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ON THE CROSSOVER EFFECTS OF BREXIT AND COVID-19

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On the crossover effects of Brexit and COVID-19

Abstract: This study is the first to investigate the crossover effect of the UK's exit from the European Union, commonly referred to as Brexit, and the COVID-19 pandemic. First, we confirm the results of studies exploring Brexit and respond to critiques of the literature. By applying the synthetic control group method, this paper reveals the impact of Brexit on GDP per capita (up until the most recent data) has been negative. In a second step, we show that, while COVID-19 had a negative impact on all developed economies, the confluence of the two events resulted in considerably more adverse outcomes in the United Kingdom.

Keywords: *Brexit, COVID-19, Great Britain, growth*
JEL: *E65, F13, F15, F55*

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1 Introduction

After the UK population voted to leave the EU on June 23, 2016, a protracted phase of negotiations ensued. Eventually, the UK exited the European Union on January 31, 2020. The subsequent transition period and final exit on January 1, 2021, which saw the EU–UK relationship transform into the present Free Trade Agreement called the Trade and Cooperation Agreement (TCA), were overshadowed by the first year of the COVID-19 pandemic, which had a more severe economic impact on the UK than on any other developed country (cf. Du et al., 2023; Gasiorek & Tamberi, 2023). Moreover, the recovery took longer, despite the UK having lifted its COVID-19-related restrictions earlier than many of its peers, in part due to their fast vaccination campaign (Springford, 2022).

While previous studies have examined the impact of each event separately, surprisingly little research has been conducted on the interaction between the two. Given the magnitude of both effects on the UK economy, it is hard to believe that they did not influence each other to some extent. To fill this gap, this paper presents the first evidence on the combined economic impact of Brexit and the COVID-19 pandemic.

While the majority of the literature has predicted a negative economic impact of Brexit, there is no consensus on the magnitude of this impact (for a literature overview, see Belke et al., 2018 or Dhingra & Sampson, 2022). As a first step, we replicate some of the key findings from the literature on the economic outcomes of Brexit prior to the COVID-19 pandemic. Following Springford (2022), this paper employs the Synthetic Control Method (SCM), a counterfactual approach, to assess the economic trajectory of Britain in the absence of Brexit up to the most recent data. It utilizes a different donor pool and covariates than that in the prevailing literature, with the aim of corroborating the assertion that Brexit has had a negative impact on the UK economy compared with a scenario in which the UK had not left the European Union.

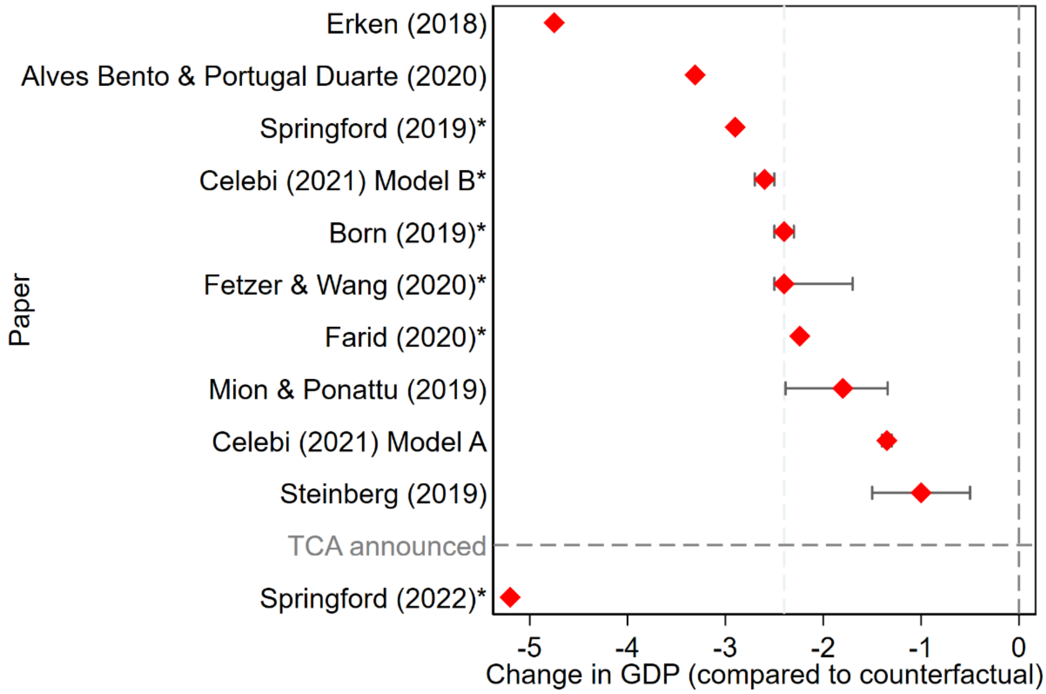
In a second step, we extend the time horizon of the literature to the post-COVID-19 era to disentangle the potential outcomes of Brexit and COVID-19 and the impact of the former on the latter. In doing so, we present initial evidence indicating that the severe economic decline observed in 2020 and the subsequent slow recovery were most likely not solely attributable to the effects of COVID-19 or the United Kingdom's withdrawal from the European Union but rather the unique combination of these two economic impacts.

Although Brexit was merely announced and not yet implemented, studies estimated effects that were already induced by the referendum in 2016 (e.g., Born et al., 2019, Fernandes & Winters, 2021). At this point in time, economists were confronted with a considerable degree of missing information regarding the future and tried to make predictions about the potential impact. Most of that missing information, such as the future EU–UK relationship or the final exit date, was elucidated when the TCA was announced in 2020. Therefore, Figure 1 shows the results of the empirical studies, which are subdivided into papers that were written before and after 2020.

In the years following the referendum, early studies employing counterfactuals to ascertain the impact of the Brexit referendum and its subsequent negotiations on the economy were published. Studies in the first phase working with the Synthetic Control

Method, which in this context was first used by Born et al. (2019), estimated that Brexit effects until 2020 ranged from -2.2% to -2.9% (denoted with an asterisk in Figure 1). In the time between the referendum and the announcement of the TCA in December 2020, all the projected short run estimates are negative, but the magnitudes differ greatly. Erken et al. (2018) predicted a decline in GDP growth of 4.75% in the short run (2020). Steinberg (2019), on the other hand, finds only small losses in real GDP of approximately 0.9%.

Figure 1 Literature Overview of estimated Short-Term Effects



Note: This overview is divided into two sections. The horizontal dashed line represents the January 2020 announcement of the definitive departure, with its corresponding transition to an EU-UK-FTA. The blue dashed vertical line represents the median outcome of all exhibited papers. The graph displays the baseline results for each paper with a red dot and upper and lower estimates for some papers. Papers, that are marked with an asterisk used SCM as their primary method, as this paper does as well. For aesthetic reasons, the "et al." suffix has been omitted from this graph. All effects shown are a projected FTA scenario.

Following the UK's definite departure in January 2020, economists were cognizant of the various factors that would influence the future EU–UK relationship. At the time, it was known that a Free Trade Agreement would ensue following the final exit, and the impact of post-referendum uncertainty could be quantified. Furthermore, the COVID-19 pandemic emerged, representing a persistent shock that could not have been factored in previously. Springford (2022) concluded that the UK experienced a reduction in GDP of 5.2% relative to a synthetic counterfactual by the end of 2021 due to Brexit. Notably, the second period of literature does not present a substantial number of estimates concerning the influence of Brexit on the UK's GDP. Instead, numerous studies delve into other pivotal economic indicators, including trade (e.g., Gasiorek & Tamberi, 2023; Lucio et al., 2024) and foreign direct investment (FDI) (e.g., An et al., 2023).

The remainder of this paper is structured as follows. The subsequent chapter examines the data utilized. Thereafter, the methodology employed and the rationale behind its design are elucidated in greater detail in Chapter 3. The primary findings are presented in Chapter 4, followed by a series of robustness checks. Ultimately, the results are discussed, and the paper is concluded.

