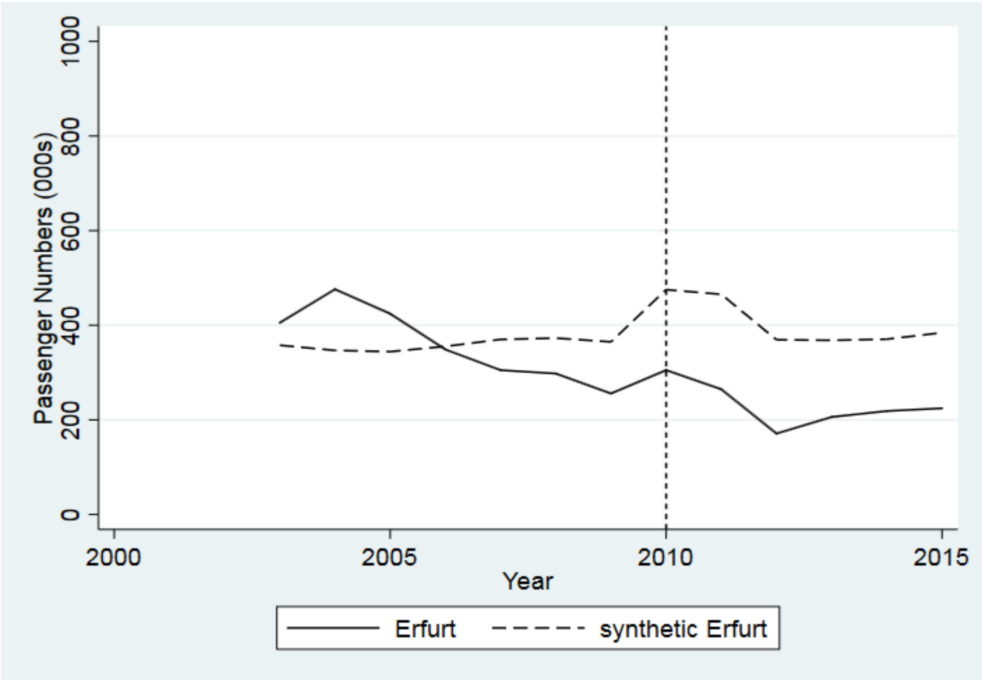


Figure 46. Synthetic Control – Frankfurt Hahn Airport

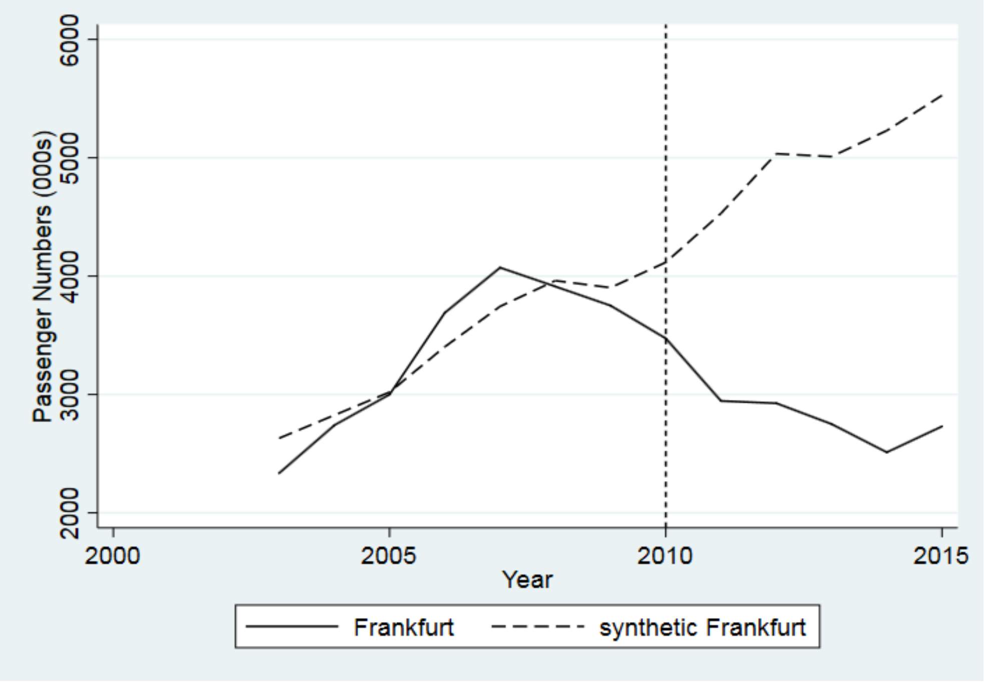


Figure 47. Synthetic Control - Friedrichshafen Airport

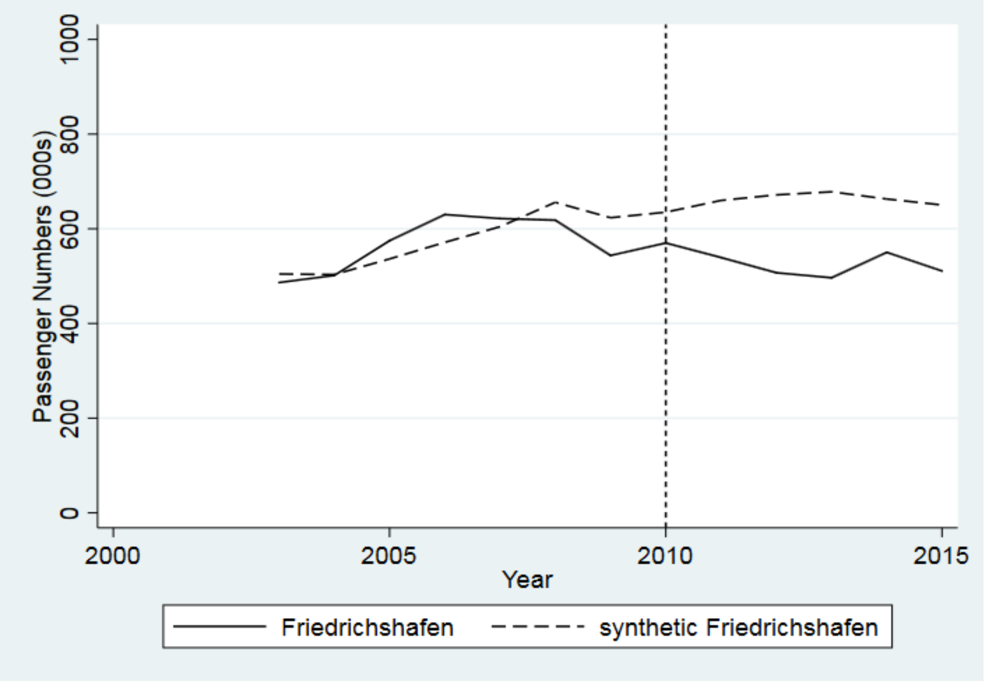


Figure 48. Synthetic Control – Hamburg Airport

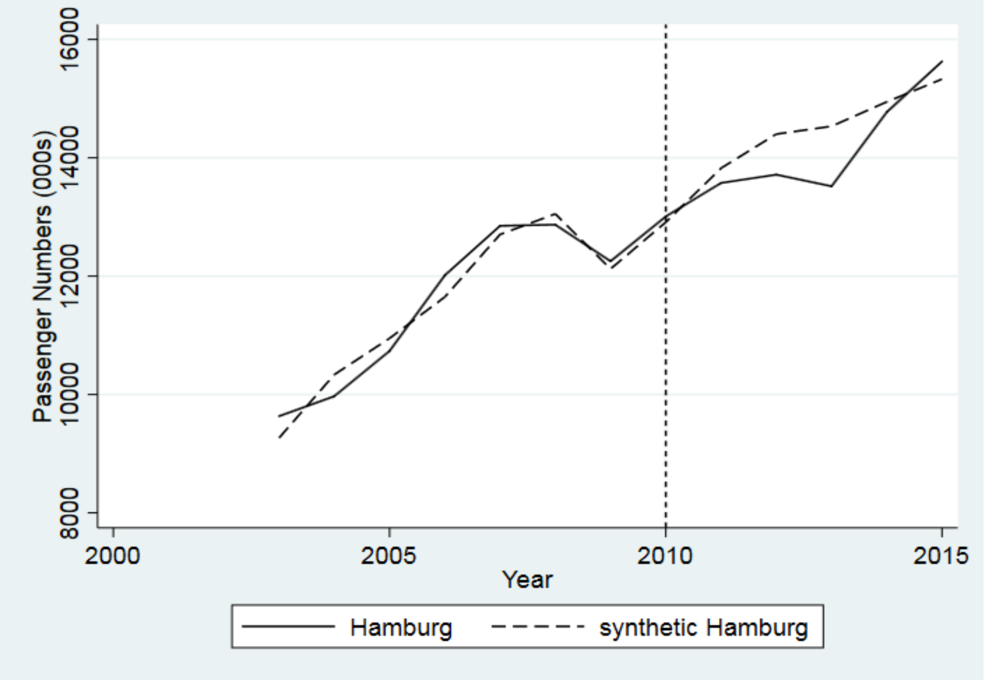


Figure 49. Synthetic Control – Hannover Airport

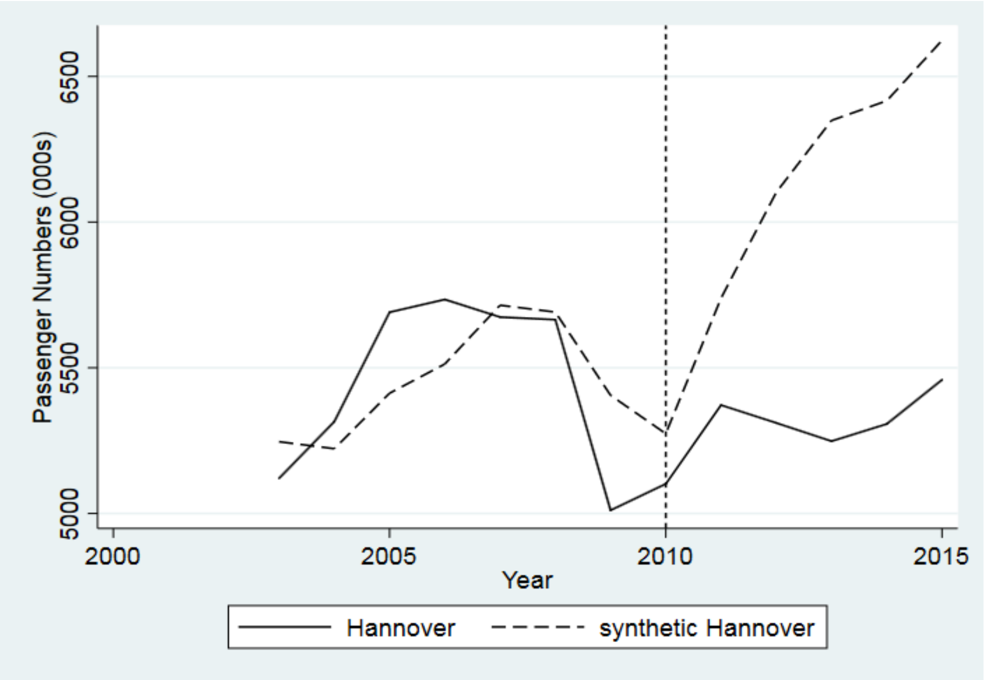


Figure 50. Synthetic Control – Karlsruhe Airport

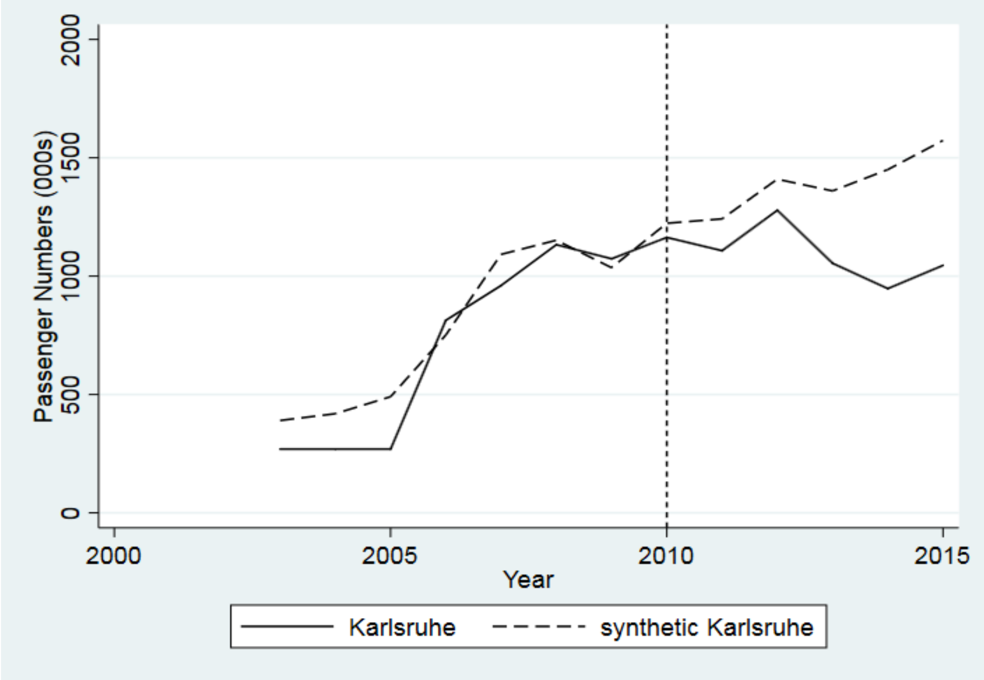


Figure 51. Synthetic Control – Leipzig Airport

