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A Breakup Between the UK and the EU: The Impact of the Brexit Referendum on Household Savings Rate in the United Kingdom

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Abstract. This paper investigates the causal impact of the Brexit referendum on the household savings rate in the United Kingdom, both in the short and long term, by treating the referendum as a natural experiment. The Synthetic Control Method is used to create a counterfactual that tracks the UK's household savings rate before the referendum. The short-term results suggest that the Brexit referendum had a negative impact on the household savings rate, with a decline of 3 percentage points, which is statistically significant at the 5% level. The long-term effects are examined by including the COVID-19 pandemic and Brexit withdrawal period of 2020 Q1 - 2022 Q3. The results suggest that the negative effect of the Brexit referendum on household savings in the UK persists until the pandemic begins in 2020 Q1, after which there was a sharp increase in the household savings rate. To interpret the findings, the Theory of Precautionary Savings and the Permanent Income Hypothesis are employed. This paper contributes to the literature by investigating the impact of the Brexit referendum on a macroeconomic indicator that has not been studied before, and by providing a long-term perspective that includes the effects of both the COVID-19 pandemic and the Brexit withdrawal.

Keywords: Household Savings, Brexit, Referendum, COVID-19, Synthetic Control Method, Economic Impact, Policy Uncertainty, Precautionary Saving, Permanent Income Hypothesis

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Concepts and Definitions

COVID-19	Coronavirus Disease 2019
DiD	Difference-In-Difference
GDP	Gross Domestic Product
GDPI	An Income Approach Of GDP
GNDI	Gross National Disposable Income
LCPIH	Life Cycle/Permanent Income Hypothesis
MSPE	Mean Square Prediction Error
PIH	Permanent Income Hypothesis
RMSPE	Root Mean Square Prediction Error
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SCM	Synthetic Control Method
The EU	The European Union
The UK	The United Kingdom
The US	The United States

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1. Introduction

Household savings is an important macroeconomic measure as it sheds light on a country's stability and potential for long-term economic prosperity (Buchholz, 2014; Rocher and Stierle, 2015). Every penny that an individual saves in his or her account can later be borrowed to another individual or organization to make valuable investments for society with financial institutions as the intermediary. Thus, a country's investment capabilities are closely interlinked with savings, where households are a crucial contributor.

Viewed from the vantage point of individual households, savings accounts serve a dual purpose. On the one hand, they function as a safety net to mitigate any forthcoming economic adversities (Baiardi et al, 2020). On the other hand, they offer a source of funds for investing in essential services such as education and healthcare, thereby contributing to raising the standard of living (Rocher and Stierle, 2015).

In 2016, the United Kingdom (the UK) held a referendum to determine if it would continue its membership in the European Union (the EU) (Walker, 2021). This referendum had wide macroeconomic and political implications for the UK, as it entailed uncertainty and eventually a withdrawal from an integrated economic and political union (e.g, see Born et al., 2019; Steinberg, 2019). This paper seeks to examine the causal impact of the Brexit referendum on the British households savings rate by treating the Brexit referendum as a natural experiment. Given the unforeseen and unspecified consequences of the referendum outcome, it can be regarded as exogenous (Born et al., 2019), thereby motivating the use of the Synthetic Control Method (the SCM). The SCM offers a suitable means of evaluating the effects of the Brexit referendum on household savings rate, allowing for comparisons to be made between the UK and countries with similar pre-Brexit characteristics.

Previous studies have analyzed the Brexit referendum's impact on multiple economic indicators, such as foreign direct investments, international trade, and welfare loss (e.g., see Hiau Looi and Alessandro, 2017; Breinlich et al., 2017; Jackson and Shepotylo, 2018; Steinberg, 2019; Breinlich et al., 2020; Douch and Edwards, 2021; Krena and Lawless, 2022). The guiding study of this paper is called "The Costs of Economic Nationalism: Evidence from the Brexit Experiment" written by Born et al. and published in *The Economic Journal* in 2019. In their paper, Born et al. (2019) applied the SCM to investigate the effect of the referendum on GDP and its components. The main findings showed a GDP loss of 1.7%-2.5% by the year-end of 2018 and the effects caused by the referendum seem persistent (Born et al., 2019).

Our paper contributes to the existing literature by first of all investigating the Brexit referendum's impact on a macroeconomic indicator that to the best of our knowledge has not been investigated before. Secondly, this paper provides a long-term perspective given that it includes quarters up until 2022 Q3 whilst estimates in the paper of Born et al. (2019) end in 2018 Q2. This additional time period involves two important events, namely the COVID-19 pandemic and the Brexit withdrawal. Considering the economic shocks that occurred during this turbulent period and the subsequent launch of government support packages (Ulrich Ruch and Taskin, 2022), it is relevant to investigate if the initial treatment effect persists through this additional time period or if it is swept through.

With those aims in mind, we have formulated the main research question of this paper:

What is the short-term and long-term effect of the Brexit referendum in 2016 on Household Savings Rate in the United Kingdom?