2 Data

We construct a dataset featuring 35 member countries of the OECD. Our observation period starts in the first quarter of 2009, which is the first year following the financial crisis in 2007-08, and concludes with the last available data point in the fourth quarter of 2022, yielding a total of 56 observation periods.

Similar to the literature previously reviewed, this study uses data on real GDP per capita to analyze the economic impact. In line with Springford (2022) and Born et al. (2019), the covariates encompass a comprehensive array of key economic figures and demographic indicators. In SCM settings, a broad selection of covariates is needed to construct a counterfactual, which will be elaborated in Chapter 3. The economic variables include the inflation rate, the inward foreign direct investment (FDI) in billion US dollars, restrictions on FDI (on all sectors and on the tertiary sector each), exports, and gross fixed capital formation (which are both expressed in billion US dollars). Furthermore, an indicator of the dependency on Russian fossil fuels was included. The demographic indicators include the population size, the labor force participation rate, the percentage of the labor force with a degree in tertiary education, and the migration rate.

The majority of the variables are obtained from the Organization for Economic Co-operation and Development (OECD). Exceptions are the net migration and population variables (both of which are sourced from the World Bank, which provides data from the United Nations Population Division), and the indicator of Russian imports relative to domestic fossil fuel consumption (International Energy Agency (IEA)). A comprehensive list of all utilized covariates can be found in Table 1.

The available covariates were typically reported on a quarterly basis, whereas certain variables, such as the population size or the Russian dependency indicator, were reported only on an annual basis. Consequently, the annual reported value was employed for all four quarters of the corresponding year, in accordance with the prevailing practice in the literature (e.g., Springford, 2022).

Table 1 Summary Statistics

Variables	Mean	SD	Min	Max
GDP per capita	39754.9	16768.56	11091.9	111200.7
Inflation rate	2.30	2.82	-3.75	23.77
Inward FDI (in Bio. USD)	3.39	12.47	-268.11	130.88
Restriction on all sectors	0.064	0.059	0.004	0.240
Restriction on tertiary sector	0.073	0.062	0.007	0.242
Exports (in Bio. USD)	346.95	376.13	5.38	2119.44
Gross Fixed Capital Formation (in Bio. USD)	209.81	270.37	1.77	1376.99
Dependency on Russian Fossils	0.17	0.25	0	1.65
Population size (in Mio. people)	26.5	32.5	0.3	128.0
Labor force rate (in percent)	80.13	4.40	68.16	89.28
Rate of tertiary education (in percent)	41.63	10.74	17.24	69.85
Migration Rate (in percent)	0.30	0.50	-1.50	2.42

3 Methodology

The Synthetic Control Method (SCM), which was initially proposed by Abadie & Gardeazabal (2003) and popularized by Abadie et al. (2010), has emerged as the most prevalent method for policy evaluation in the academic literature over the past decade (Athey & Imbens, 2017). While the classical difference-in-differences estimation technique (DID) compares a treated unit to another control unit (or a group of units), the SCM simulates a counterfactual scenario by using a weighted combination of similar control units, which strives to emulate the treated unit as closely as possible in terms of specific covariates and pre-treatment trends. In contrast to the DID, the SCM is able to disentangle two different effects, such as the Brexit and the COVID-19 pandemic. Moreover, if the parallel trend assumption of DID is not fulfilled, then the application of the SCM may compensate for this through its function of reweighting units to align them with pre-treatment trends. Consequently, the results are highly contingent upon three key factors: the units in the donor pool, in this instance, the timing of treatment, and the selection of covariates.

Concerning the covariates, we draw on Springford (2022) and include inflation, Gross Fixed Capital Formation (in millions of US dollars), exports, and Foreign Direct Investment (FDI, in millions of US dollars). The inflation rate may also be relevant because it reached unusually high levels in international comparisons (Fernandes & Winters, 2021). Exports constituted 31% of the GDP of GB in 2019-Q4, and 42% of UK exports were directed to the EU in the periods preceding the referendum (Graziano et al., 2020). In addition to these variables used by Springford (2022), two parameters of the OECD FDI Regulatory Restrictiveness Index (for all sectors and for the tertiary sector independently) were employed to account for a predicted reduction in openness (cf. Carril-Caccia & Pavlova, 2018, for similar reasoning).

In addition to measures of population size and the labor force participation rate (cf. Born et al., 2019; Erken et al., 2018), the percentage of citizens with a degree in tertiary education is included, similar to Springford (2022), who also used a variable on education. Moreover, a reduction in migration was a significant argument for people supporting the Leave position. Given the direct link between labor force reduction and economic performance, a covariate displaying net migration per capita is also included (cf. Hantzsche et al. 2019).

To account for one of the most significant economic shocks of the new decade, namely, the energy price shock, an additional variable has been included in the model. This shock was precipitated by the Russian invasion of Ukraine and the subsequent imposition of global sanctions against the former. This is gauged by an indicator that reports the ratio of Russian imports to the total domestic fuel consumption, thereby illustrating the extent of dependence on Russian imports and the potential magnitude of the energy price shock.

Furthermore, following Abadie et al. (2010), a series of lagged dependent variables is included to enable a more precise fitting of the pre-treatment period and to control for unobservable characteristics. In contrast to other studies (e.g., Born et al., 2019), it was decided to not use the full pre-treatment period but instead focus on the thirteen lags leading up to the referendum.[1]

Our estimation equation reads:

$$Y_{it}^{N} = \delta_t + \theta_t Z_i + \lambda_t \mu_i + \varepsilon_{it} \tag{1}$$

where Y_{it}^{N} is the outcome of the synthetic UK, δ_t is the time trend and Z_i are the predictors, i.e., the mentioned covariates and pre-treatment trends. The weights w_j are then chosen so that the predictors match the synthetic UK, consisting of the J control units, as closely as possible.

$$\sum_{j=1}^{J} w_j^* Z_j = Z_{UK}$$

with $w_j \geq 0$ and $\sum w_j = 1$. Finally, the effect of the intervention can be calculated by the difference between the estimated synthetic UK and the actual observed UK.[2]

[1] For more information on the handling of the lagged dependent variables and why using all lags in the pre-treatment period is problematic, please see the Robustness section.

[2] For more theoretical background on the SCM, cf. Abadie et al. (2010).

3.1 Treatment definition, independence and timing

A fundamental tenet of SCM is the assertion that the treatment should be independent of the outcome of interest in the pre-treatment period. This ensures that no anticipation effects are possible (cf. Gilchrist et al., 2022). While undisputed for most treatments analyzed, the treatment timing has been debated in the case of the Brexit.[3]

In accordance with the prevailing view in the literature, the second quarter of 2016 was selected as the treatment period in this study, the quarter in which the outcome of the referendum was announced (e.g., Gasiorek & Tamberi, 2023, Born et al., 2019, Breinlich et al., 2020). Although the United Kingdom was a member of the European Union until January 31, 2020, the effects of the referendum outcome appeared to have manifested earlier. Douch et al. (2019) observed that UK firms reoriented their export flows from the EU to non-EU markets, primarily to emerging economies and Commonwealth Nations, following the Brexit referendum in 2016. While some studies question whether the referendum fulfills the condition of being random in affected units or in the timing of treatment (e.g., Du & Shepotylo, 2022a), numerous studies contend that the Brexit referendum meets the criteria of being an unanticipated shock (e.g., Born et al., 2019, Chung et al., 2023), as the vote outcome was not expected. This occurred in an otherwise stable macroeconomic environment, as the economic conditions did not change significantly in the 12 months following the referendum (Fernandes & Winters 2021). Wu et al. (2021) even characterized Brexit as a "high-quality natural experiment" (p. 241) in their analysis of market behavior in the context of uncertainty on the night of the referendum.