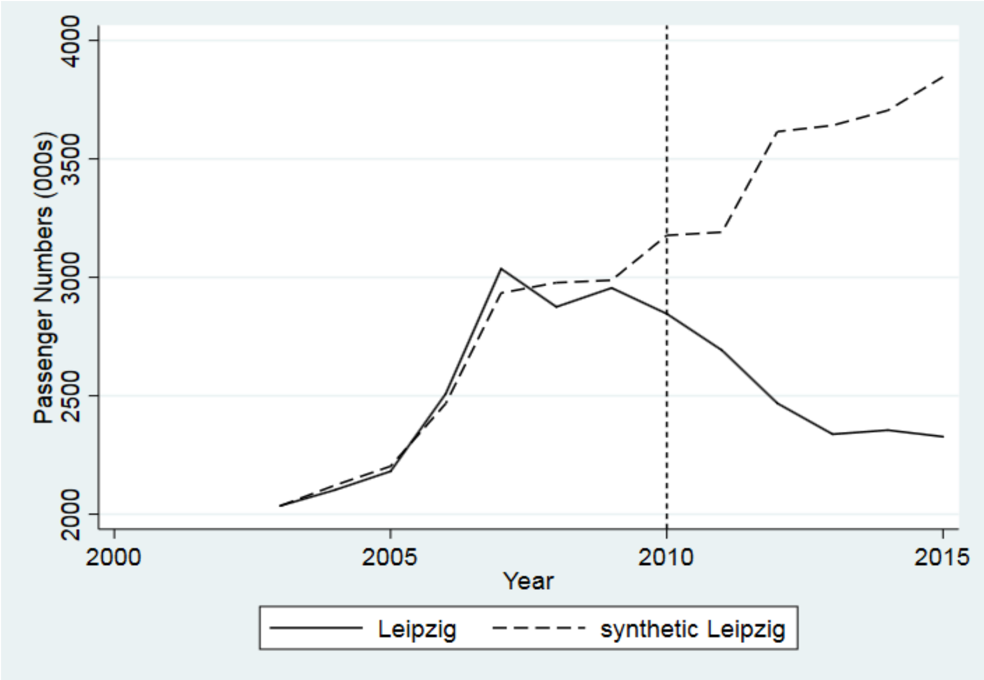


Figure 52. Synthetic Control – Luxembourg Airport

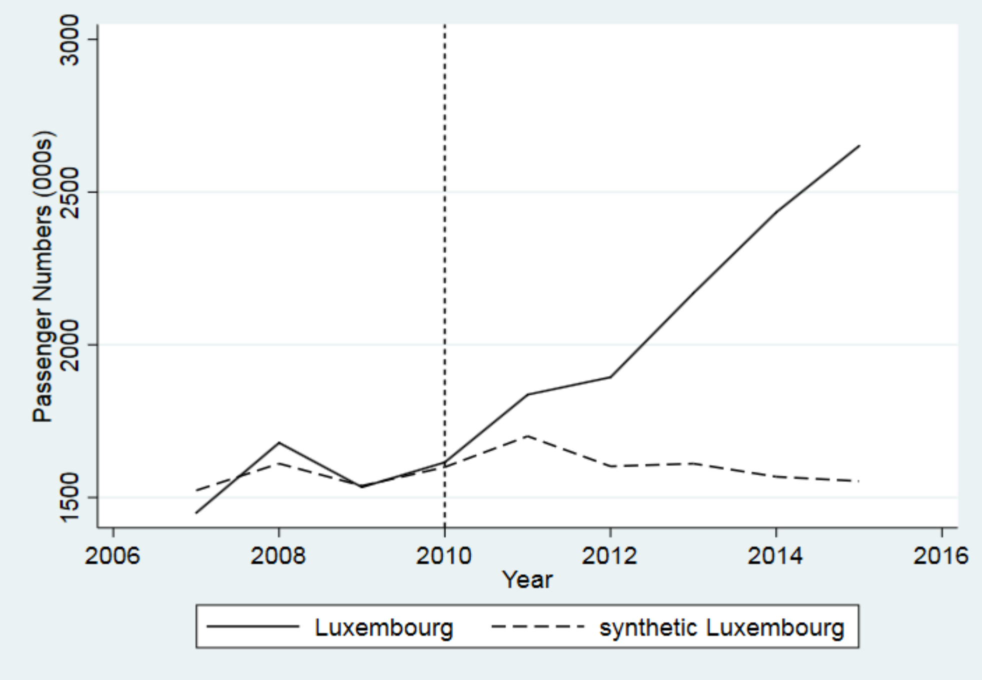


Figure 53. Synthetic Control - Maastricht Airport

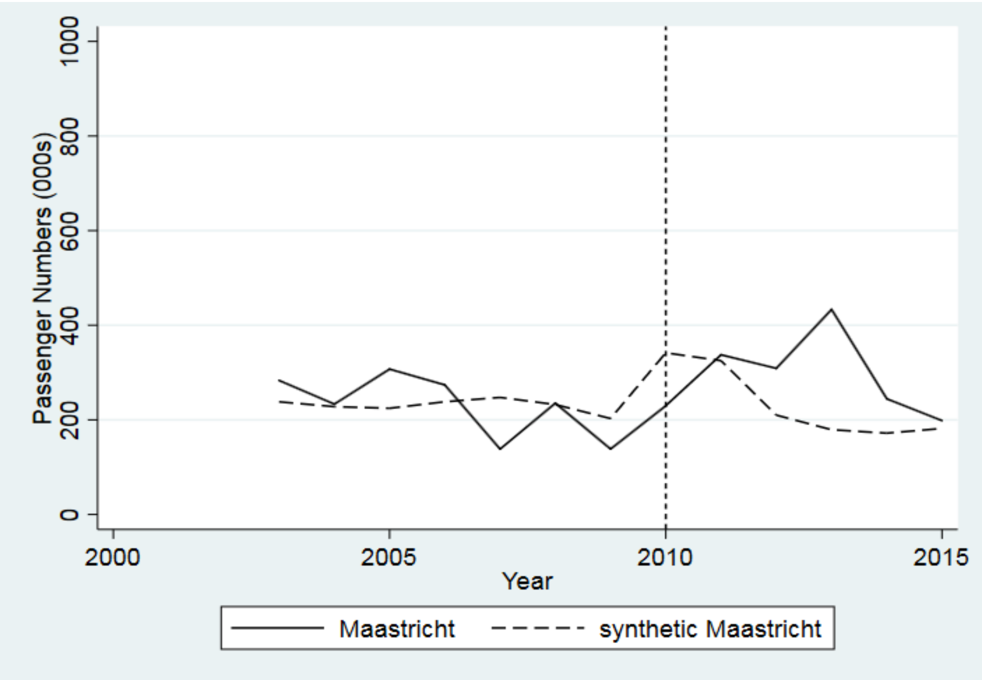


Figure 54. Synthetic Control – Metz Airport

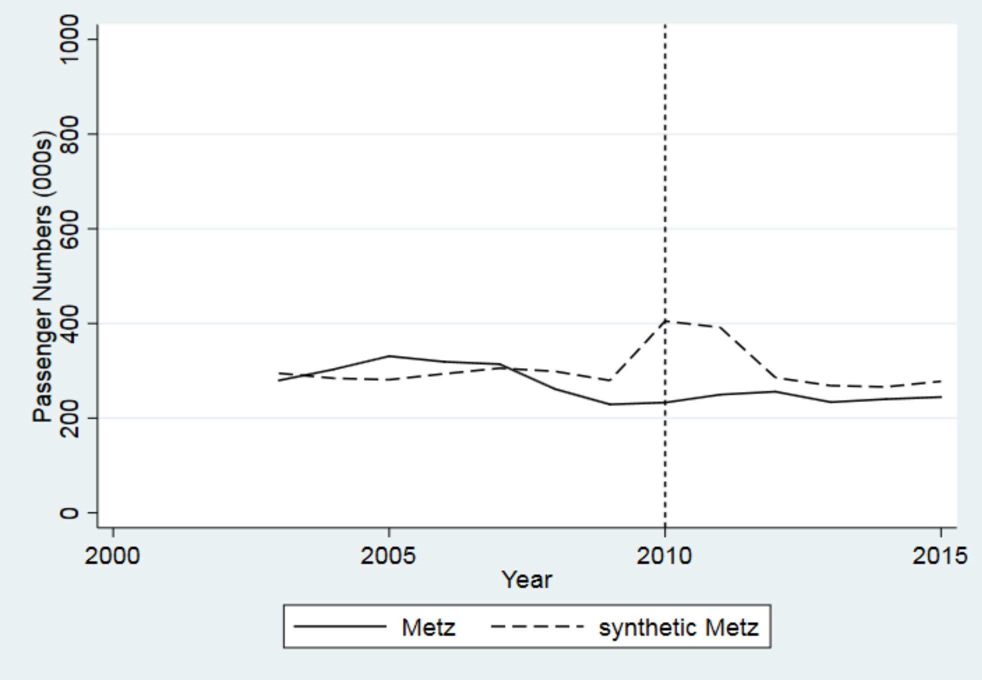


Figure 55. Synthetic Control – Munich Airport

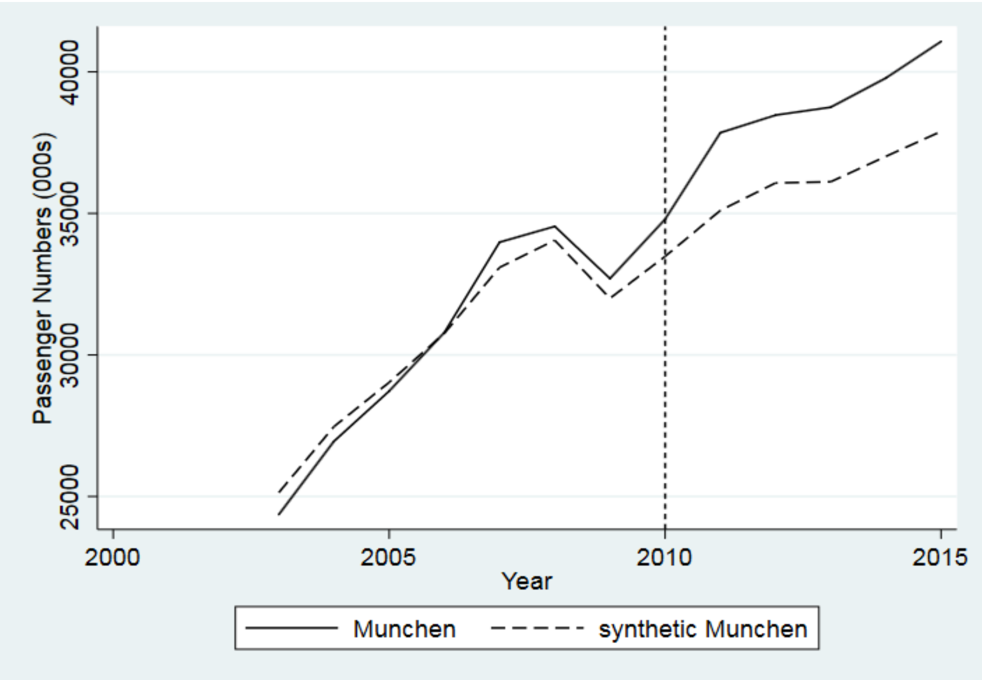


Figure 56. Synthetic Control – Munster Airport

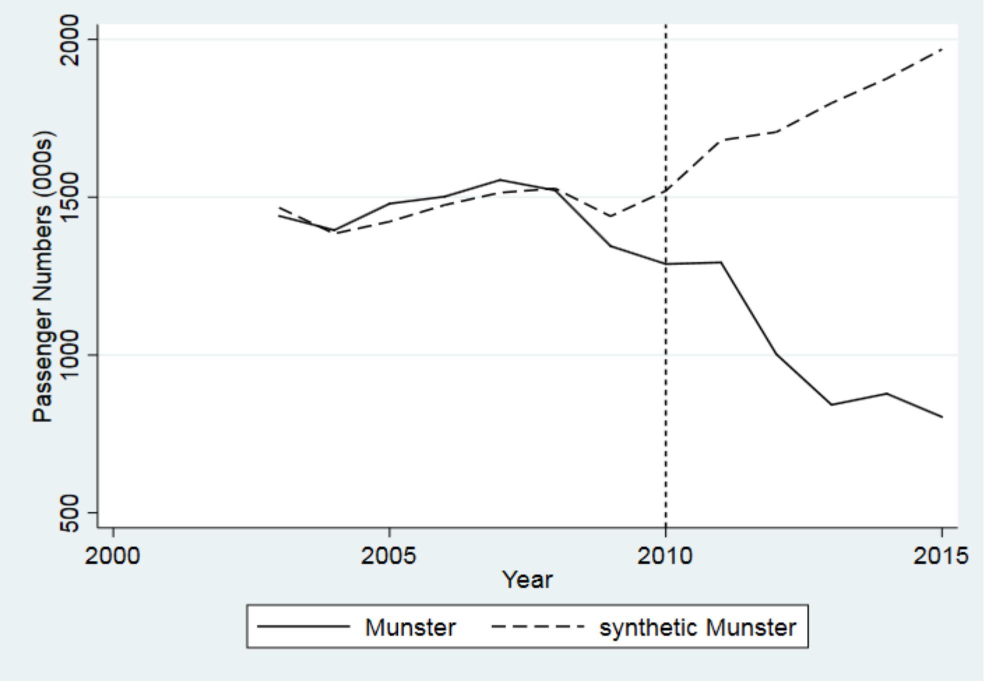


Figure 57. Synthetic Control – Nuremberg Airport

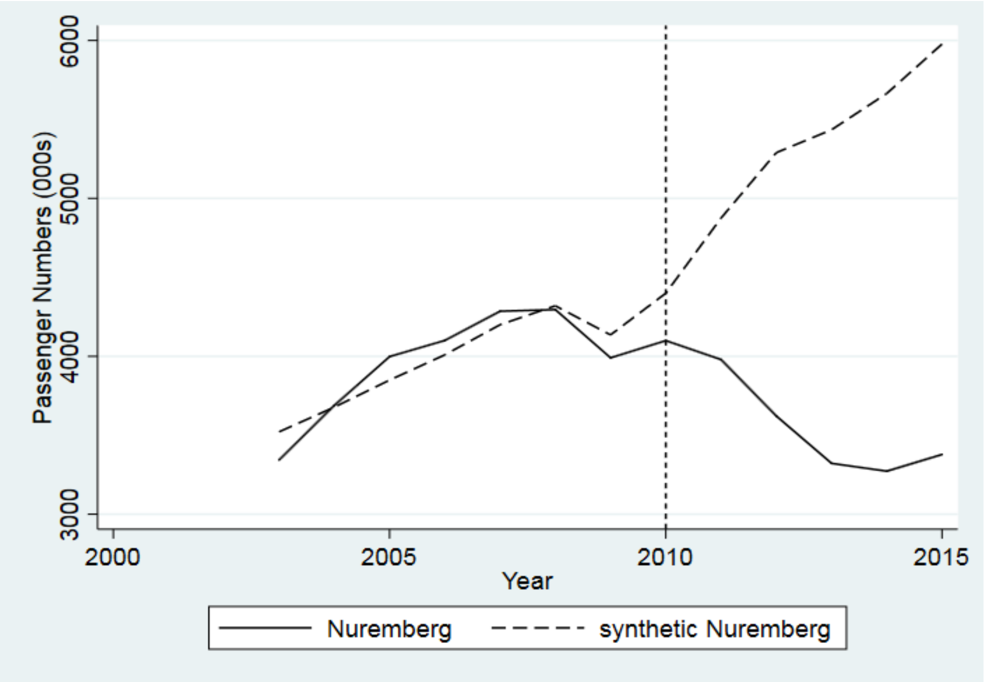