To answer this research question, the SCM is employed. It is a comparative case study, where comparison is made between the household savings rate of the UK to a counterfactual that is constructed synthetically by using multiple countries and predictors. In this paper, the counterfactual is designed to mirror the baseline level and fluctuations of the UK's household savings rate prior to the Brexit referendum. It is important to note that the Brexit referendum is considered a "treatment" and is not assigned to the counterfactual unit. Given that the counterfactual accurately tracks the UK's household savings rate before the treatment, it can be presumed that the UK's post-Brexit development would have followed a similar pattern to the counterfactual if it was not for the Brexit referendum. When a set of assumptions hold, a causal inference can be drawn by comparing the trend of the counterfactual to that of the UK after the Brexit referendum. The results are analyzed with the help of the Theory of Precautionary Savings and the Permanent Income Hypothesis (the PIH).

The research relies on quarterly data on nine macroeconomic indicators for 23 countries during 2003 Q1 – 2022 Q3. The *OECD* and *Eurostat* databases are the main sources from which the data is obtained. The nine indicators – household savings rate expressed as a percentage of disposable income, GDP, GDP per capita, real GDP growth, household consumption, inflation rate, old-age dependency ratio, unemployment rate and long-term interest rates – are theoretically motivated as the main drivers of household savings rate (Loayza et al., 2000; Grigoli et al., 2014; Rocher and Stierle, 2015).

The short-term findings indicate that the Brexit referendum had a negative impact on the household savings rate in the UK. The household savings rate is estimated to have declined by 3 percentage points after the Brexit referendum, and the treatment effect is significant at the 5% significance level. Robustness tests show that these primary results seem robust. In a second phase when the time period of 2020 Q1 – 2022 Q3 is included, the long-term effects are investigated. The first observation is that the negative effect of the Brexit referendum on household savings in the UK seems to persist up until the pandemic began in 2020 Q1. The second observation is that there is a large increase in the household savings rate in both the UK and the counterfactual as the pandemic unfolded – the spike amounts to ca. 20 percentage points in the UK and ca. 10 percentage points in the counterfactual. Despite this large spike in the UK's household savings rate, the estimated treatment effect is still significant in the long-run.

The results are in line with previous studies that have shown a deteriorating and persisting effect of the Brexit referendum on the British economy (e.g, see Born et al., 2019; Steinberg, 2019). The immediate dissaving pattern in the short-term can be explained by the PIH as the theory suggests that households save less in economic downturns. The spike in savings that occurred in 2020 can be seen as a precautionary savings pattern but can also be regarded as a reaction to the increase in permanent income due to government support packages.

The subsequent sections of this paper are organized as follows. Section two commences by providing a definition of the household savings rate, and by highlighting the significance of this economic indicator. It then proceeds to present an overview of a sequence of events set in motion by the Brexit referendum, along with a background on the COVID-19 pandemic. Section three undertakes an extensive literature review to establish an understanding of previous research on the subject. Following this, three separate parts are presented and explained, starting with theoretical models, then

methodology, and data. The data section concludes with data visualization of the main variables. The results are structured into short- and long-term parts, with an analysis provided in the discussion section. Finally, the paper concludes with our findings, implications, and suggestions for future research.

2. Background

The household savings rate is a measure of the percentage of disposable income that households save. A negative rate indicates that households spend more money than they earn, resulting in net borrowing (Rocher and Stierle, 2015). On the other hand, a positive rate indicates that households have made financial and/or non-financial acquisitions. Financial investments can include "deposits in a savings account" or "repayments" of loans, while non-financial investments may involve purchases of assets such as gold or housing (Rocher and Stierle, 2015). In Europe, households generally act as "net lenders to the economy", although there are significant national variations (Rocher and Stierle, 2015).

For every household, savings are a crucial source of financing for many important economic activities, including healthcare, education, and vacation, making it an essential measure of a household's financial health given its significant impact (Glosh et al., 2022; Rocher and Stierle, 2015). At a macro level, household savings also play a crucial role in determining the available credit for investments and, as such, affect a country's economic growth and prosperity (Buchholz, 2014; Rocher and Stierle, 2015). In other words, the percentage of disposable income that households save has wide-reaching implications at both household and national levels. Consequently, the household savings rate is a critical macroeconomic variable that must not be overlooked when examining the impact of a policy shock on the economy.

During 2000-2021, the rate of household savings was on average 6.78% for the EU and 3.25% for the UK (*OECD*, 2023f). As shown in the graphs in Appendix 1, the UK exhibits a lower household savings rate on average compared with other European countries (*OECD*, 2023f), which may give an indication of the British cultural attitudes toward savings. Because of the below-average savings rate, the data suggests that the British economy may be more vulnerable to external shocks given that domestic investment projects may rely more on foreign capital (Rocher and Stierle, 2015). Consequently, the relevance of our research question becomes increasingly important to policymakers seeking to understand the magnitude of Brexit's effect on the British household savings.