3.2 Donor pool

In line with Born et al. (2019) and Springford (2022), the donor pool for the synthetic UK consists of all OECD countries. Abadie et al. (2015) outline two fundamental assump-

[3] Graziano et al. (2020) and Douch & Edwards (2022) chose 2015 as their timing of treatment, arguing that the announcement a referendum will be held already introduced a certain degree of uncertainty and had an impact on the economy. In another possible timing approach, Du et al. (2023) decided on the final exit in 2021, as only then did the UK leave the Single Market.

tions that must be considered when constructing the donor pool to guarantee the reliability of the results. First, the donor pool should be restricted to countries that are similar in relevant characteristics to achieve a higher degree of comparability and to avoid overfitting. By focusing on OECD countries, comparability is ensured, as all members have economic systems, trade profiles, demographics, and institutions similar to those of the UK.[4] Moreover, comprehensive and reliable data are accessible for all countries. Table A1 in the Appendix lists all potential donors.

Second, units that have been affected by the treatment and those that have experienced significant idiosyncratic shocks must be excluded from the donor pool. This presents a significant challenge, as Mion & Ponattu (2019) found that nearly all comparable countries were at least indirectly affected by Brexit to some extent (see Table 2 for an overview[5]). Following the majority opinion, this paper considers OECD countries as well as European countries as potential donors. Given the UK's deep integration into global value chains, the effects of Brexit may have been felt across the globe. However, as proposed by Douch & Edwards (2021), the Brexit vote is regarded as a treatment that has had a more pronounced impact on the UK economy relative to its neighboring countries. Following Mion & Ponattu (2019) and Chen et al. (2018), Ireland was eliminated due to its close economic proximity to the UK. Second, Turkey was excluded from the donor pool due to insufficient data coverage on essential variables, including GDP per capita. Third, the USA was dropped due to concerns regarding criticism directed at Springford (2022) by Gudgin (2022). Gudgin proposed that the synthetic UK may have been driven by the United States, given the latter's post-treatment period upturn, which he attributed to Donald Trump's tax policies.

[4] In their criticism on studies exploring the impact of Brexit, Gudgin (2022) regards the banking crisis of 2007-2008 as fundamental to continued challenges of the British economy. However, since all major economies had been affected by the same crises, an attribution of the post-referendum downturn to the financial crisis seems difficult.

[5] The majority of displayed papers of *Table 2* use other dependent variables than GDP, including trade flows and FDI. As they do not explicitly provide an estimation of the effect of Brexit on GDP, they are not included in the literature review of *Figure 1*.

With Ireland, the USA, and Turkey dropped from the donor pool, there remained 34 countries.

Table 2 Studies on the question whether to use EU-members as donors

Paper pro using EU-members	Paper against using EU-members
• Born et al. (2019)	• Campos et al. (2019)
• Breinlich et al. (2020)	• Celebi (2021)
• Farid (2020)	• Douch & Edwards (2022)
• Douch & Edwards (2021)	
• Springford (2022)	
• Gasiorek & Tamberi (2023)	

4 Results

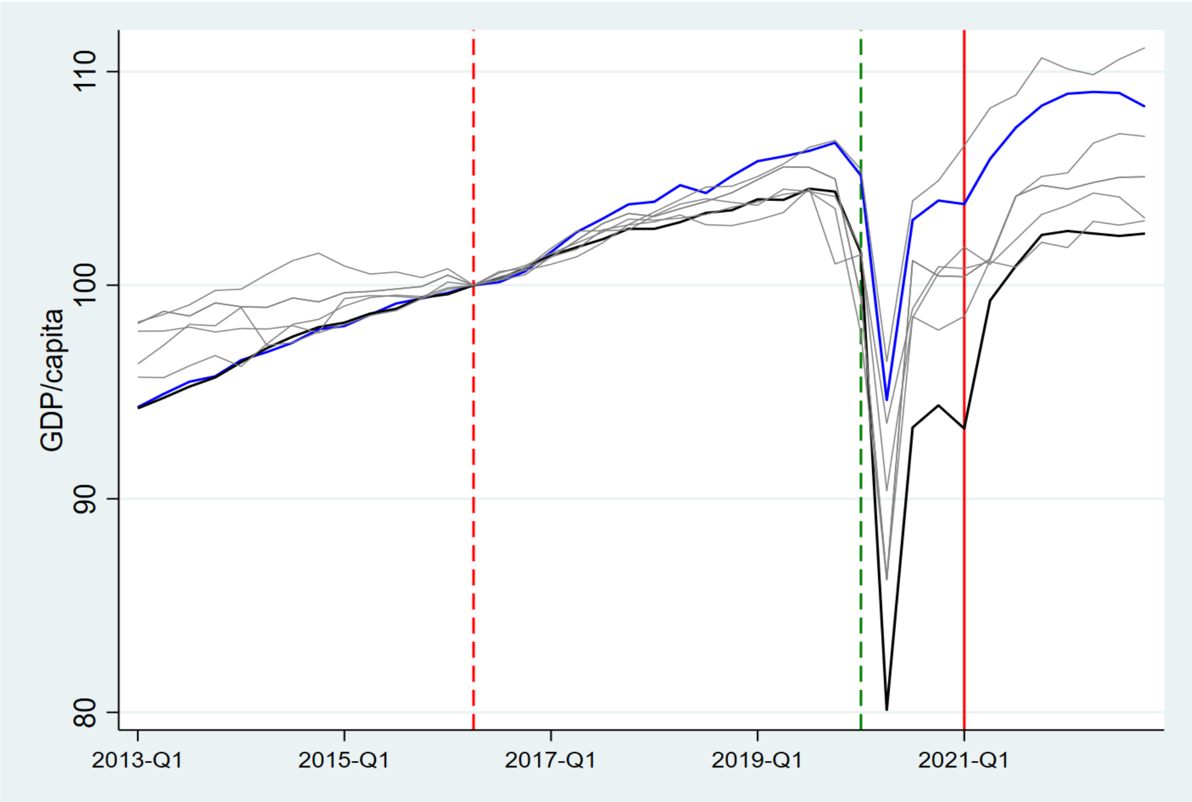
We Figure 2 shows the SCM results for the effect of the Brexit referendum as the main treatment (red dotted line) on economic activity in the UK, covering the time interval after COVID-19.[6] It is evident that in the pre-treatment period, the synthetic UK fits its factual counterpart very well, exhibiting only minimal discrepancies. In the periods following the referendum, at first, no effect was observed, but subsequently, both trends gradually diverged. This delayed effect of Brexit is consistent with the literature (see Fernandes & Winters, 2021). In the two years following the referendum, only a slight shift in GDP per capita was detected. In the fourth quarter of 2019, the discrepancy increased to approximately 960 US$ per capita (2.13%), which is in line with the results of SCM studies on the impact of the Brexit referendum (e.g., Born et al., 2019, and Springford, 2019).

Most importantly, Figure 2 suggests that the United Kingdom, which had previously undergone the Brexit referendum, was considerably more adversely affected by the COVID-19 pandemic than was its synthetic counterpart, which had not been affected by Brexit. The difference in GDP per capita increased to over 4,000 US$ (10.10%) from 2020-

[6] All graphs display the period from 2013-Q1 to 2022-Q4. This is done to put more emphasis on the lags of the pretreatment period and, of course, on the posttreatment period. The graph starts with the earliest lag used, in this case t-13, which is in line with literature (e.g. Born et al. 2019, Springford 2022). A graph displaying the period from 2009-Q1 to 2022-Q4 is included in the Appendix (*Figure A1*).

Q4. While all countries in the donor pool experienced a decline in GDP per capita during the pandemic, the United Kingdom experienced the most severe decline. Furthermore, Figure 2 shows that while all the G7 members experienced a decline in GDP per capita during the pandemic, the United Kingdom experienced the most severe decline. In the absence of the referendum, the UK would have experienced a far less severe impact from COVID-19 than it had actually experienced.