Figure 58. Synthetic Control – Saarbrucken Airport

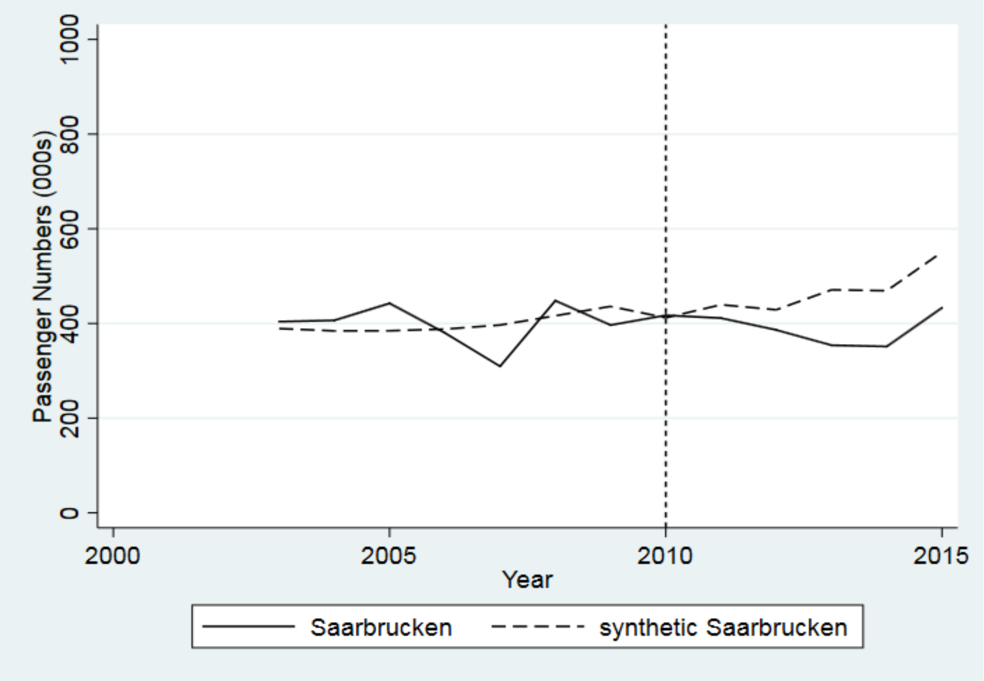


Figure 59. Synthetic Control – Stuttgart Airport

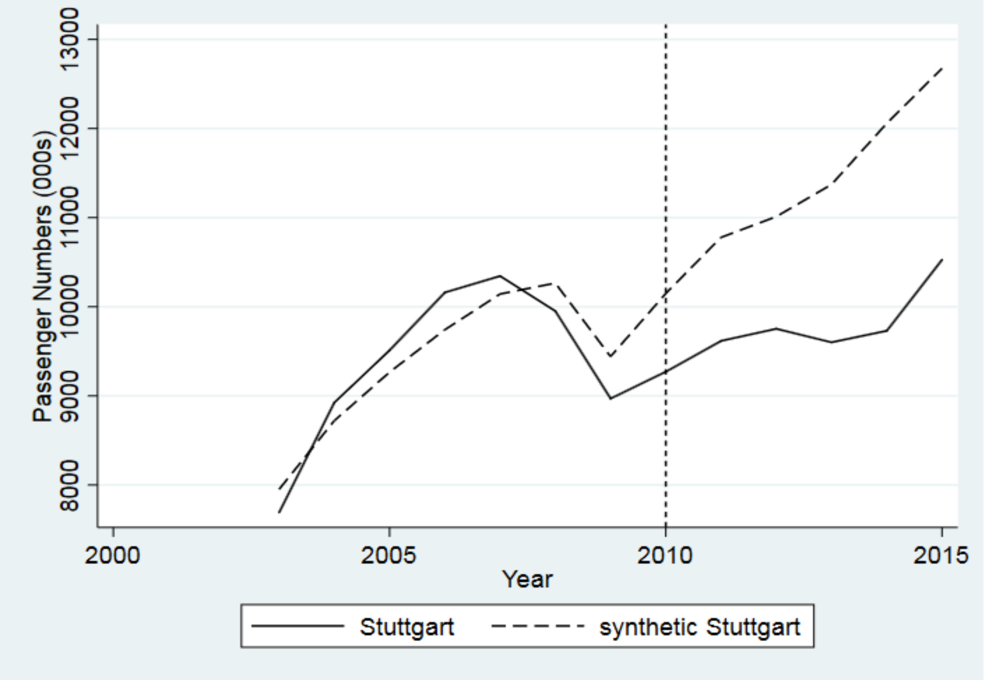


Figure 60. Synthetic Control – Szczecin Airport

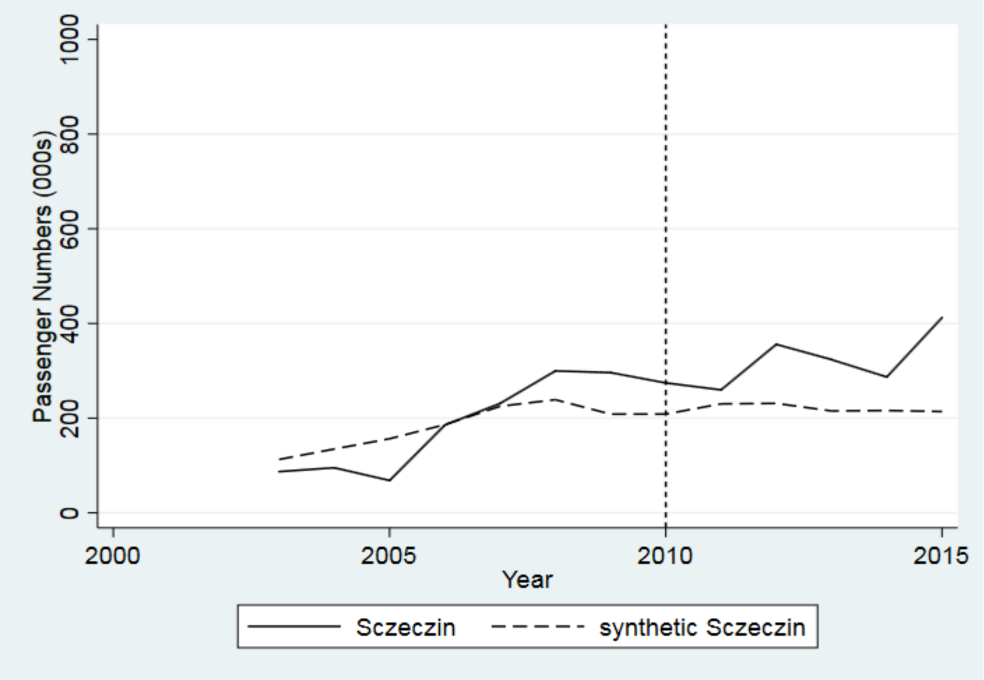
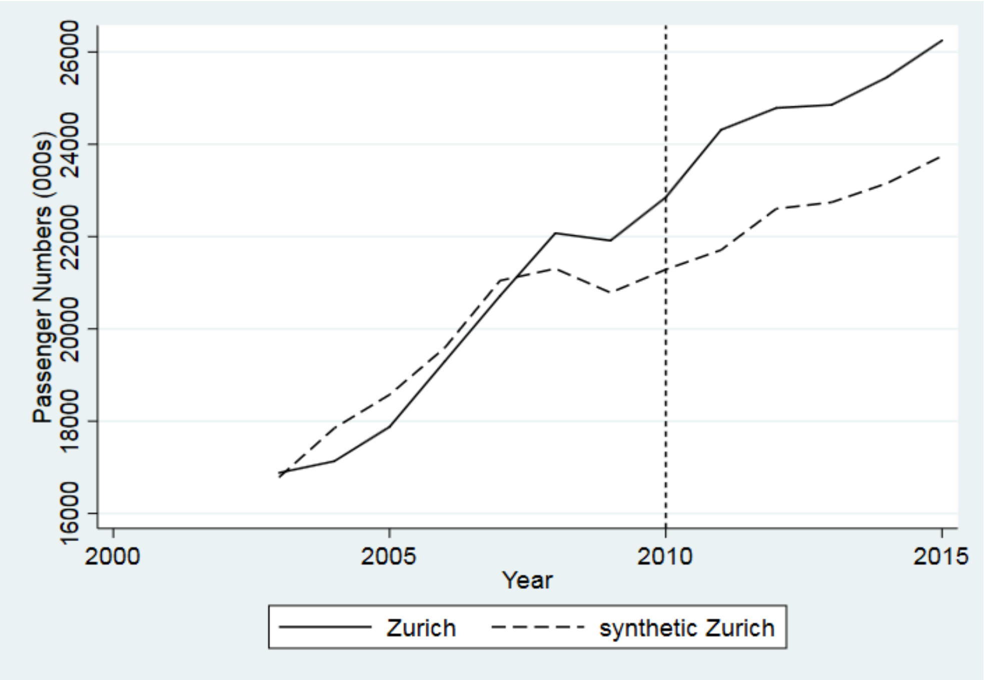
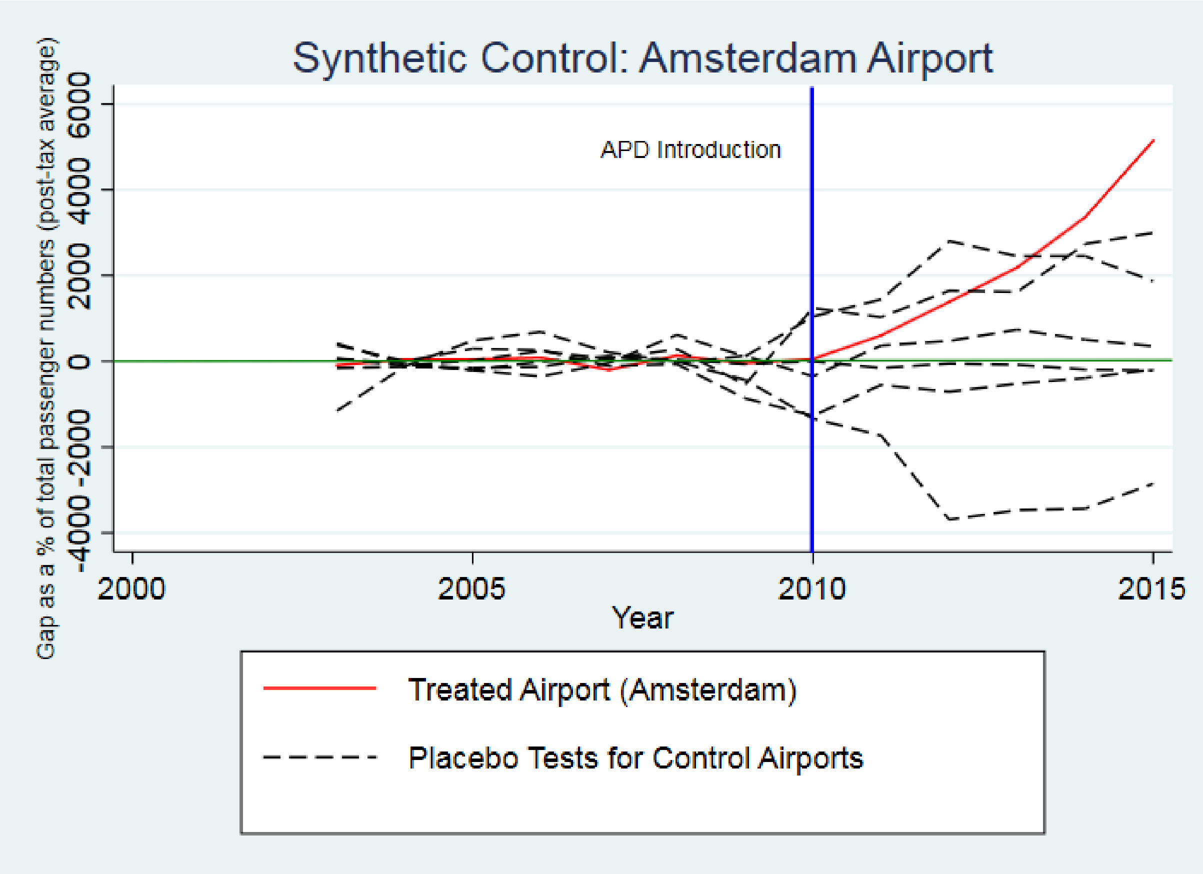
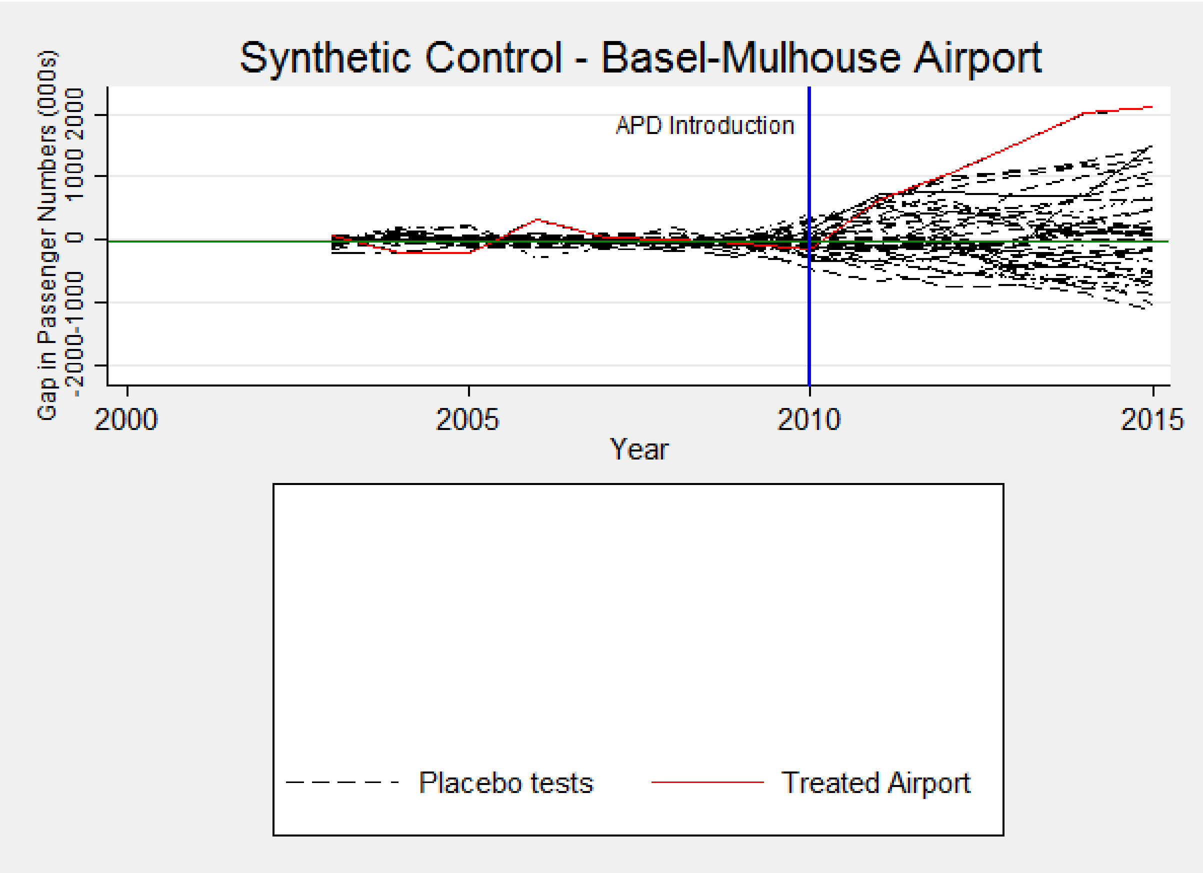


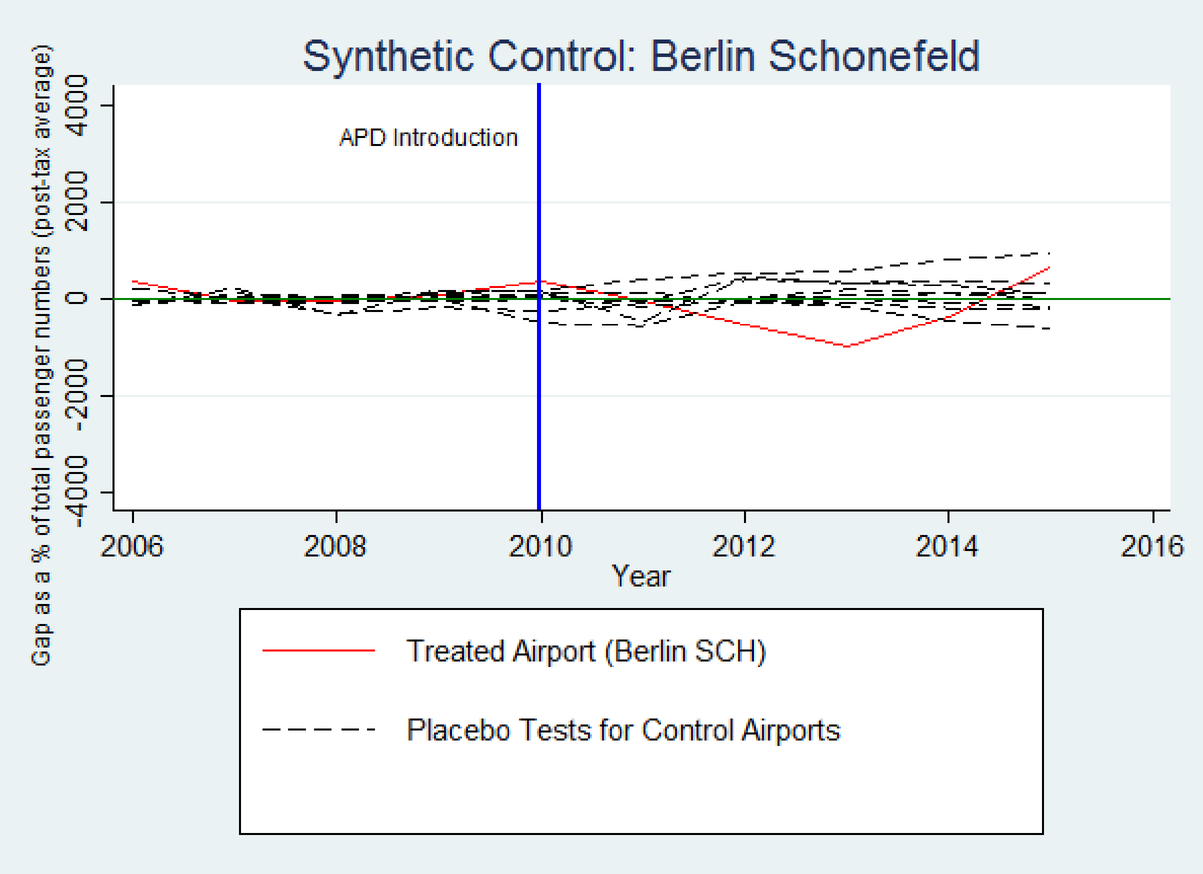
Figure 61. Synthetic Control – Zurich Airport



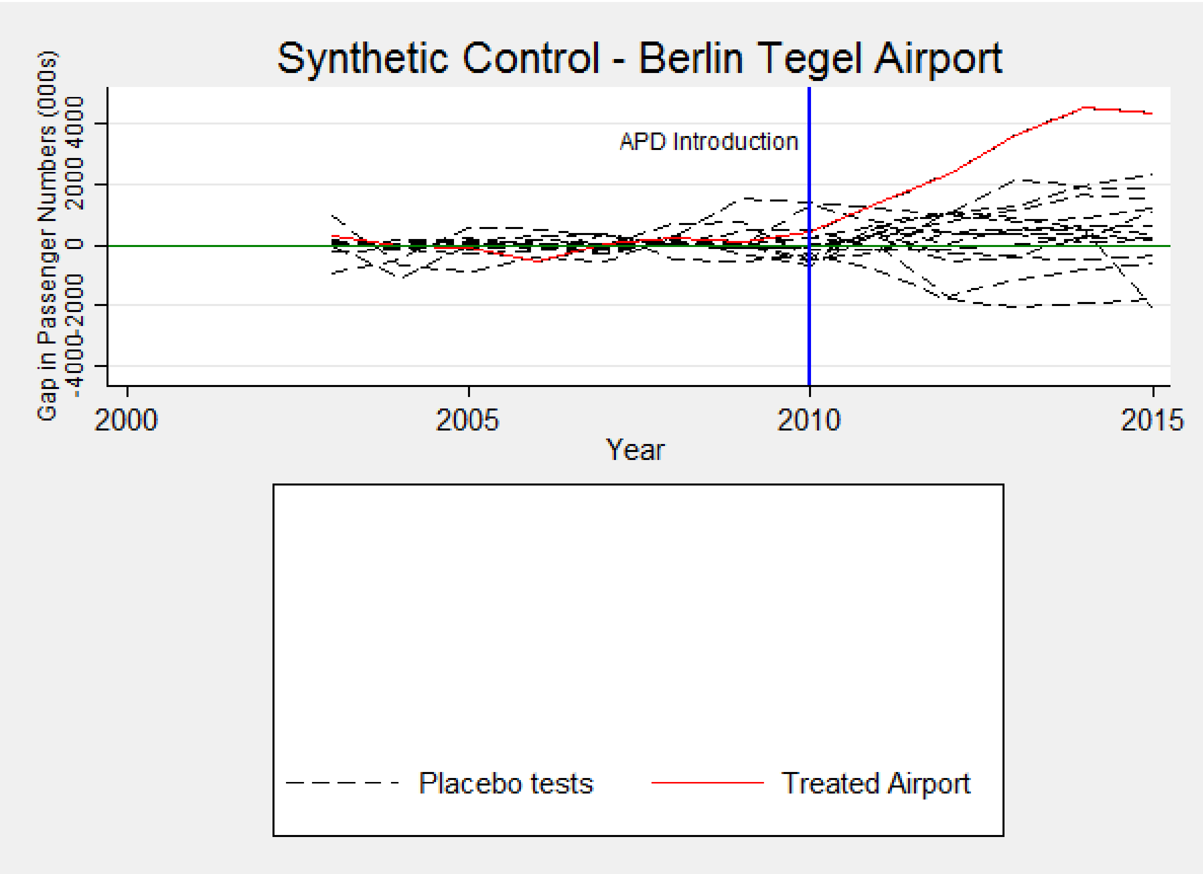
Synthetic Control: Placebo Tests (Sample A or B)