Figure 2 Combined effects of Brexit and COVID-19 on the UK economy (SCM)



Note: This figure shows the baseline result normalized on 2016-Q2. The black line denotes the real UK and the blue line denotes the synthetic UK of the baseline SCM result. The red dashed horizontal line displays the referendum in 2016-Q2, the green dashed line displays the beginning of the COVID-19 pandemic in 2020-Q1, the red solid line displays the definite departure in 2021-Q1. The SCM works well in the pre-treatment period and slowly diverges after the referendum. The COVID-19 shock had a more severe effect on a UK experiencing the Brexit, than on a counterfactual UK that had not voted to leave. Furthermore, the gray lines added denote the G6 for a better comparison.

Another visible outcome is the effect of the United Kingdom's final withdrawal from the European Union. A decline in trade during the first quarter of 2021 resulted in a reduction in GDP per capita, which occurred exclusively in the real UK and not in the synthetic UK (cf. Du & Shepotylo, 2022b). The UK subsequently demonstrated a more rapid recovery than its synthetic counterpart throughout 2021 (cf. HM Government, 2022). In 2022, both the synthetic and actual UK experienced a phase of stagnation, with both graphs exhibiting an almost parallel trend. Furthermore, it is evident that the income level in the synthetic UK surpassed its pre-COVID-19 level, whereas the income level in the actual UK remained below its value in 2019-Q4 (cf. Du & Shepotylo, 2021). The divergence between the two time series reached over 2,500 US dollars in real GDP per capita during the last period of 2022-Q4 (5.74%), which is approximately in line with the estimate of Springford (2022).

Table A1 of the Appendix presents the optimal weights utilized in the construction of the synthetic UK. Germany is the most significant contributor, accounting for 40.4% of the total, followed by Hungary (28.4%), Sweden (16.1%), and three other countries with smaller shares. Furthermore, Table A2 in the Appendix provides insight into how well the synthetic UK matches the actual UK. In this table, the means of the covariates and the lagged periods are compared for the pre-treatment period. The synthetic control allows for a more precise comparison than the average of all units, thus supporting the argument that SCM might outperform difference-in-differences between the UK and an average of OECD countries. Not only do the lags of the dependent variable exhibit a better fit, but for all covariates, with the exception of three variables (inflation rate, dependency on Russian fossils and rate of tertiary education)[7], the synthetic control enables a closer fit to the factual UK than the average of OECD countries.

5 Robustness

We present the results of five distinct robustness checks, which account for varying timeframes and control units. The primary objective is to examine the two principal robustness checks introduced by Abadie et al. (2010) and Abadie et al. (2015), namely, the In-Space-Placebo and the In-Time-Placebo.

[7] It stands to reason that dropping the variables with a worse fit than the average of OECD would leave the results better off. Since these variables are of increased economic significance, they remained part of the set of predictors. Moreover, using them anyhow is in line with Abadie et al. (2003).

The In-Space-Placebo aims to expose each unit from the donor pool to the treatment by applying the SCM. Thereafter, the difference between the unit and its synthetic counterfactual is calculated. If the discrepancy between the synthetic and actual UK was similar to the discrepancy between synthetic and actual placebo countries (which did not experience a referendum shock), then the demonstrated treatment effect was likely attributable to factors other than the referendum. In the construction of the In-Space-Placebo, every country is once applied as the treatment unit of the SCM. Consequently, the UK is initially excluded from the donor pool.

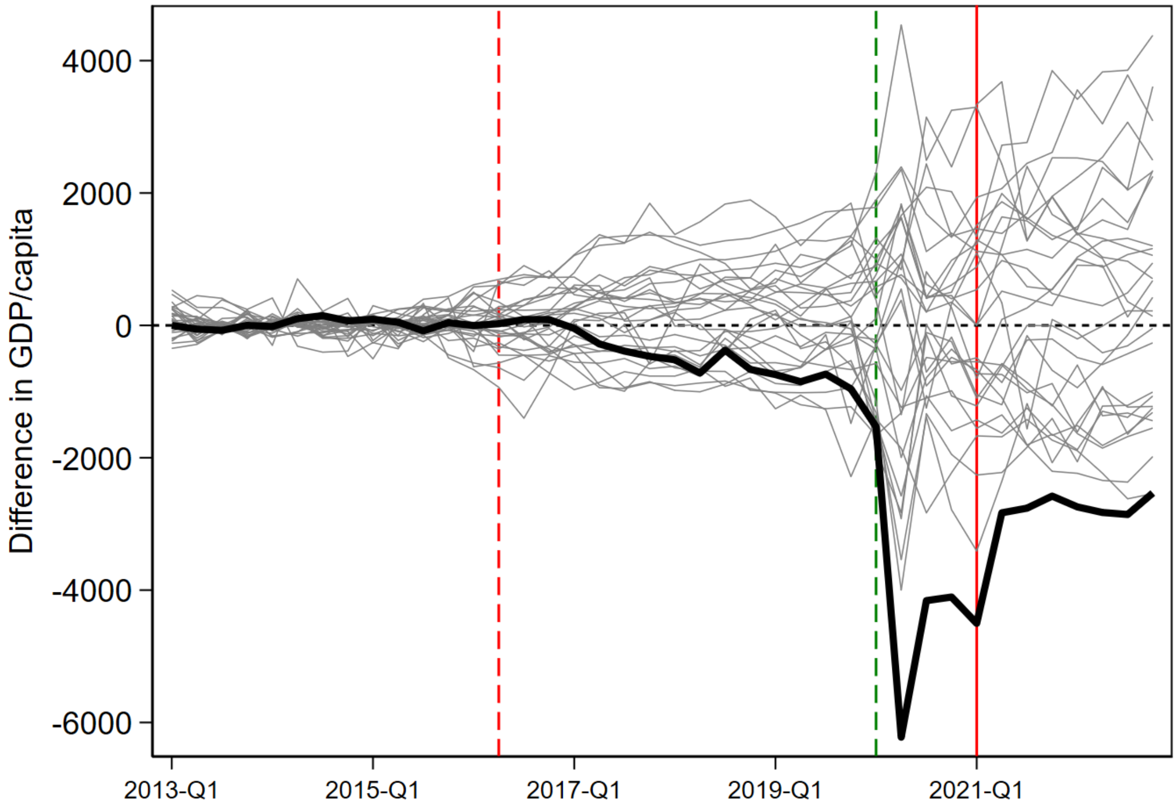
As illustrated in Figure 3, the UK visibly experienced the most pronounced decline after COVID-19 emerged, surpassing every other country in its negative effect. The pre-treatment assumption is particularly effective for the UK, as the gap remains close to zero until the referendum. Until 2019-Q4, the UK experienced heavy losses in GDP per capita, underscoring almost every placebo. Following the COVID-19 outbreak, the UK became the country with the largest discrepancy compared with its counterfactual. This confirms the thesis that the crossover effect had a particularly pronounced impact.[8]

Multiple "fake treated" countries of the In-Space-Placebo are positively affected by the Brexit shock and the COVID-19 shock. This may be attributed to a number of factors. First, the potential control group may not be an appropriate comparison for the respective treatment unit (e.g., for Costa Rica and Colombia, we encountered difficulties in calculating an appropriate synthetic control). Second, the pre-treatment fit may be worse than that for the UK and the placebo results therefore biased. Third, some countries experienced a less severe economic impact from COVID-19 due to their differing policy responses. For example, South Korea experienced a far milder pandemic shock than its potential donors did, which resulted in the difference between real and synthetic South Korea being positive. Note that the robustness test would only fail if the UK exhibited a

[8] It came to mind that since the UK is one of the largest economies in the sample, using an absolute change in GDP per capita for comparison is not suitable. Consequently, *Figure A2*, a supplementary graph depicting the In-Space-Placebo results with percentage changes was included in the Appendix, with minor changes.

similar trend to the majority of the "fake treated" placebos, indicating that the trend is likely attributable to other unobserved treatments (cf. Abadie et al., 2010).

Figure 3 In-Space-Placebo

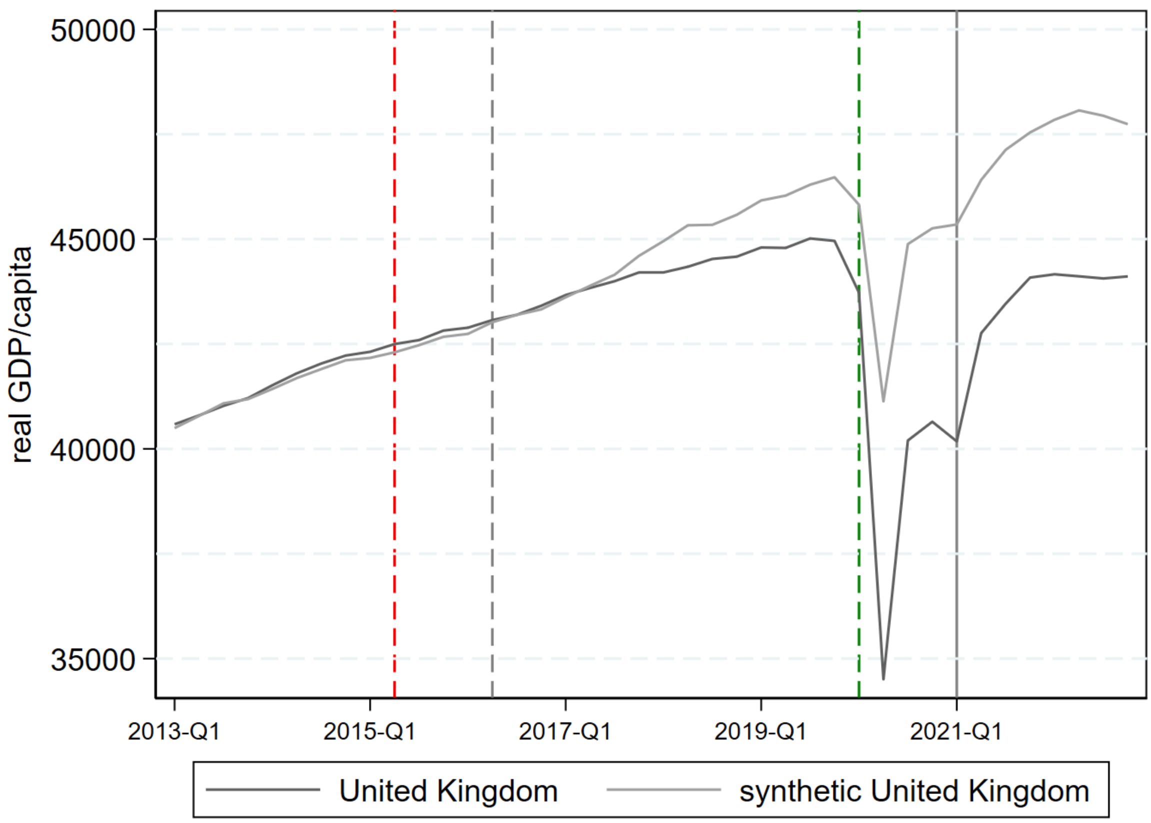


Note: The graph displays the differences in GDP per capita between every country and its respective synthetic control. The thick black line represents the UK, and the thin gray lines represent the 29 other countries, which have not been excluded. The red dashed vertical line indicates the date of the referendum in 2016-Q2, the green dashed line displays the beginning of the COVID-19 pandemic in 2020-Q1, the red solid vertical line the final exit in 2021-Q1.

With respect to the In-Time-Placebo, the timing of treatment is rearranged. It has to be rescheduled earlier back in time to ensure that the treatment has no impact on the units, thereby avoiding any potential announcement or anticipation effects. Accordingly, in this case, the treatment was rescheduled to occur four periods earlier in time, and the period 2015-Q2 was used as the treatment period, in accordance with Douch & Edwards (2022). In this quarter, the Conservatives were triumphant in the House of Commons election, resulting in the reelection of Prime Minister David Cameron, who reaffirmed his campaign pledge to hold a referendum.

As illustrated in Figure 4, the movements of both graphs demonstrated minimal changes following the referendum announcement. They exhibited almost parallel behavior in the aftermath until the referendum. This finding indicates that despite the referendum announcement, there was no discernible impact on the economy from Brexit-induced uncertainty, as a vote for Leave was generally perceived as an unlikely outcome. Following the referendum in 2016-Q2, a slow divergence occurred between the two graphs, as previously observed.

Figure 4 In-Time-Placebo with Conservative Victory as Timing of Treatment



Note: The dashed gray line displays the referendum in 2016-Q2, the green dashed line displays the beginning of the COVID-19 pandemic in 2020-Q1, the solid gray line displays the definite departure in 2021-Q1. The dashed red line displays the Conservative Election Victory in 2015-Q2 and subsequently the announcement of the referendum.

Abadie et al. (2015) put forth an additional robustness test to evaluate the influence of major donors on the outcomes and the extent to which the results are susceptible to the exclusion of specific donors. In the Leave-One-Out (LOO) test, the donor with the highest weight is iteratively removed, and the SCM is then recalculated. Figure A3 in the Appendix illustrates the results for the LOO test. The black line once again illustrates the discrepancies between synthetic and factual UK, whereas the gray lines demonstrate the results obtained with iteratively dropped donors. The graph corroborates our findings, as the discrepancies are more pronounced than those in the main SCM results and are therefore not driven by any donor. Therefore, it can be concluded that the findings of this study are sufficiently robust to variations in the donor pool.

Additionally, another event study was conducted. It is crucial to acknowledge from the outset that the DID design is severely flawed in this context, as it is unable to separate the impacts of Brexit and COVID-19. Consequently, it is included solely as an additional robustness test. In this case, the synthetic weights derived from the main analysis were employed, and the synthetic counterfactual was contrasted with the actual UK in a conventional DID setting (Figure A4 in the Appendix). While the previously noted negative effects of the referendum until 2019-Q4 are still visible, they are not significant. Only at the beginning of the COVID-19 pandemic did the effects start to become significantly negative. Importantly, all countries in the donor pool experienced an economic impact from COVID-19. As only the UK experienced both impacts from Brexit and the pandemic, the significant negative shock is likely to come from the crossover effect.

Kaul et al. (2021) criticized the practice of many SCM papers that use the dependent variable lags from all available pretreatment periods as predictors, demonstrating that this approach may render the covariates irrelevant, regardless of their importance in predicting the post-treatment values. While this paper did not utilize all available pre-treatment periods, it employed 13 lags from 29 pre-treatment periods leading up to the referendum. However, only four of these variables were used in another robustness test. This is not only consistent with Kaul et al. (2021) but also with Abadie et al. (2010), who utilized three (t-1, t-9 t-14) out of 19 pre-treatment periods as covariates. The results are presented in Figure A5. When the lags are reduced to four (t-1, t-5, t-9, t-13), the effect becomes slightly smaller, and the pre-treatment period fits slightly worse. Both synthetic UKs behave approximately the same way, and the effects seem to be robust to the number of utilized pre-treatment lags.

6 Discussion and Conclusion

The United Kingdom's GDP per capita has demonstrably diminished as a consequence of the 2016 Brexit referendum. Following the divergence between the UK and its counterfactual after the referendum, the COVID-19 pandemic and the final withdrawal and transition to an FTA widened this gap and further worsened the situation. By the end of 2019, the UK was 2.13% poorer, and after the COVID-19 pandemic and final exit, the UK was projected to be 5.74% poorer in terms of real GDP per capita than a counterfactual in which it had not voted to leave the EU.