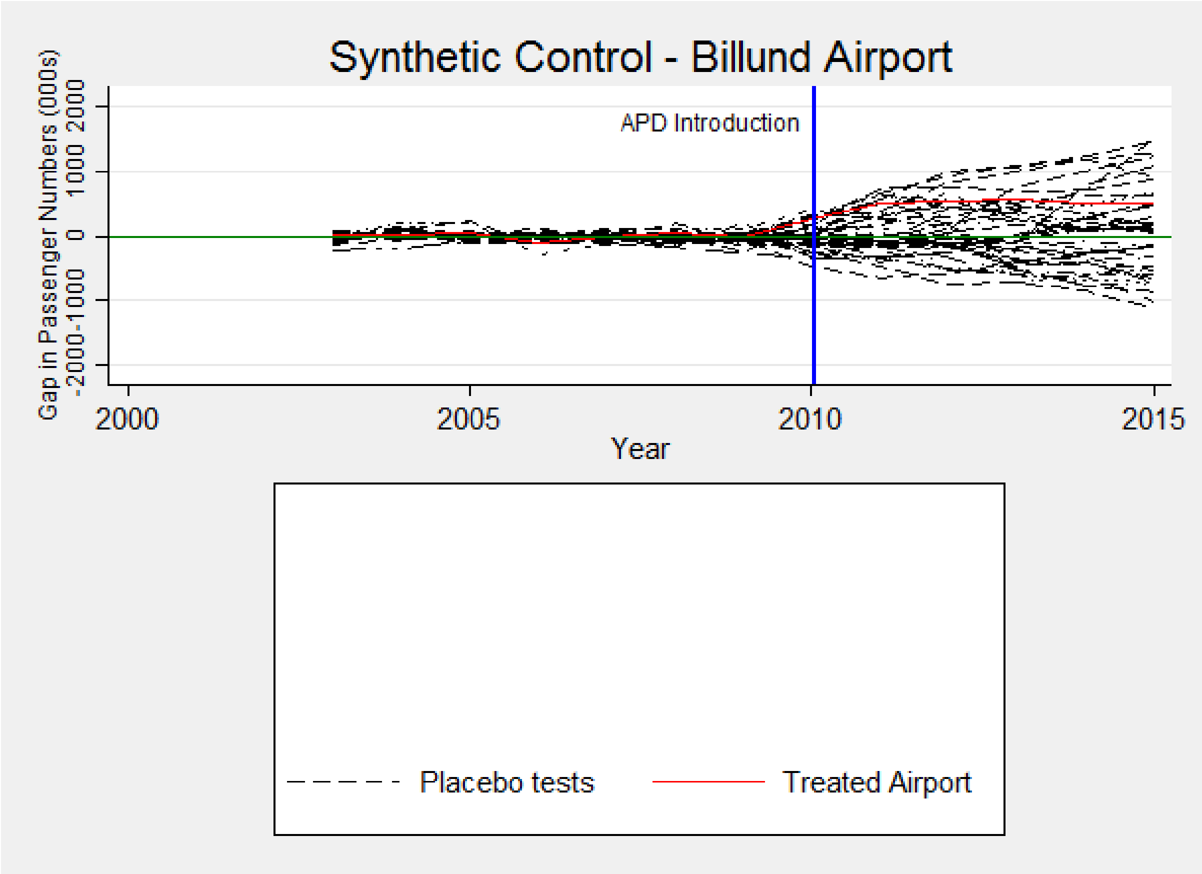


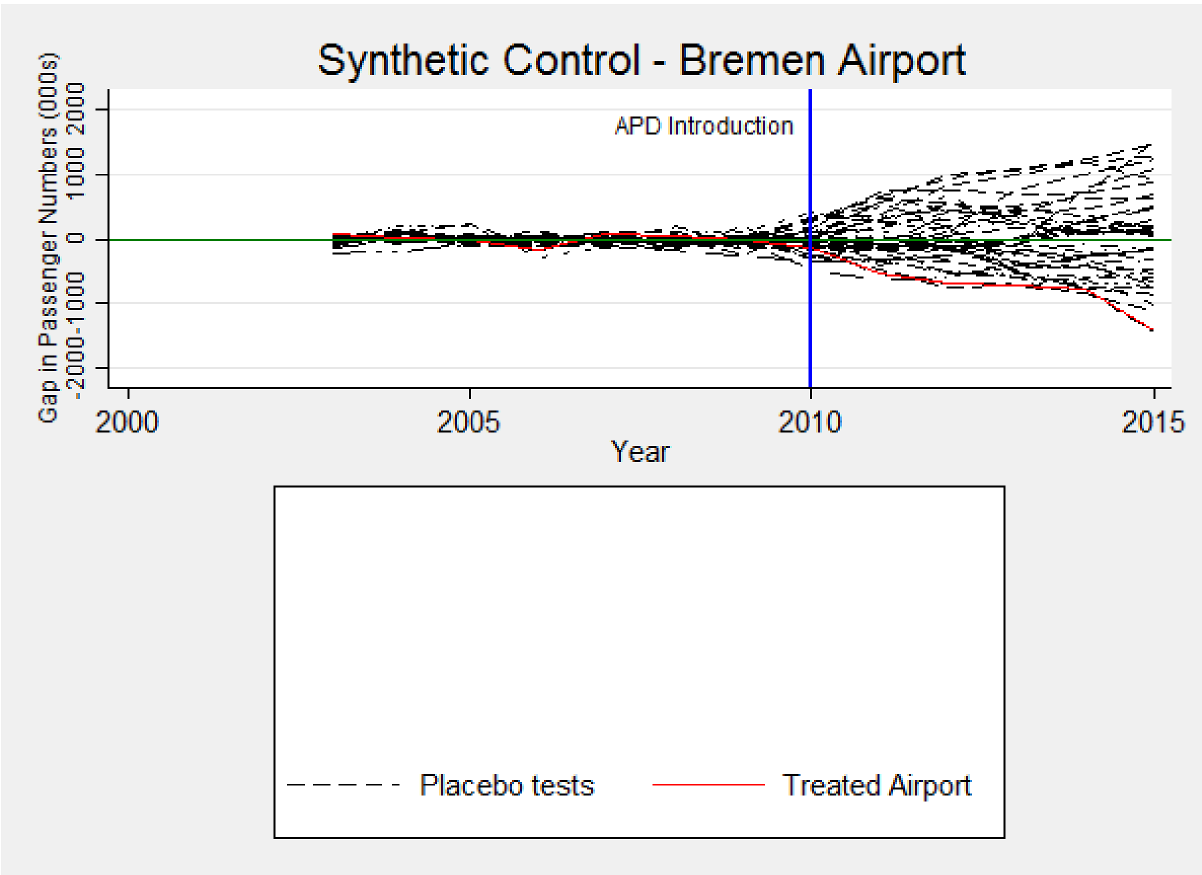


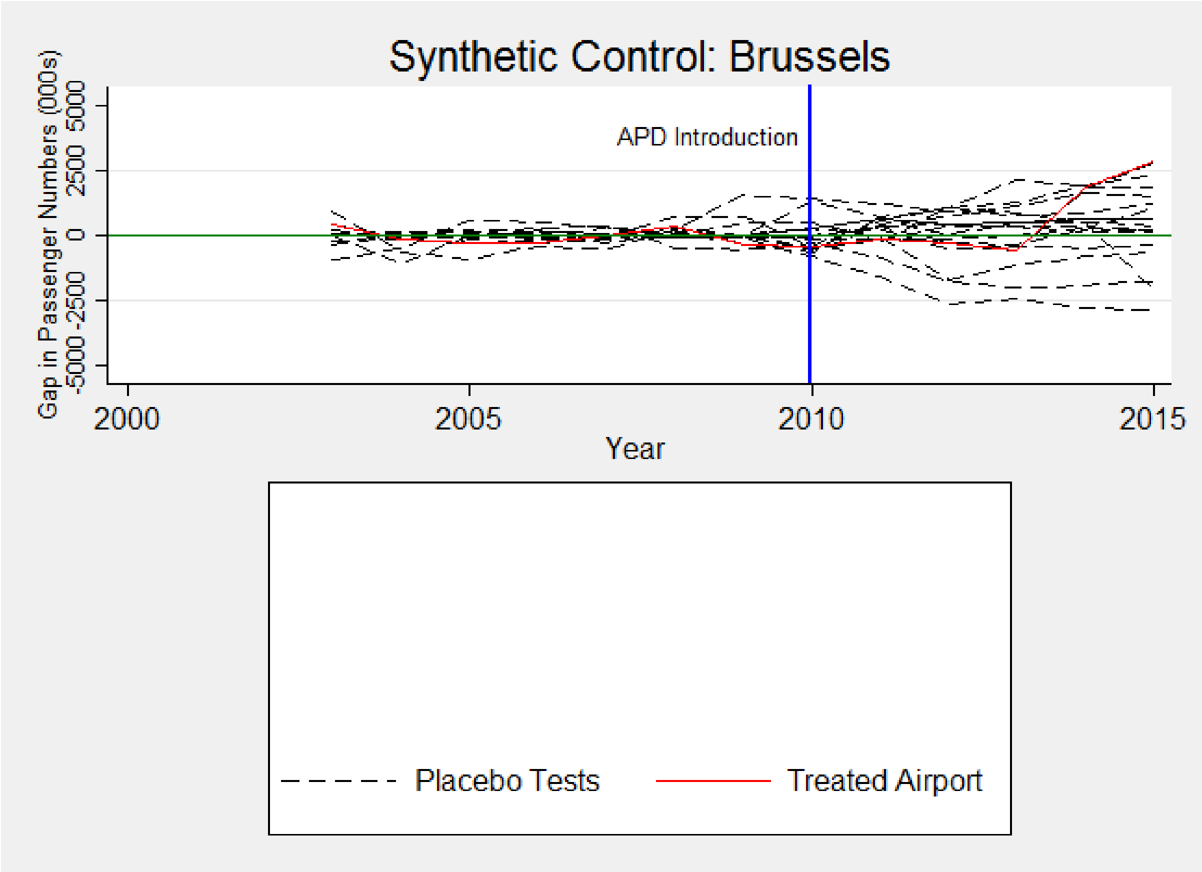
Synthetic Control: Berlin Schonefeld
Gap as a % of total passenger numbers (post-tax average)
-4000
-2000
0
2000
4000
APD Introduction
2006
2008
2010
2012
2014
2016
Year
Treated Airport (Berlin SCH)
Placebo Tests for Control Airports

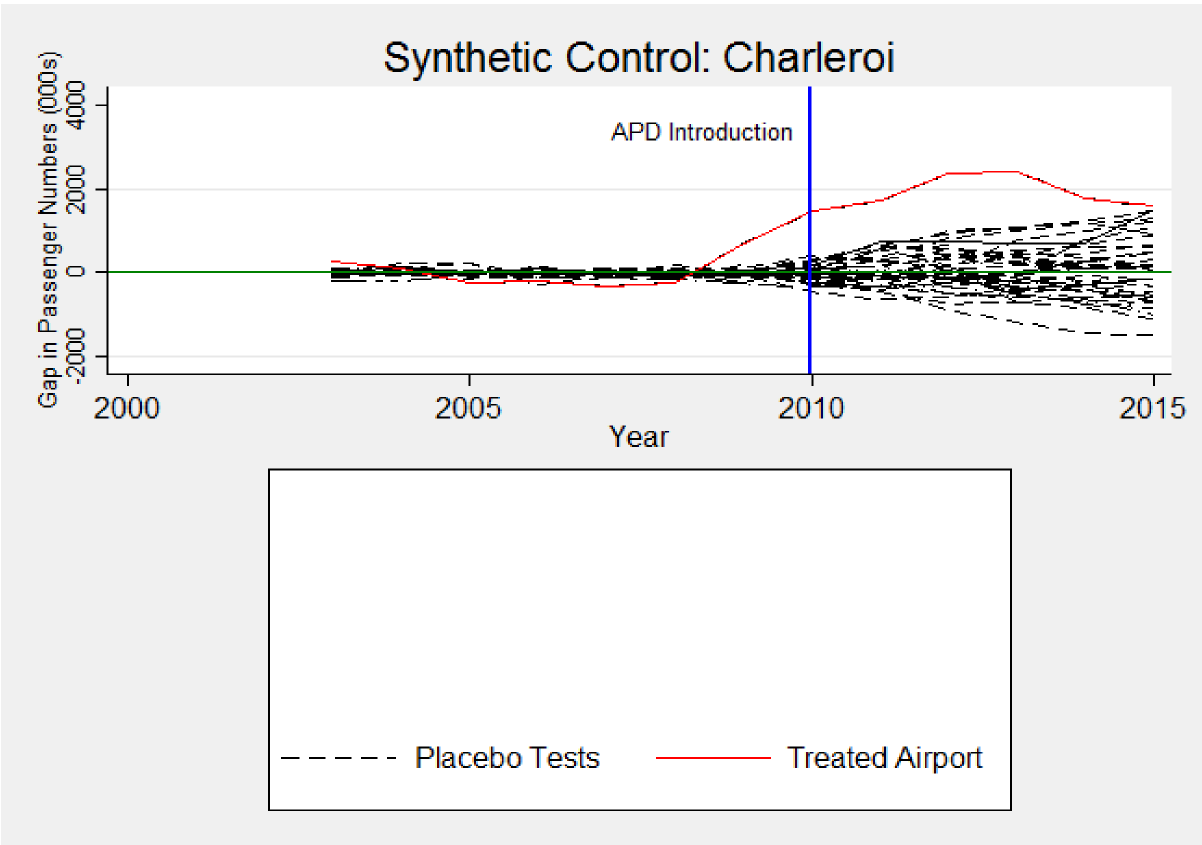


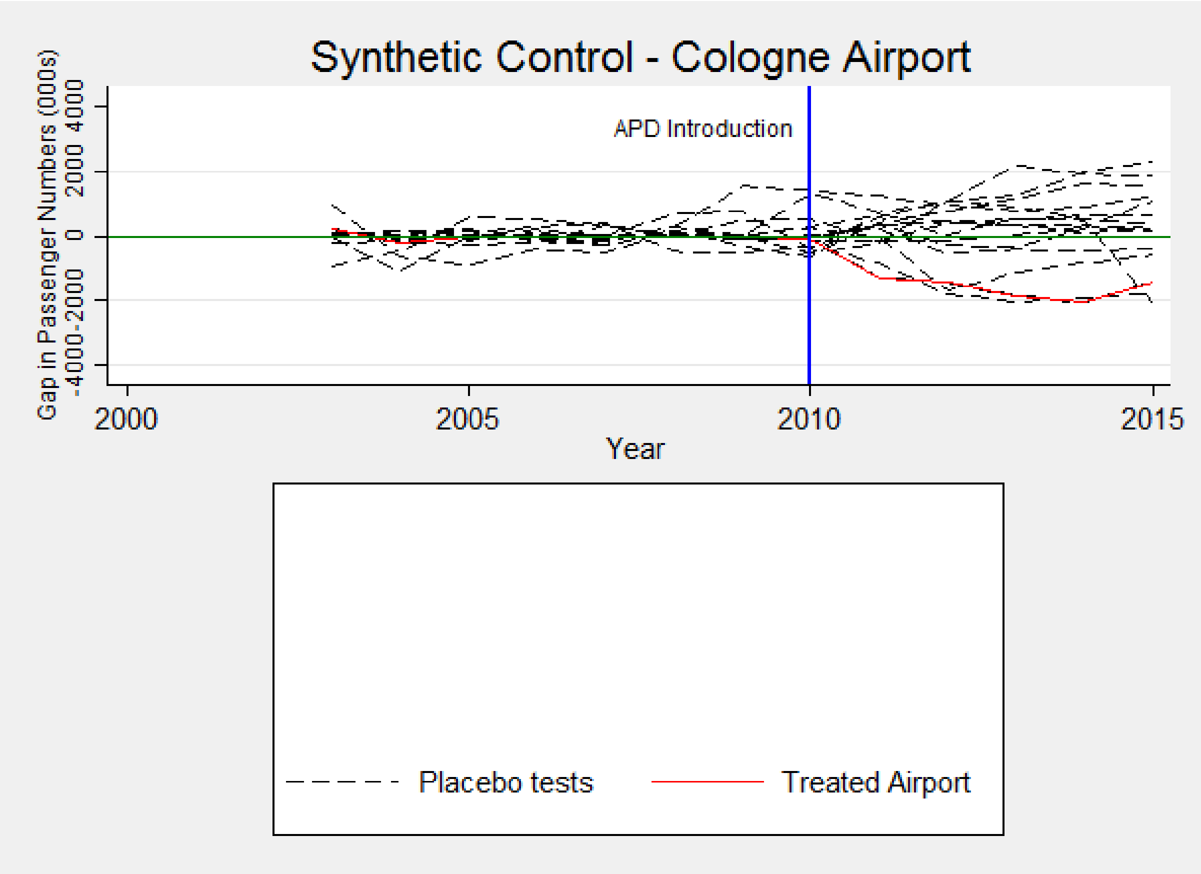
Synthetic Control - Berlin Tegel Airport
Gap in Passenger Numbers (000s)
-4000
-2000
0
2000
4000
APD Introduction
2000
2005
2010
2015
Year
Placebo tests
Treated Airport

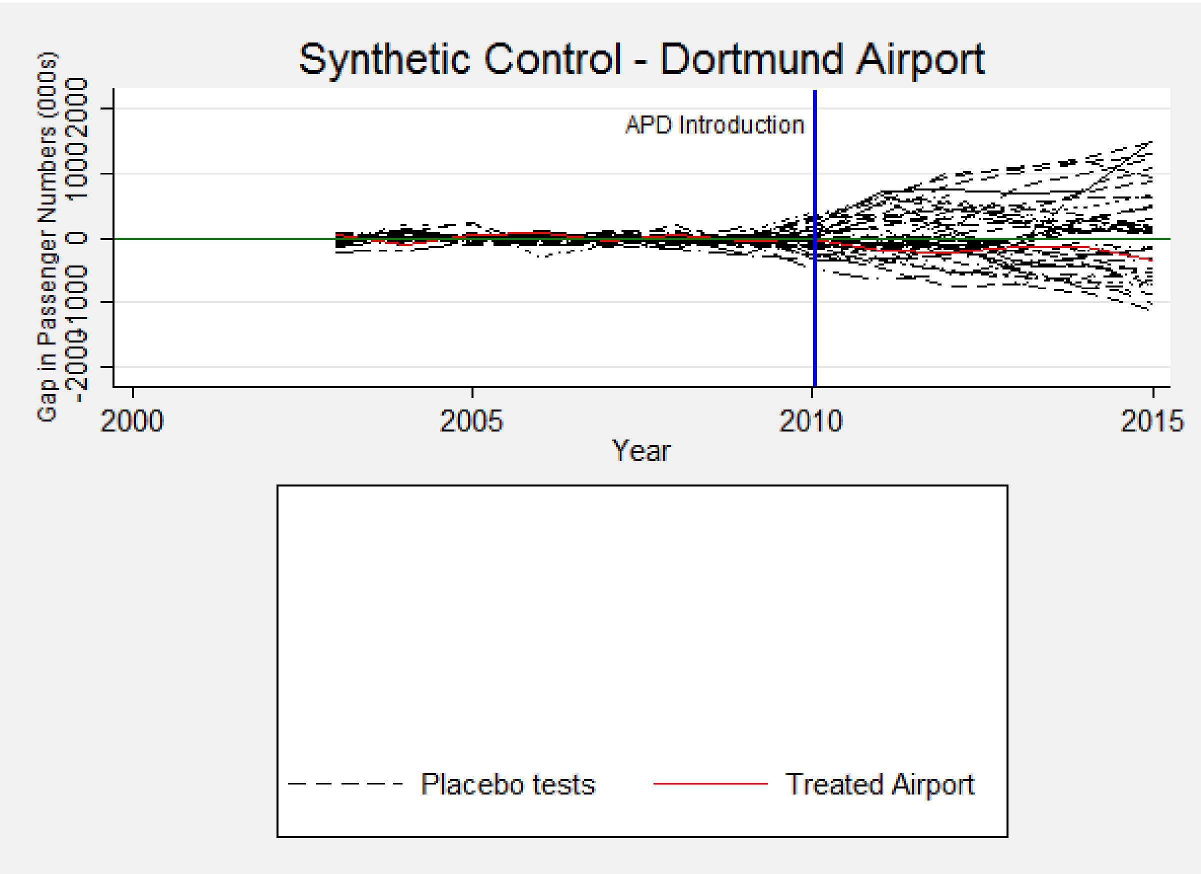

Synthetic Control - Billund Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport

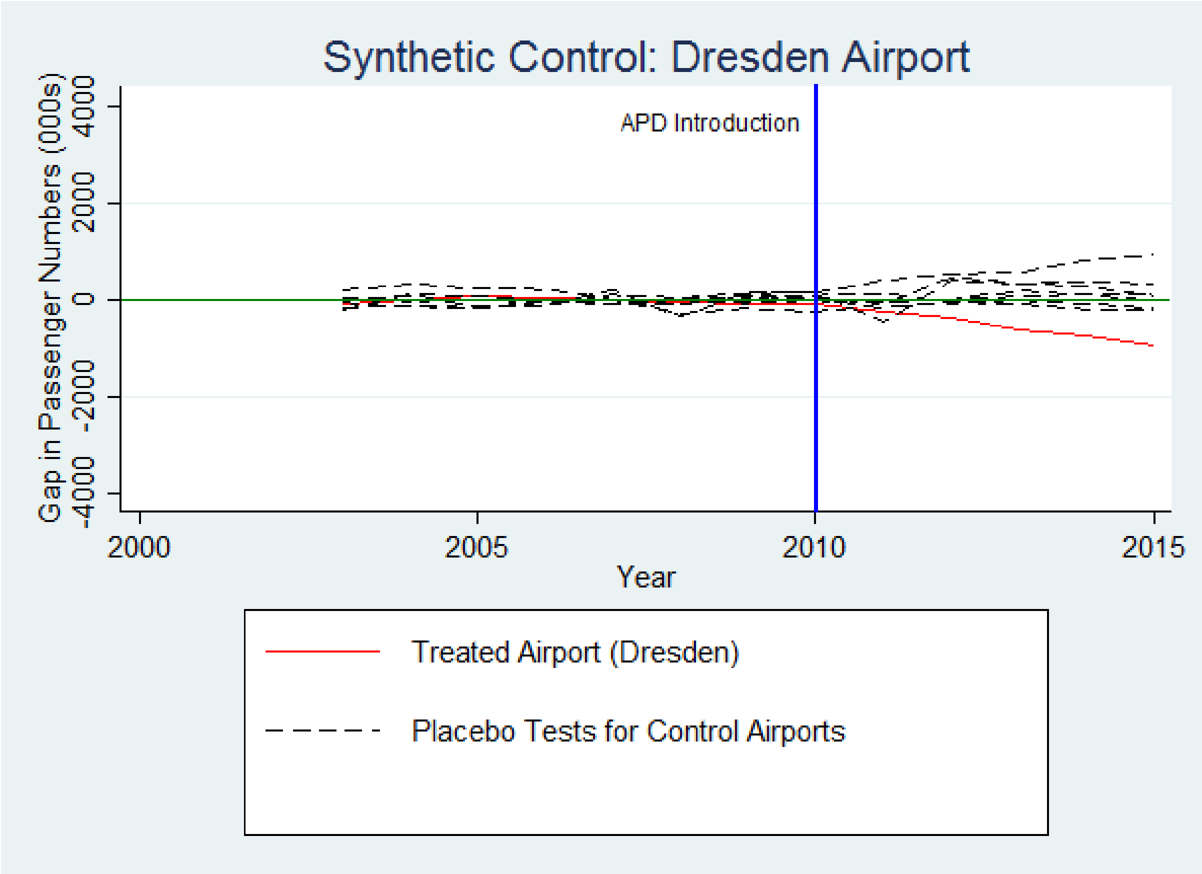

Synthetic Control - Bremen Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport


Synthetic Control: Brussels
APD Introduction
Gap in Passenger Numbers (000s)
-5000
-2500
0
2500
5000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport

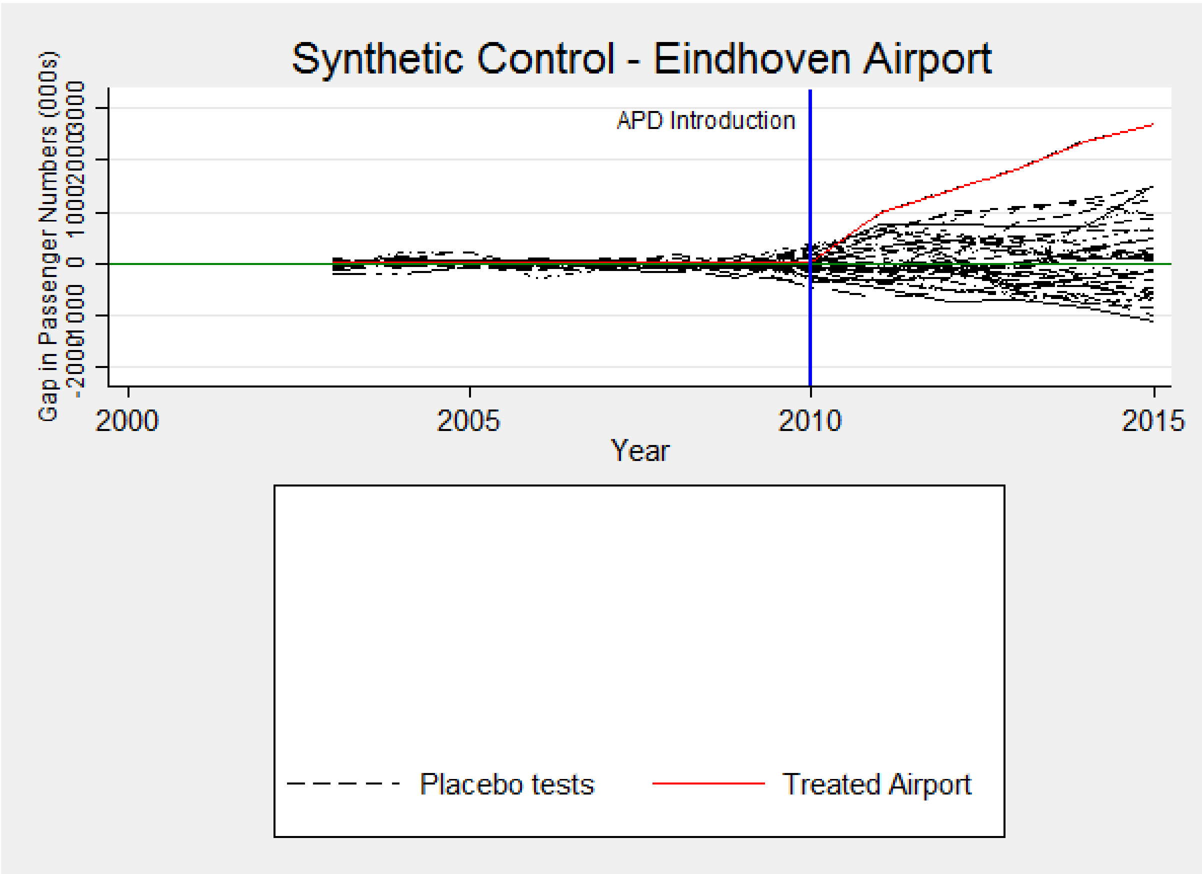

Synthetic Control: Charleroi
APD Introduction
Gap in Passenger Numbers (000s)
-2000
0
2000
4000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport


Synthetic Control - Cologne Airport
Gap in Passenger Numbers (000s)
-4000
-2000
0
2000
4000
APD Introduction
2000
2005
2010
2015
Year
Placebo tests
Treated Airport

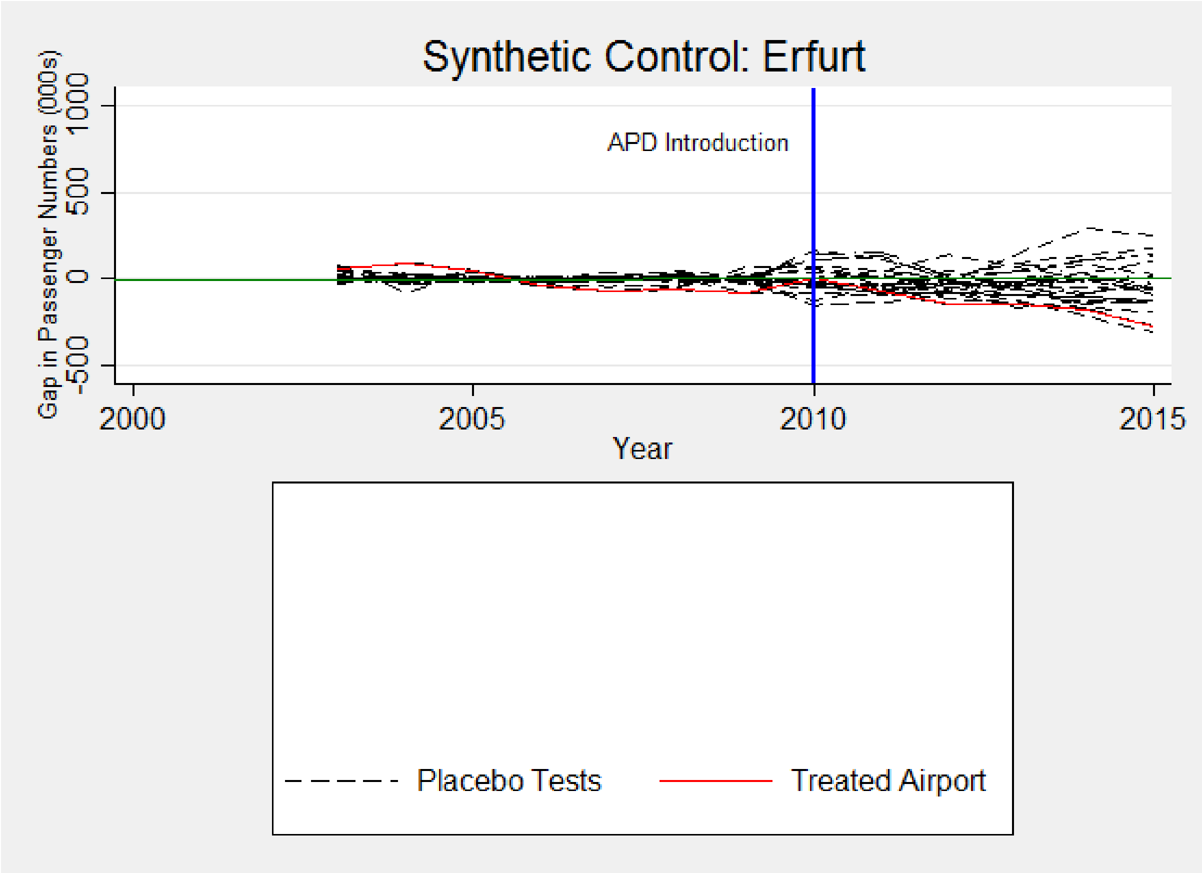

Synthetic Control - Dortmund Airport
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
APD Introduction
2000
2005
2010
2015
Year
Placebo tests
Treated Airport

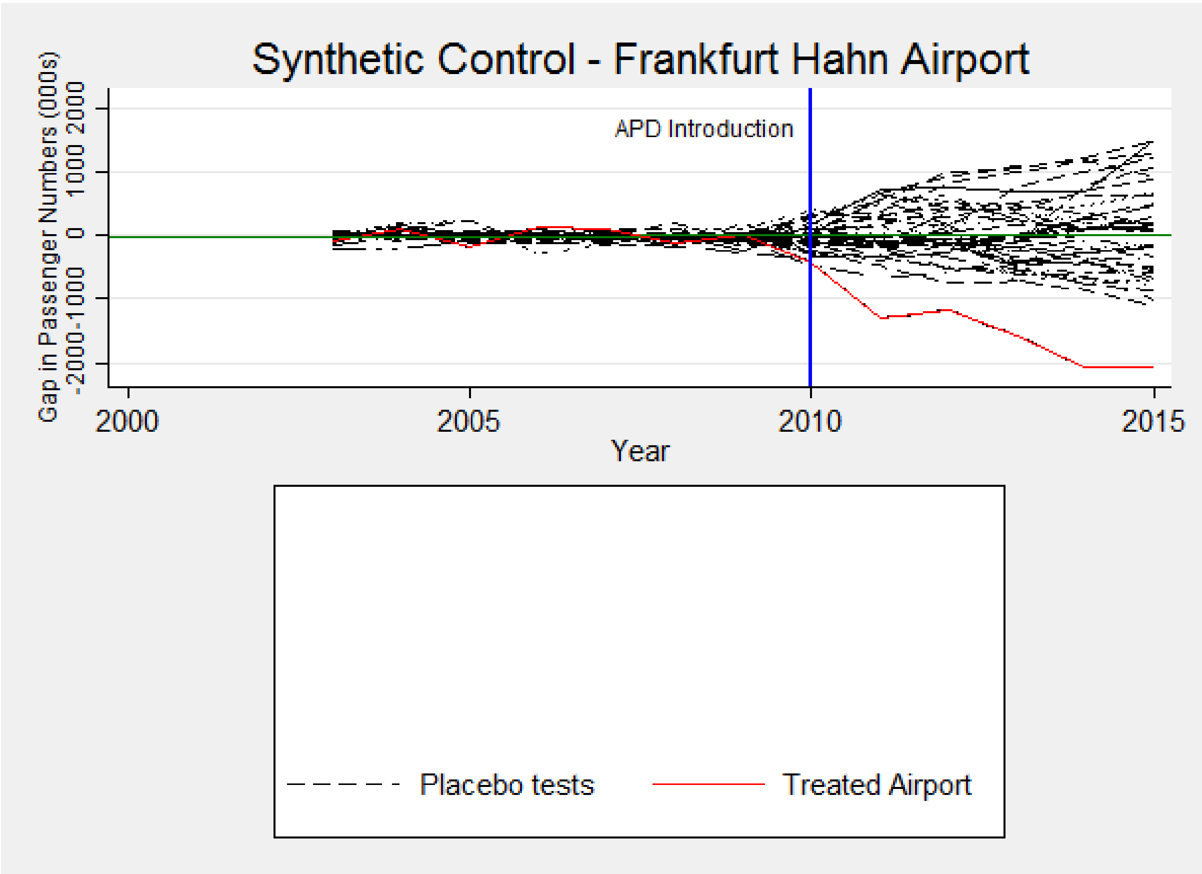


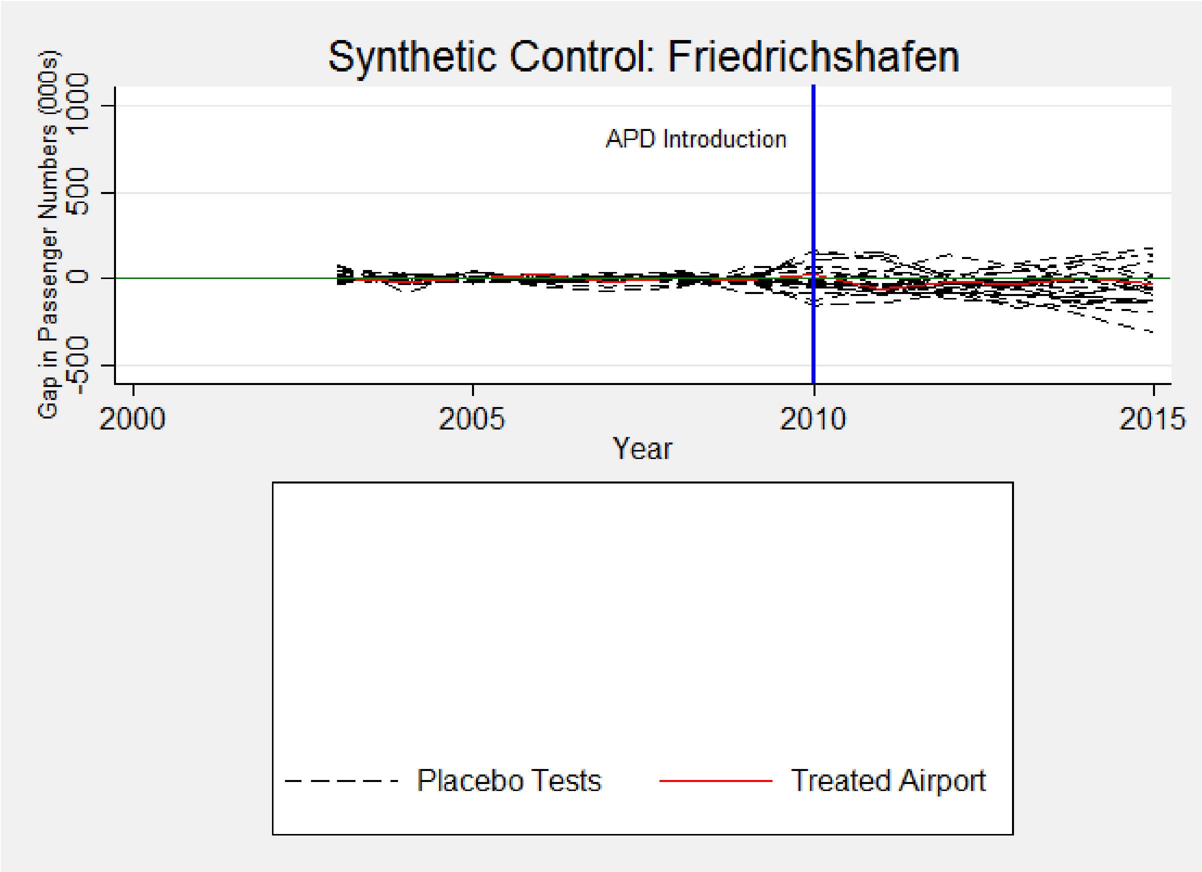
Synthetic Control: Dresden Airport
APD Introduction
Gap in Passenger Numbers (000s)
-4000
-2000
0
2000
4000
2000
2005
2010
2015
Year
Treated Airport (Dresden)
Placebo Tests for Control Airports

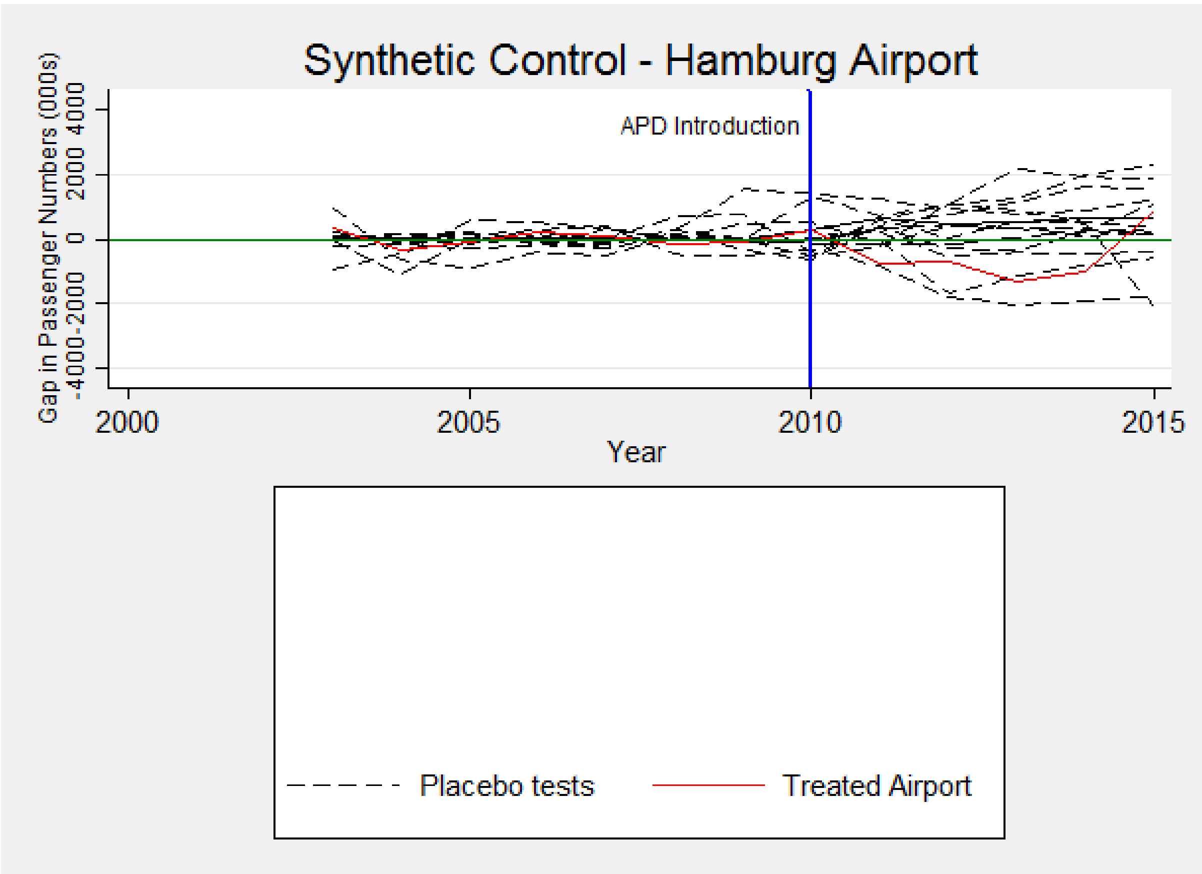


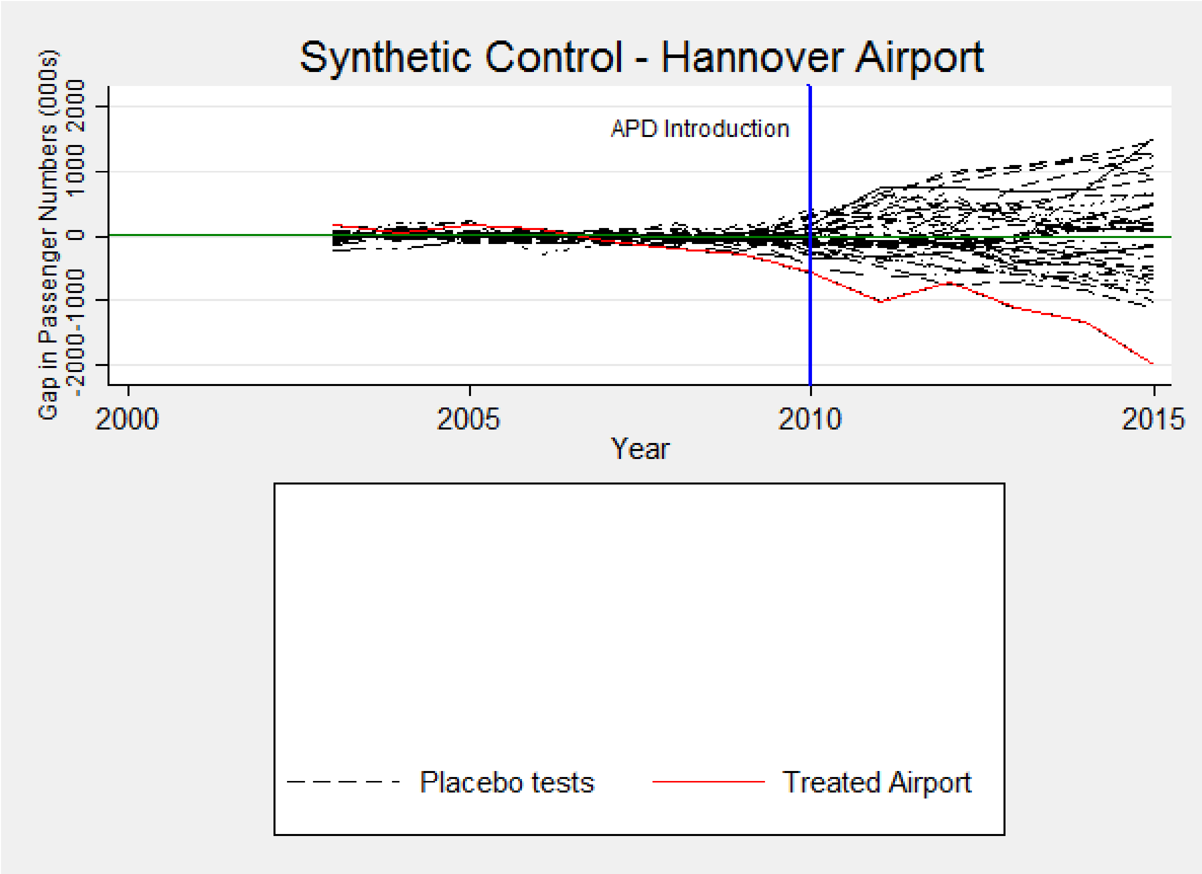
Synthetic Control - Eindhoven Airport
APD Introduction
Gap in Passenger Numbers (000s)
2000
2005
2010
2015
Year
Placebo tests
Treated Airport