Our baseline results until 2019 and 2022 are comparable to those of Born et al. (2019) and Springford (2022), respectively, who also employed SCM as the primary method, despite the use of a distinct donor pool and covariates. As previously stated, the estimation results of the first temporal cluster using the SCM were largely consistent across all reviewed papers, with these results being relatively similar.[9]

In addition, this study provides the first evidence that the UK's substantial economic decline during the COVID-19 pandemic was not solely attributable to the virus and the implemented countermeasures but rather a consequence of the combined impact of the virus and the preexisting effects of Brexit.

There are various potential explanations for why the economic effects of the COVID-19 pandemic may have been amplified through Brexit. First, the pre-exit trade effects observed by Douch et al. (2019) may have been intensified by the one-of-a-kind disruption of international supply chains caused by the pandemic. Du & Shepotylo (2022a) provided evidence that, from 2016 to 2019, services trade fell by 5.7% compared with a counterfactual in which the UK population voted to remain in the EU. Trade in services has been highly affected by COVID-19, while trade in goods has recovered faster (Bank of England, 2021), but the former is highly relevant for the UK economy (Dhingra et al.,

[9] An updated literature review comparison figure, including the results of this paper, can be found in the Appendix (Figure A6).

2017). This finding suggests that the Brexit referendum-induced reduction in services trade was likely worsened by the pandemic.

Second, Portes (2022) noted that net migration to the UK from EU countries substantially decreased in the years after the referendum, providing evidence that the pandemic worsened this trend through different channels. Many European migrants worked in service sectors, which were shut down during the early pandemic. Foreign students may have decided to work from their home country due to increased use of online teaching.

Crafts (2019) emphasized that the disappointing productivity performance of the UK will not be fixed by Brexit but rather worsened, and Bloom et al. (2023) provided evidence that COVID-19 worsened this situation even more. Blundell et al. (2022) found that lower-earning households especially suffered from job losses due lack of opportunities to work from home. King (2021) underlined the synergy of Brexit and COVID-19 and its combined negative effect on the labor market, pointing to labor shortages in seasonal agricultural labor amidst the harvesting season and the heavy reliance of the National Health Service on immigrant and immigrant-origin staff.

In the COVID-19 era, a debate has emerged that attributes weakened economic performance to the effects of the pandemic and its death tolls rather than to the consequences of Brexit (e.g., Gudgin, 2022), but Gagnon et al. (2023) show that the number of deaths had a minimal economic influence in advanced economies, whereas the stringency of lockdown restrictions had a significantly negative effect on GDP growth. As the UK lifted these restrictions early and opened up the economy faster than its peers did (Springford 2022), measures against the pandemic could hardly be solely responsible for the downturn.

We acknowledge the potential limitations of our research. As is always the case when working with counterfactuals, estimating the unobserved is inherently uncertain and should therefore be treated with caution. Moreover, as the referendum in 2016 only had signaling effects with no direct but rather indirect economic consequences in terms of anticipation or uncertainty, the final exit in 2020 had direct economic consequences in terms of a reduction in trade. We deliberately did not distinguish between the two different kinds of impact but explored how a UK population that had voted to stay would have performed over the subsequent seven years. Furthermore, although we found significant effects in combination with the COVID-19 pandemic, it is difficult to disentangle them. While we were unable to quantify the precise impact of either shock, we were still able to provide an estimate of the combined impact and present convincing evidence, supported by a broad range of robustness checks. The impact of Brexit and COVID-19 has resulted in a notable decline in the United Kingdom's per capita income. Prior to Brexit, the European Union was the largest trading partner for the UK and was predicted to remain so in the years to come (Chang, 2018). Future research could study how this will unfold in the upcoming years and classify the long-term estimates. Dhingra & Sampson (2022) project a decline in GDP of up to 3% by 2030 relative to a baseline scenario where the UK had not left the EU. It is anticipated that now, after the gradual dissipation of the initial shock of Brexit (Chung et al. 2023) and the diminished economic significance of the pandemic, the factual and counterfactual UK are likely to have similar trends and may even converge, with the factual UK remaining considerably poorer. This paper indicates that exiting the Single Market may entail significant costs. Moreover, unexpected global shocks are likely to further exacerbate the situation.

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Appendix

Table A1 Weights of the synthetic UK

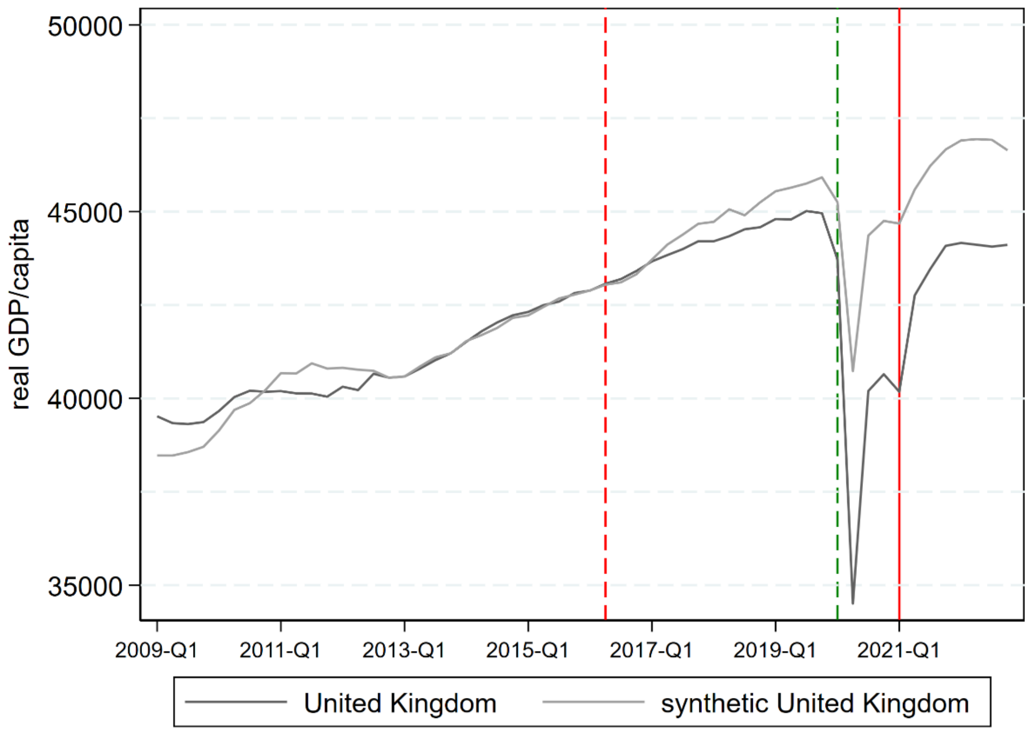
Country	Weight	Country	Weight
Australia	0	Italy	0
Austria	0	Japan	0
Belgium	0	Latvia	0
Canada	0	Lithuania	0
Chile	0	Luxembourg	0
Colombia	0	Mexico	0
Costa Rica	0	Netherlands	0
Czech Republic	0	Norway	0.064
Denmark	0	New Zealand	0
Estonia	0	Poland	0
Finland	0	Portugal	0
France	0	Slovakia	0
Germany	0.404	Slovenia	0
Greece	0	Spain	0.056
Hungary	0.284	South Korea	0
Iceland	0	Sweden	0.161
Israel	0	Switzerland	0.03

Table A2 Covariates Comparison between UK, synthetic UK and the Donor Pool

Variables	UK	synthetic UK	Average of all 34 Control Countries
Inflation rate	2.086	1.536	1.793
Inward FDI (in Bio. USD)	14.947	4.807	3.465
Restriction on all sectors	0.040	0.036	0.065
Restriction on tertiary sector	0.029	0.049	0.075
Exports (in Bio. USD)	714.7	778.5	297.1
Gross Fixed Capital Formation (in Bio. USD)	425.5	354.5	190.4
Dependency on Russian Fossils	0.0732	0.265	0.180
Population size (in Mio. people)	63.8	40.3	25.0
Labor force rate (in percent)	79.91	80.27	79.082
Rate of tertiary education (in percent)	47.79	33.32	39.07
Migration Rate (in percent)	0.425	0.382	0.237
$GDP/capita_{t-1}$	40760.66	40723.08	37909.87
$GDP/capita_{t-2}$	40684.40	40646.94	37854.04
$GDP/capita_{t-3}$	40610.99	40568.91	37796.67
$GDP/capita_{t-4}$	40535.50	40493.66	37738.76
$GDP/capita_{t-5}$	40461.39	40421.64	37686.90
$GDP/capita_{t-6}$	40384.76	40346.26	37633.80
$GDP/capita_{t-7}$	40309.79	40276.21	37585.66
$GDP/capita_{t-8}$	40238.84	40208.51	37544.75
$GDP/capita_{t-9}$	40174.95	40142.20	37501.86
$GDP/capita_{t-10}$	40120.49	40086.05	37460.92
$GDP/capita_{t-11}$	40070.24	40029.75	37422.27
$GDP/capita_{t-12}$	40027.47	39981.26	37387.33
$GDP/capita_{t-13}$	39992.59	39943.43	37358.82

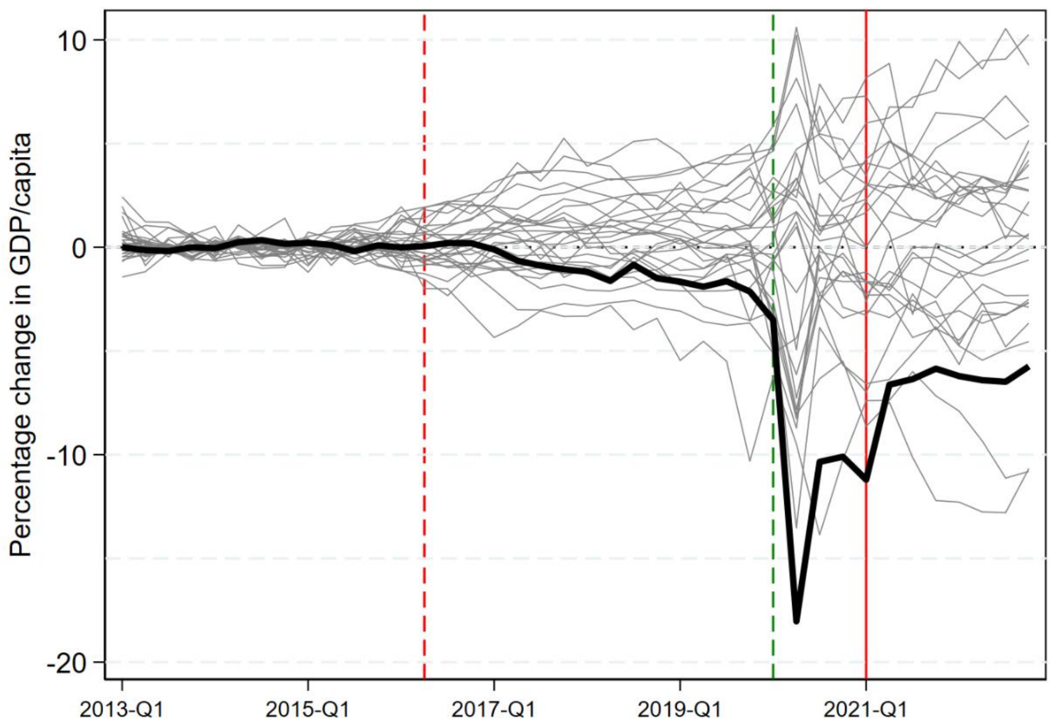
Note: The lagged dependent variable does fit much better than the average of the control countries. Regarding the Covariates, only for three variables the synthetic UK has a worse fit than the average of the controls (inflation rate, dependency on Russian fossils and rate of tertiary education).

Figure A1 SCM main result (Full graph)



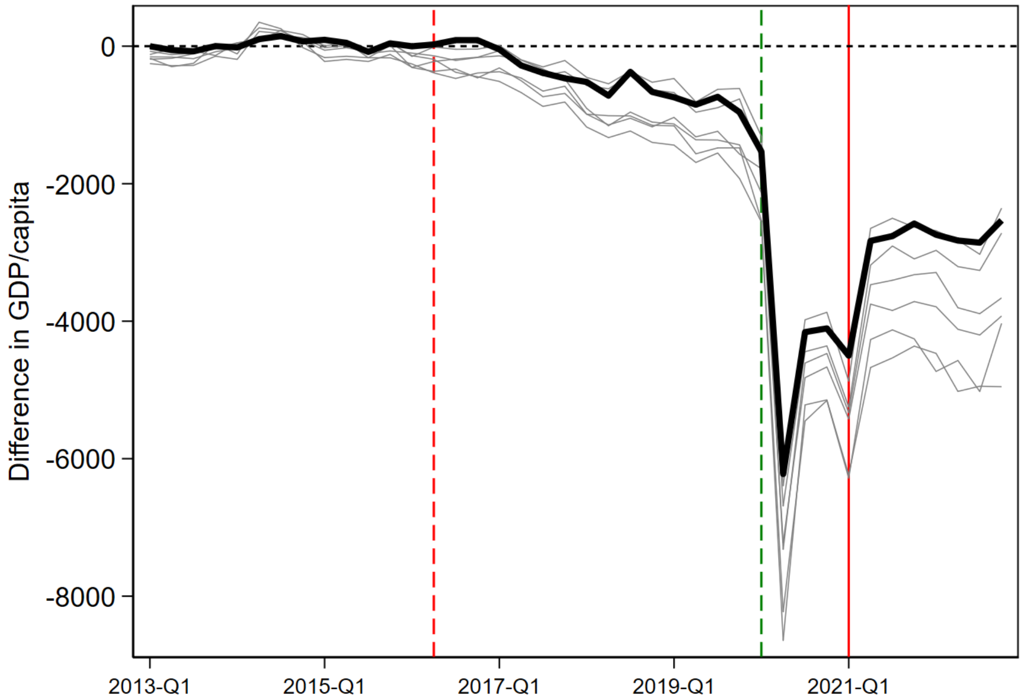
Note: As no lag previous to t-13 is included, the fit does not work perfectly in this horizon, as expected. Most of the literature included all lags of the pre-treatment period (e.g. Born et al. 2019, Springford 2022) and therefore guarantee perfect fits for the whole pre-treatment period.

Figure A2 In-Space-Placebo (Percentage Change of GDP)