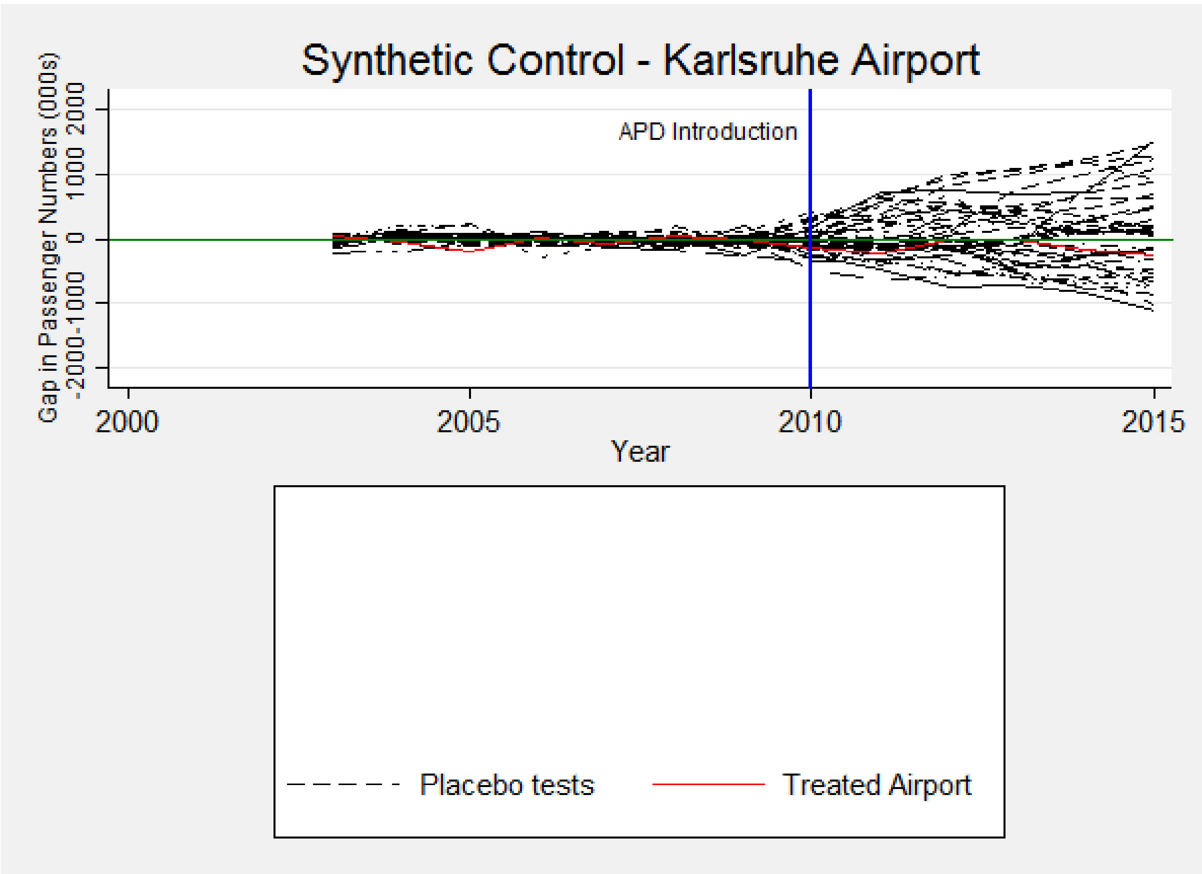

Synthetic Control: Erfurt
APD Introduction
Gap in Passenger Numbers (000s)
-500
0
500
1000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport

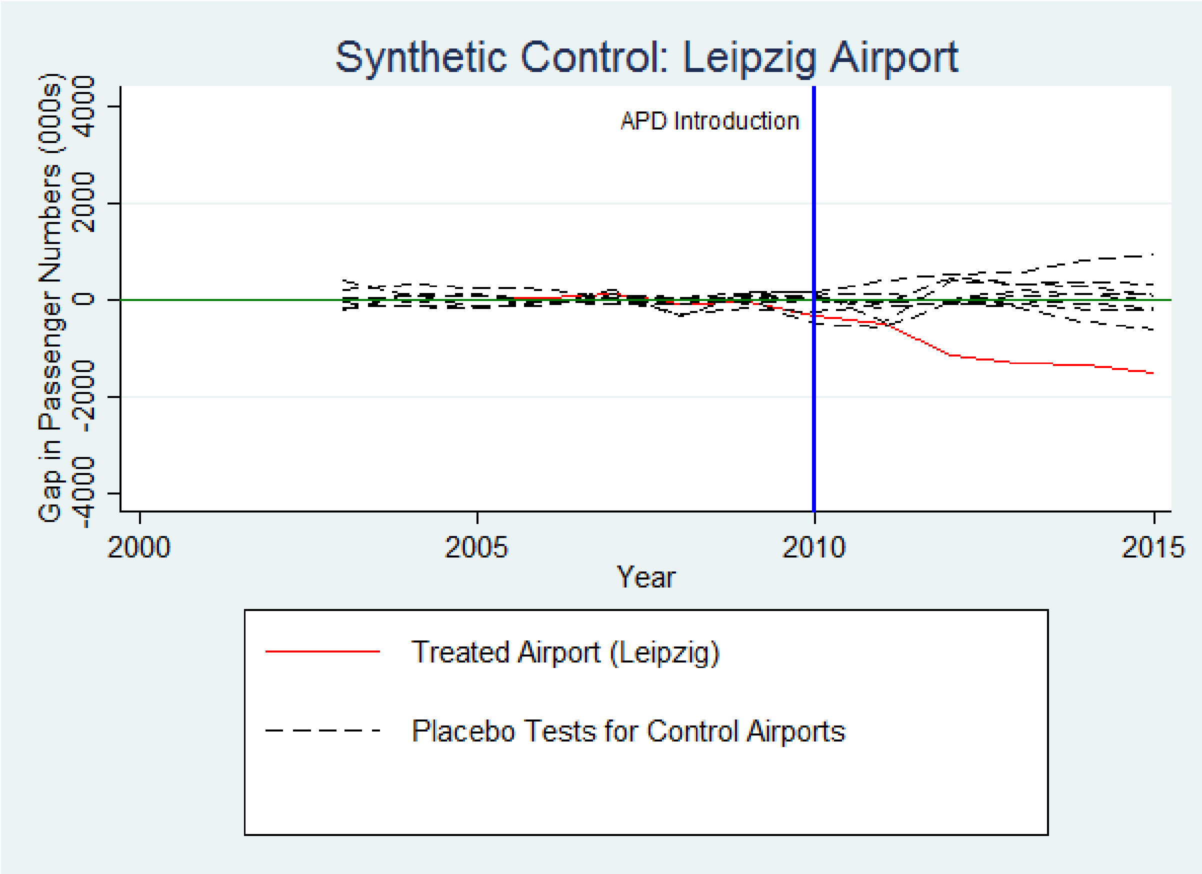

Synthetic Control - Frankfurt Hahn Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport

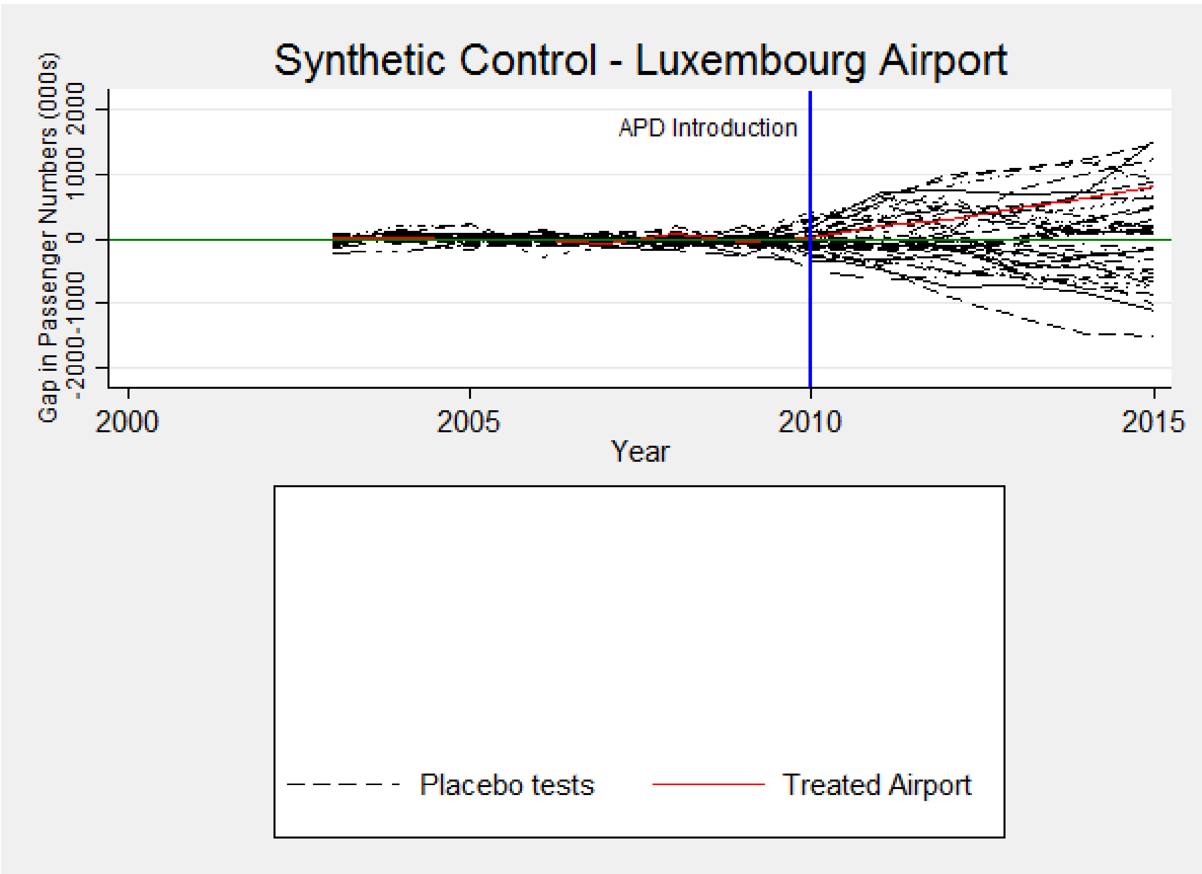

Synthetic Control: Friedrichshafen
APD Introduction
Gap in Passenger Numbers (000s)
-500
0
500
1000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport

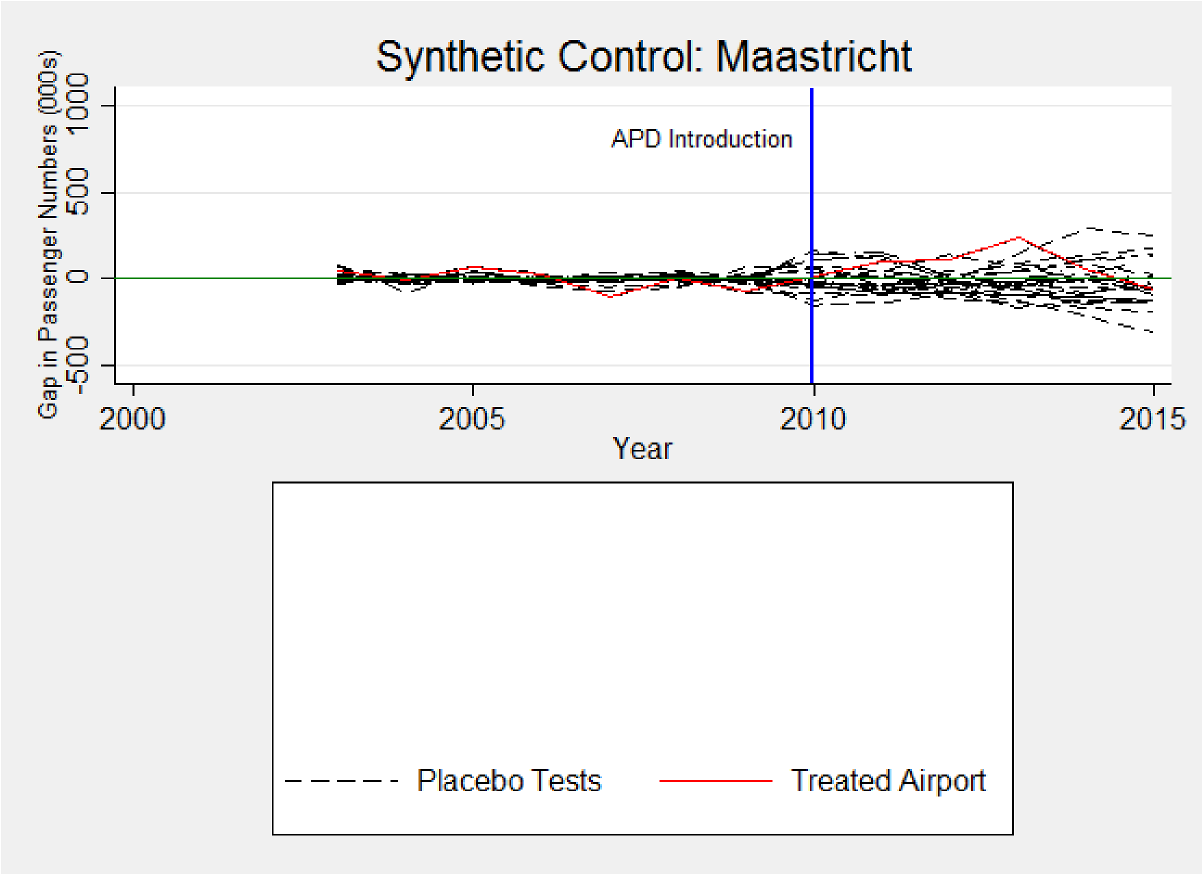

Synthetic Control - Hamburg Airport
APD Introduction
Gap in Passenger Numbers (000s)
-4000
-2000
0
2000
4000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport


Synthetic Control - Hannover Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport

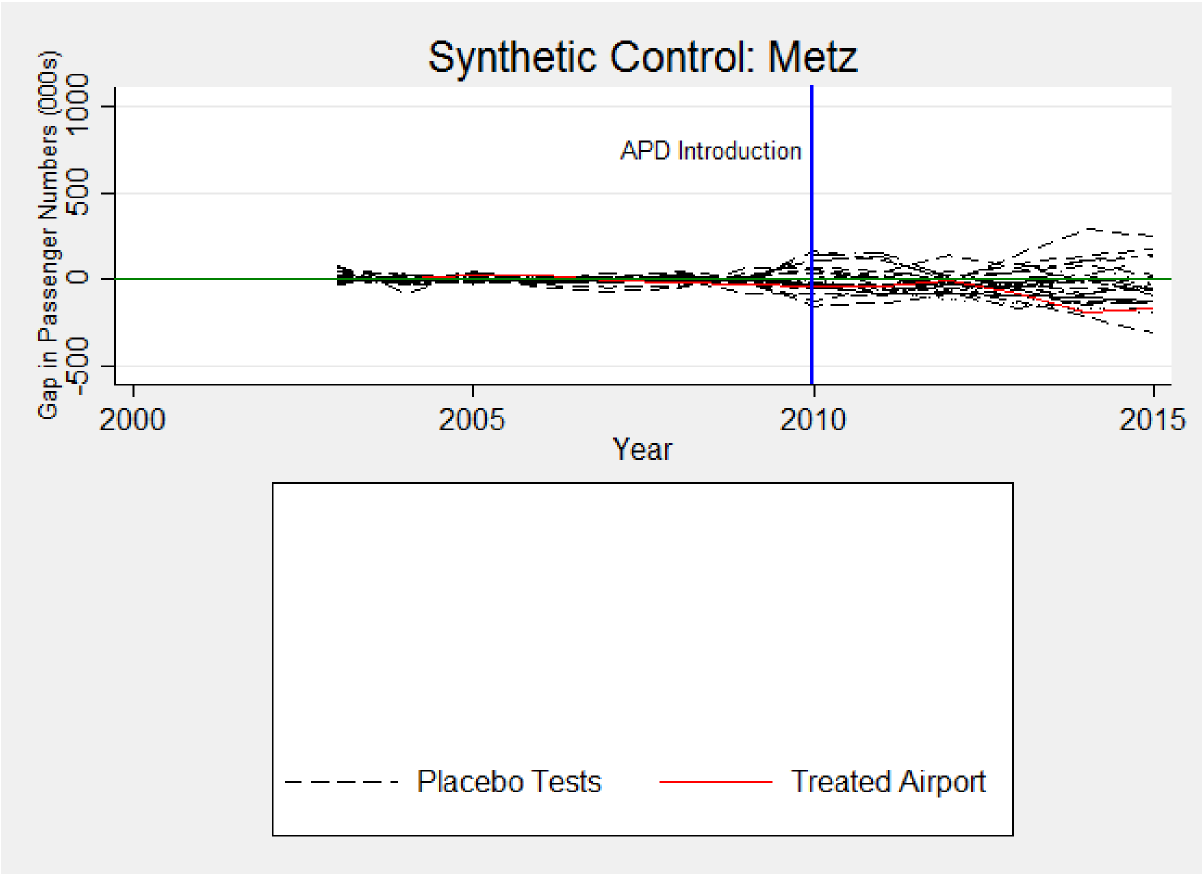

Synthetic Control - Karlsruhe Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport


Synthetic Control: Leipzig Airport
APD Introduction
Gap in Passenger Numbers (000s)
-4000
-2000
0
2000
4000
2000
2005
2010
2015
Year
Treated Airport (Leipzig)
Placebo Tests for Control Airports

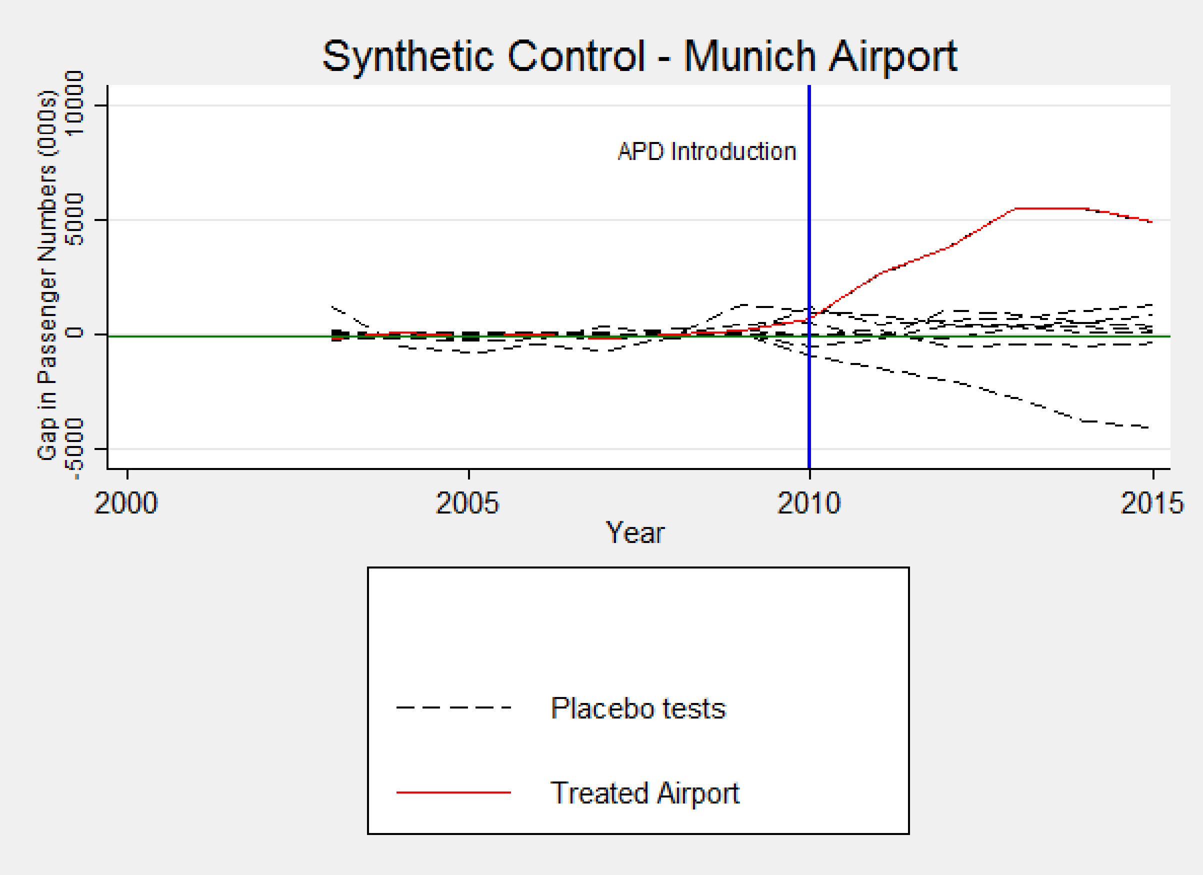

Synthetic Control - Luxembourg Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport

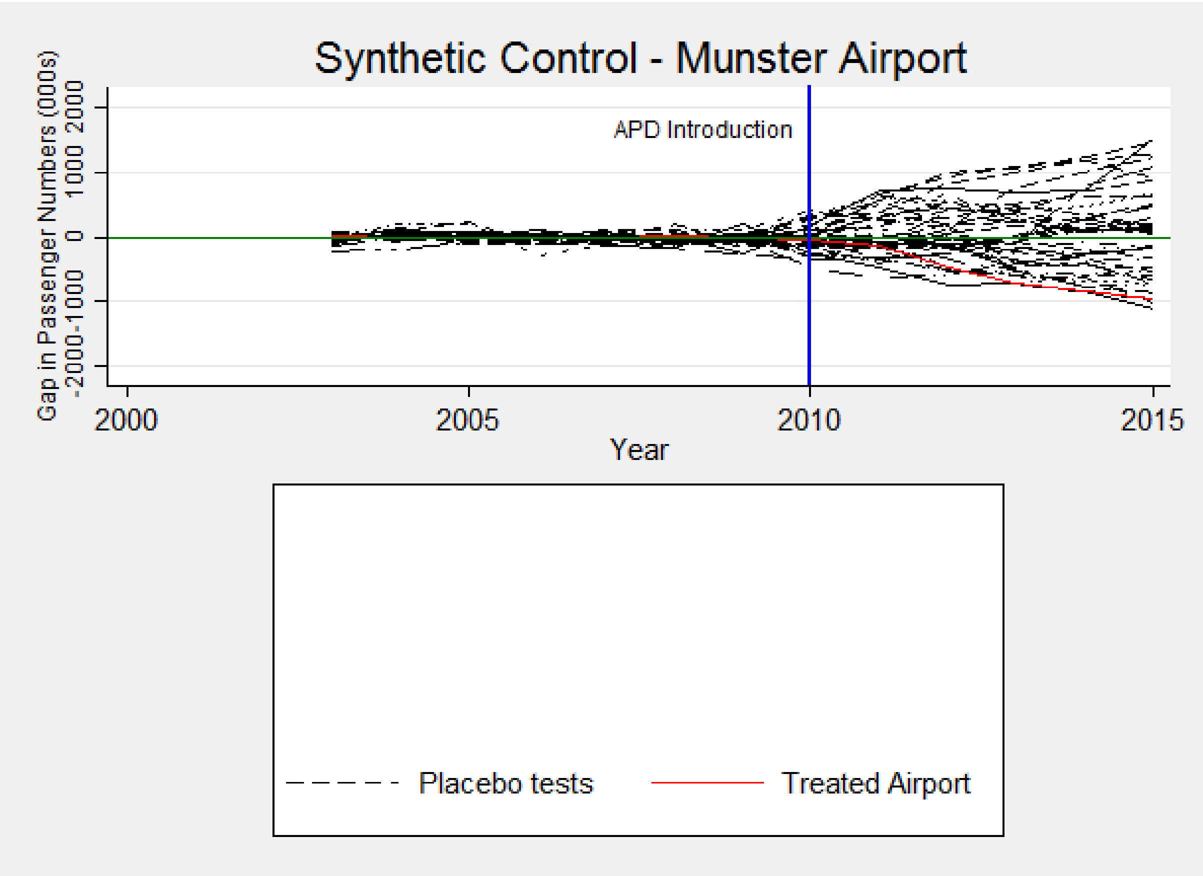


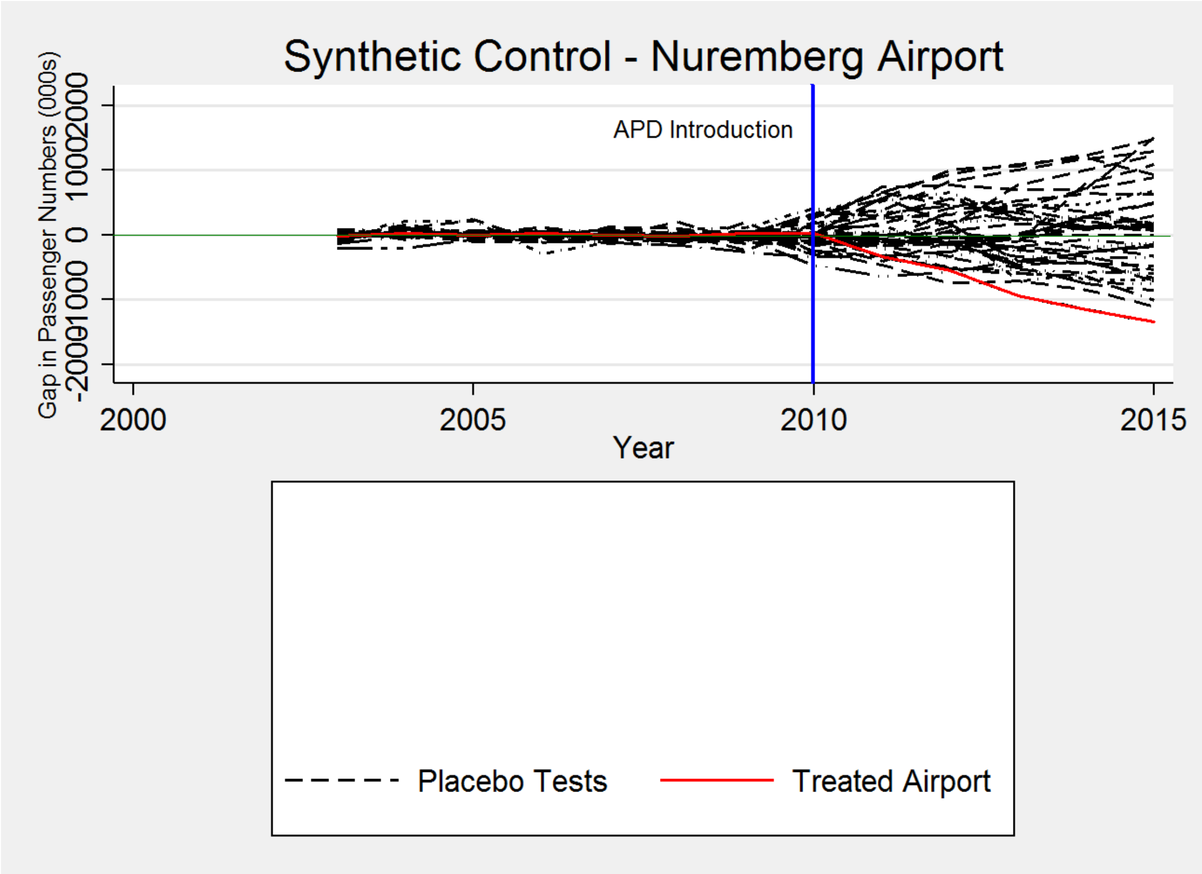
Synthetic Control: Maastricht
APD Introduction
Gap in Passenger Numbers (000s)
-500
0
500
1000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport

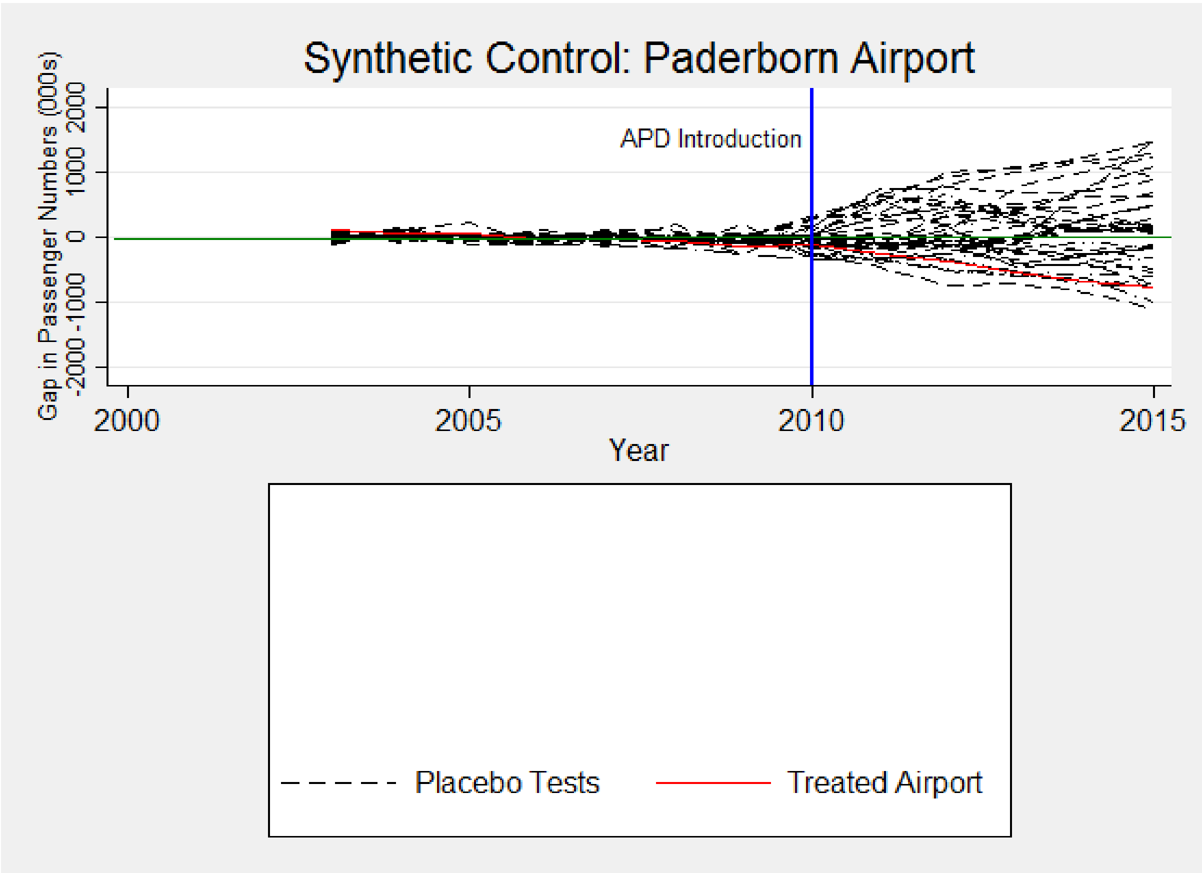


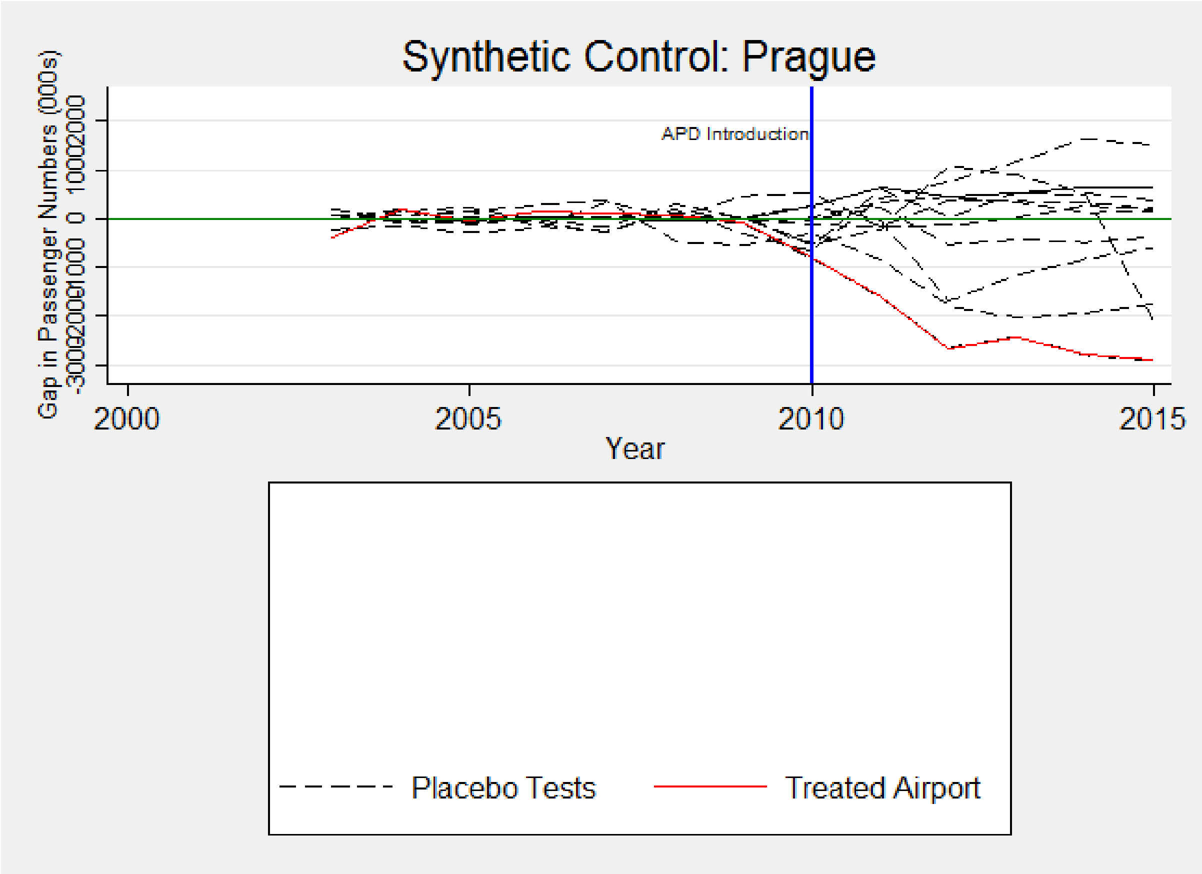
Synthetic Control: Metz
APD Introduction
Gap in Passenger Numbers (000s)
-500
0
500
1000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport


Synthetic Control - Munich Airport
APD Introduction
Gap in Passenger Numbers (000s)
-5000
0
5000
10000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport

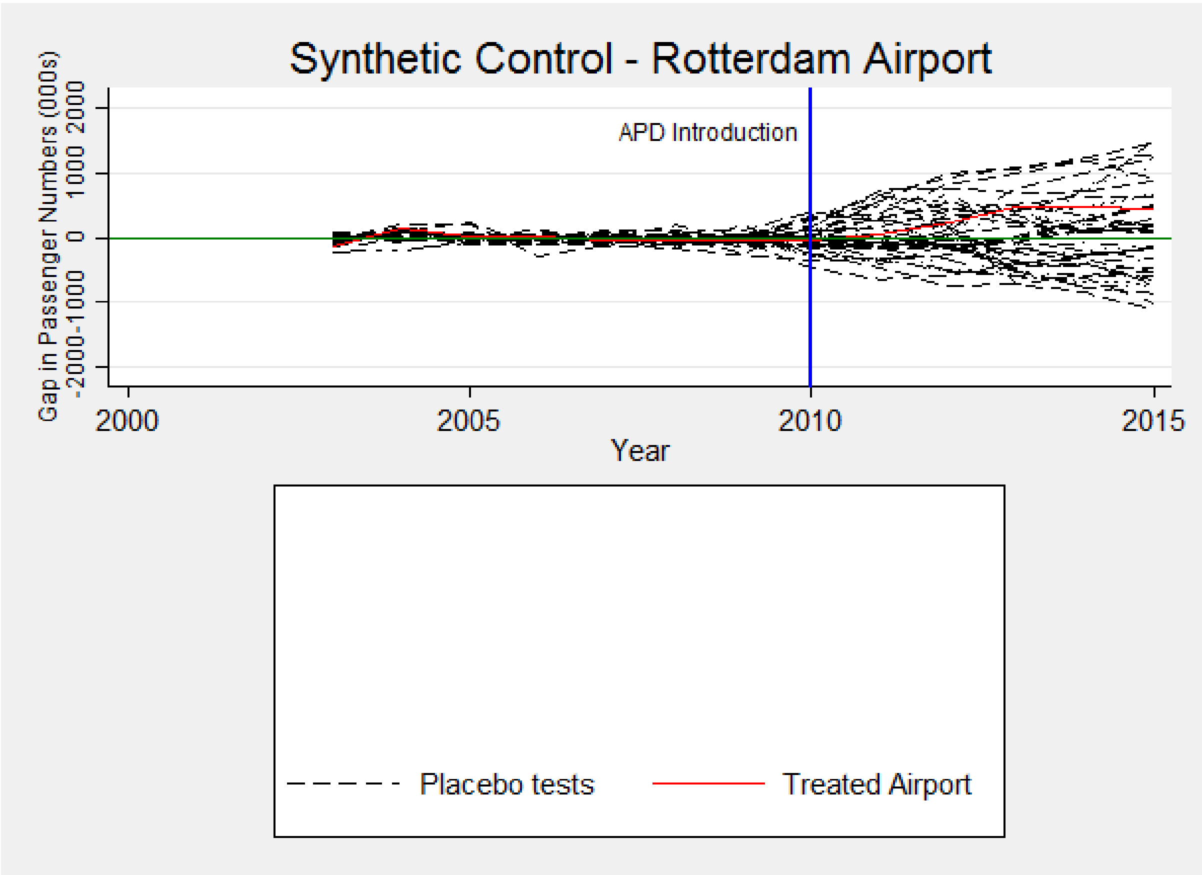

Synthetic Control - Munster Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport


Synthetic Control - Nuremberg Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport

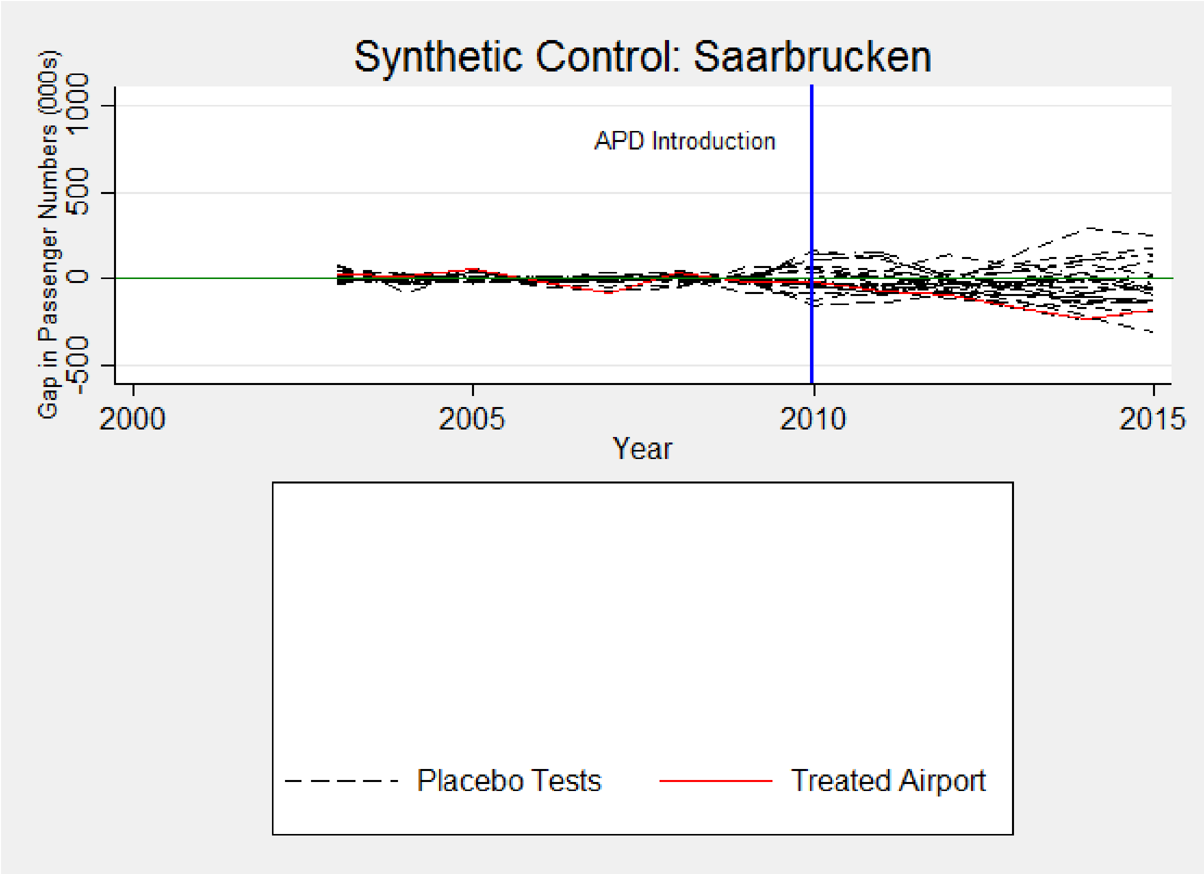

Synthetic Control: Paderborn Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport

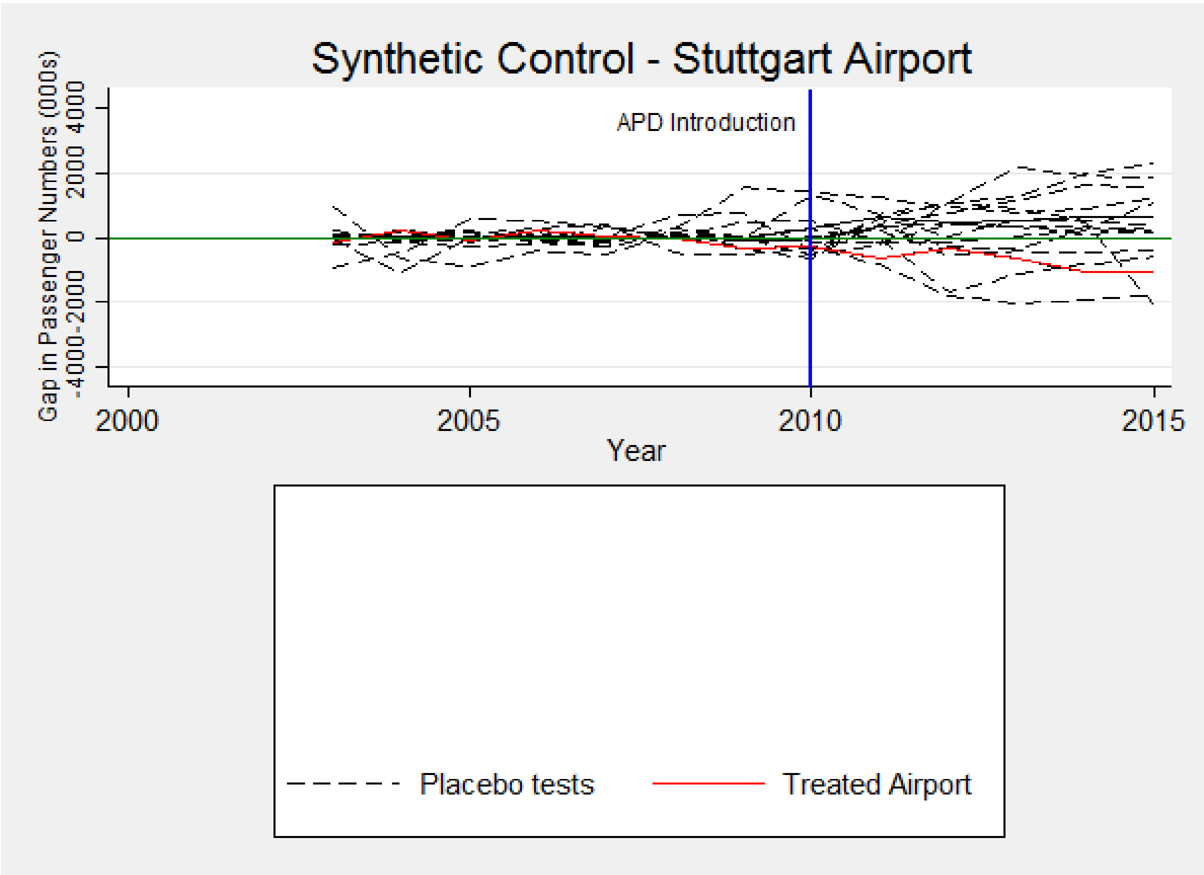


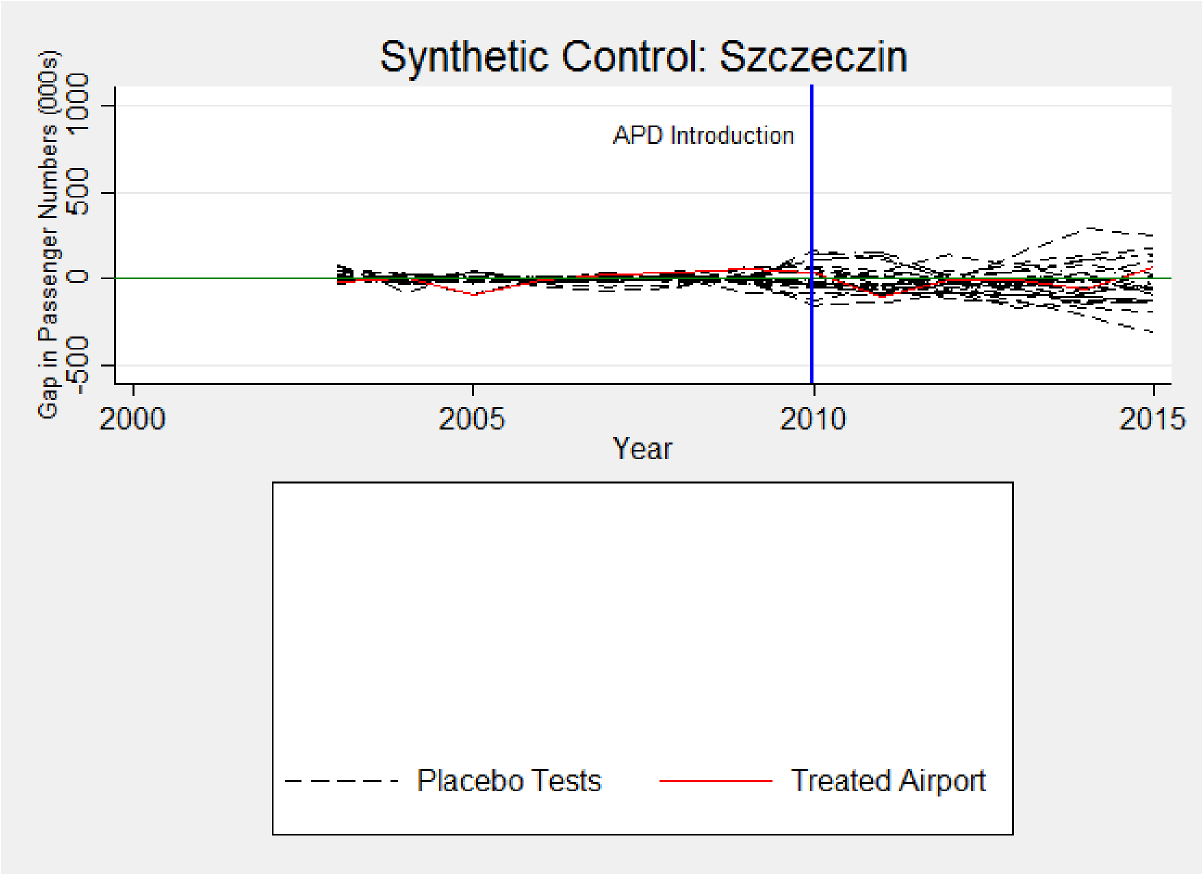
Synthetic Control: Prague
APD Introduction
Gap in Passenger Numbers (000s)
-3000
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport

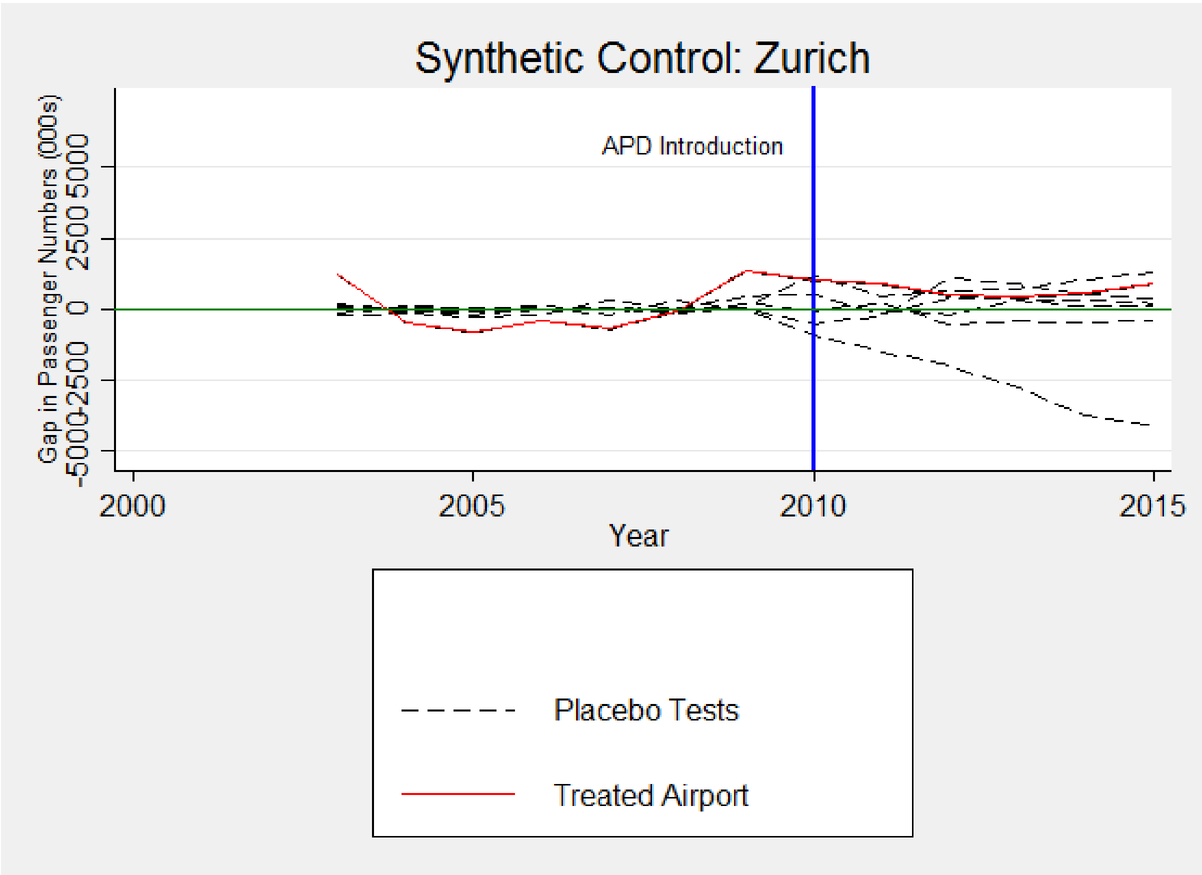


Synthetic Control - Rotterdam Airport
APD Introduction
Gap in Passenger Numbers (000s)
-2000
-1000
0
1000
2000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport


Synthetic Control: Saarbrucken
APD Introduction
Gap in Passenger Numbers (000s)
-500
0
500
1000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport


Synthetic Control - Stuttgart Airport
APD Introduction
Gap in Passenger Numbers (000s)
-4000
-2000
0
2000
4000
2000
2005
2010
2015
Year
Placebo tests
Treated Airport


Synthetic Control: Szczeczin
APD Introduction
Gap in Passenger Numbers (000s)
-500
0
500
1000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport


Synthetic Control: Zurich
APD Introduction
Gap in Passenger Numbers (000s)
-5000
-2500
0
2500
5000
2000
2005
2010
2015
Year
Placebo Tests
Treated Airport

Robustness Check: Unadjusted Synthetic Controls for Dutch Airports[2]

Figure 62. Synthetic Control – Amsterdam Airport (Unadjusted)

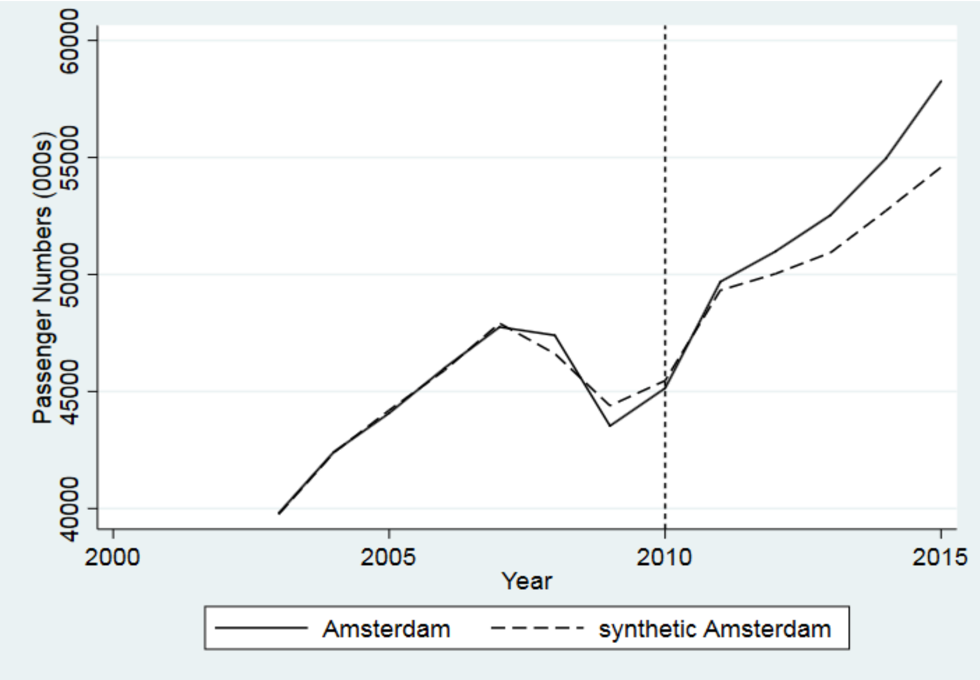
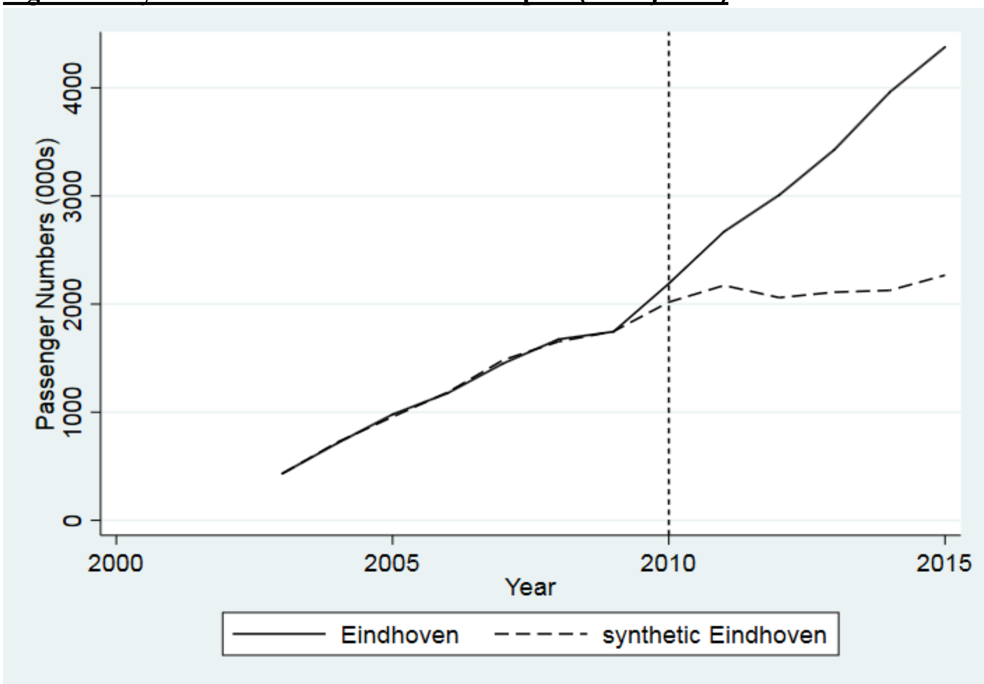


Figure 63. Synthetic Control – Eindhoven Airport (Unadjusted)



[2] Adjustments were not used in the cases of Rotterdam and Maastricht airports, as the synthetic control model for the Dutch AT could not properly estimate counterfactuals for these airports.

Figure 64. Synthetic Control – Dutch AT Case - Amsterdam Airport

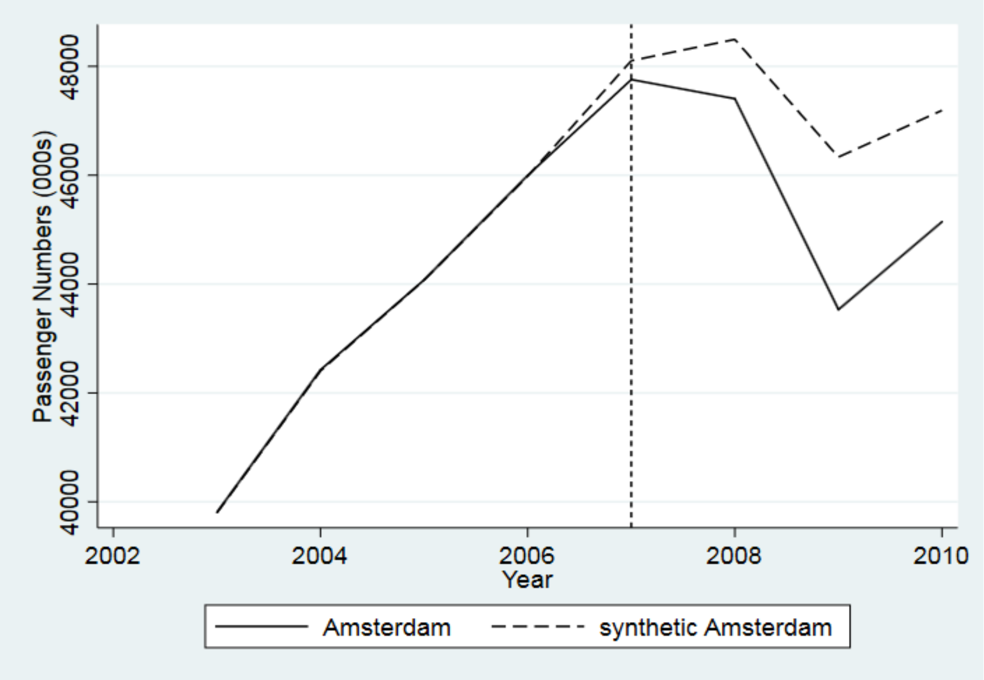


Figure 65. Synthetic Control – Dutch AT Case – Eindhoven Airport