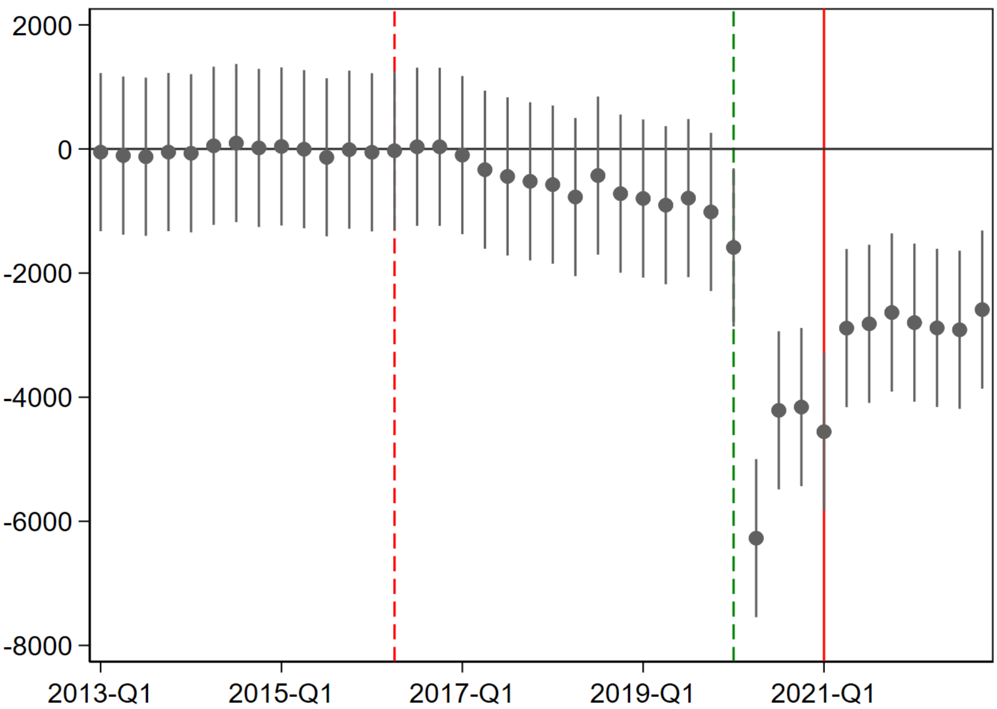
Note: The graph displays the relative differences in GDP per capita between every country and its respective synthetic control. The thick black line represents the UK, and the thin gray lines represent the potential donors. The dashed vertical line indicates the date of the referendum in 2016-Q2, the green dashed line displays the beginning of the COVID-19 pandemic in 2020-Q1, the solid vertical line the final exit in 2021-Q1.

Figure A3 Leave-One-Out-Test



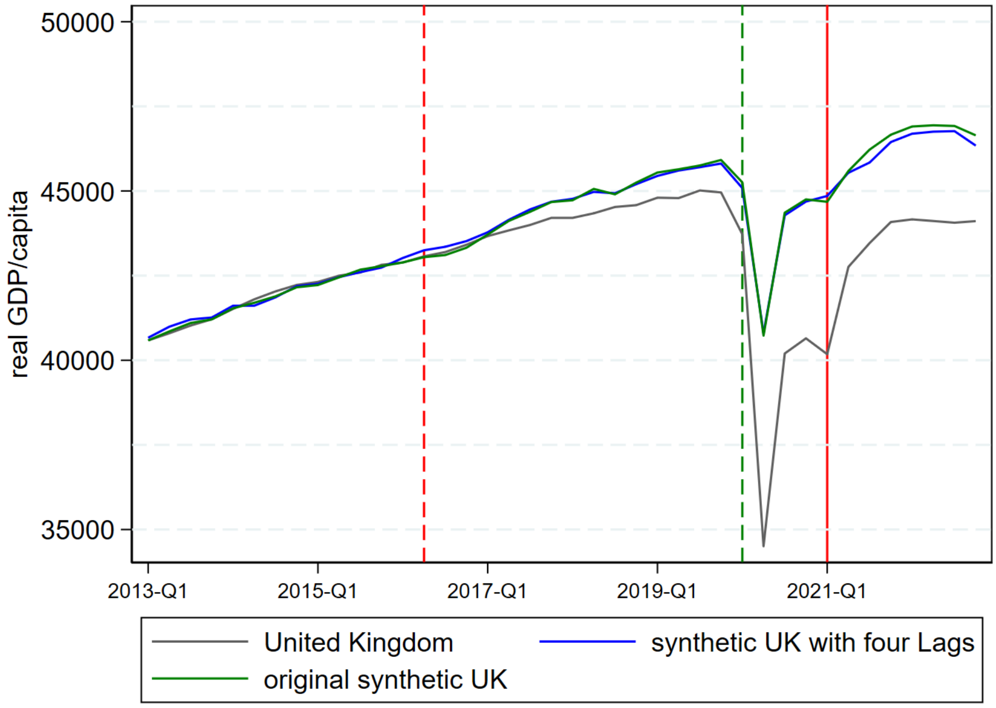
Note: The red dashed line displays the referendum in 2016-Q2, the green dashed line displays the beginning of the Covid-19 pandemic in 2020-Q1, the solid red line displays the definite departure in 2021-Q1. The graphs show the difference in GDP per capita between the factual UK and synthetic UK, after applying the LOO-test. For every gray line the corresponding largest donor is dropped from the donor pool and the SCM is then rerun.

Figure A4 Event study between UK and synthetic UK



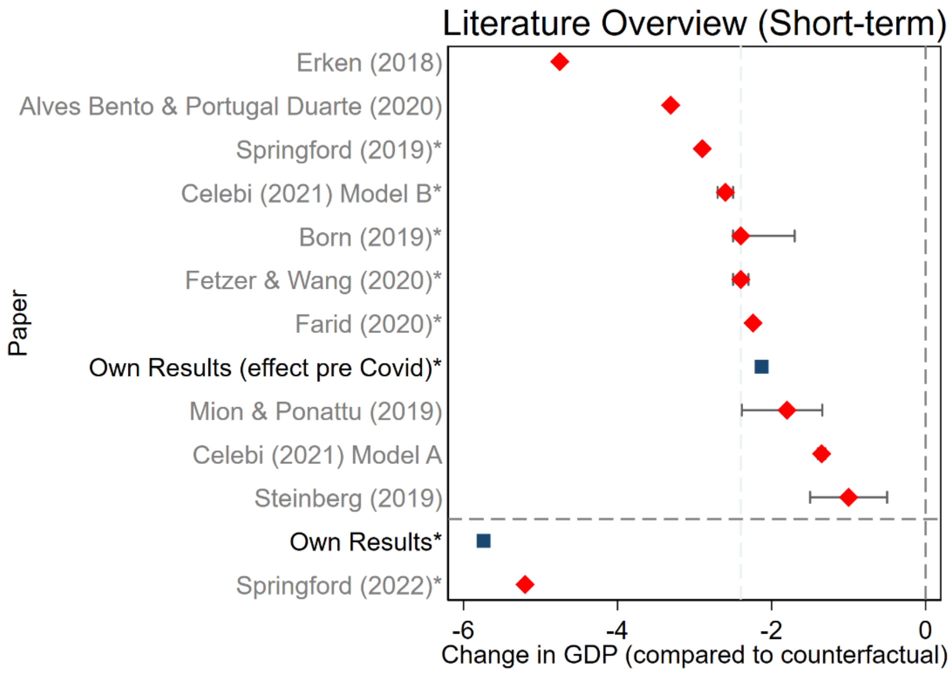
Note: This Event Study compares the differences between synthetic UK and actual UK in every quarter. Significance only appears in 2020-Q1 when the COVID-19 pandemic arises. Only after this shock, the difference between both is significant. The dashed vertical line denotes the referendum in 2016-Q2, the green dashed line displays the beginning of the COVID-19 pandemic in 2020-Q1, the solid vertical line denotes the final exit in 2021-Q1.

Figure A5 SCM (with four lags)



Note: The dashed vertical line denotes the referendum in 2016-Q2, the green dashed line displays the beginning of the Covid-19 pandemic in 2020-Q1, the solid vertical line denotes the definite departure in 2021-Q1. The blue line displays the SCM with only four lags (t-1, t-5, t-9, t-13), the green line displays the original SCM application with 13 lags. The effect is slightly smaller, while the pre-treatment fit is marginally worse. Similar tests with randomly chosen lags came to the same conclusion.

Figure A6 Updated comparison of the Literature



Note: This version of *Figure 1* displays the literature overview of short-term results as before, now including this paper's results. The two dots beneath the dashed horizontal line denote results up until 2022, the dots above denote short-term estimations up until 2019, i.e., pre-COVID. The red dot of each paper shows their baseline result, while the ranges for some papers show an upper and a lower estimate. While the red dots are from the used literature comparison in Chapter 3, the blue dots refer to this paper's results. The first blue dot represents the gap in 2019-Q4, so before the final departure date and the transition to an FTA were announced and before COVID-19 had an effect. The second blue dot show the most recent available observation gap and allows comparison with Springford (2022).

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