Furthermore, the proportion of domestic savings to GDP has increased in the UK, following the same trend as the EU, as per the *World Bank*'s statistical records in Appendix 2 (*World Bank*, 2021). This trend unequivocally substantiates the growing significance of the savings rate for the British economy, which elucidates the relevance of our paper to the existing economic literature.

2.1. The Short-Term: The Brexit Referendum and The Pre-Pandemic Years

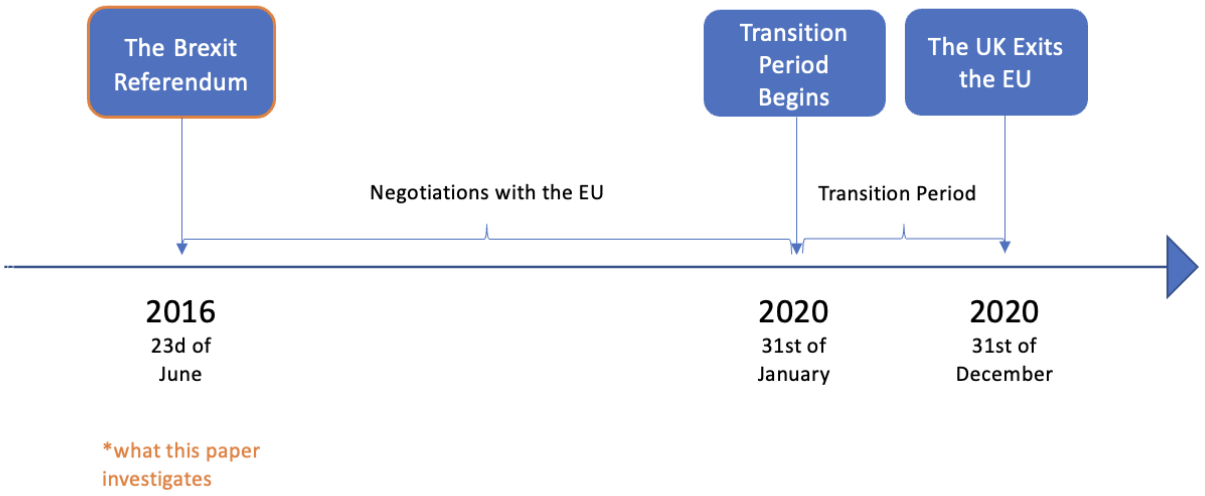
The Brexit Referendum

On February 22nd, 2016, former UK Prime Minister David Cameron announced a referendum would be held on June 23rd, allowing citizens to vote on whether the UK should remain a member state of the European Union (Walker, 2021). Millions of people tuned in to watch or listen to coverage of the event, knowing that the outcome would have significant historical implications. It was the third

national referendum in the UK and the second devoted to the EU; 41 years after the people voted to enter the EU, 51.9% of the voters now favored the decision to leave the union (Walker, 2021).

After lengthy domestic debates, negotiations with the EU, and two resigned British prime ministers later, Britain entered into a one-year transition period on January 31st, 2020, which marked its formal withdrawal from the EU. On December 31st, 2020, the UK was no longer part of the EU single market nor the customs union (Walker, 2021).

Figure 1: Timeline of Brexit



Source: Walker (2021).

The Nature of the Brexit Referendum

In this paper, the Brexit referendum is regarded as a natural experiment. The first key supporting argument is that the vote result came as a surprise, as many papers have pointed out (Hiau Looi and Alessandro, 2017; Breinlich et al., 2017; Born et al., 2019; Douch and Edwards, 2022). Davies and Studnicka (2018) highlighted that there was no clear indication from the public whether "Remain" or "Leave" was the mainstream opinion judging by the results of multiple polls before the actual referendum day. If there was any indication, it appeared as the British people were rooting for remaining in the EU given the last poll results, according to Davies and Studnicka (2018). They further explained that the assumption of the leaving decision being a shock can be buttressed by the volatile reaction on the stock market as well as the betting results from betting agencies. Born et al. (2019) also referenced the betting odds on the Betfair exchange and the search frequency on Google Trends to further support Davies and Studnicka's (2018) surprise assumption. Additionally, Born et al. (2019) raised a second argument that the result of the Brexit referendum is mainly politically-driven, because "the voting behavior was largely unrelated to the UK's recent macroeconomic performance. [...] the case for Brexit was predominantly based on the political imperative to 'take back control'." Finally, economic policy uncertainty began increasing when the referendum was announced on the 22nd of February 2016. It reached its peak in June 2016 but remained at high levels up until 2018 (Baker et al., 2023). The increased policy uncertainty further supports the assumption that the Brexit referendum was of an exogenous nature (Baker et al., 2023).

Moreover, it was unclear what the outcome of the results would entail. The UK was the first country in the history of the EU to activate article 50 of the *Treaty on the European Union* (2007) and thus

leave the union. When article 50 is activated, negotiations between the EU and the addressed country begin, as established by article 49 in the *Treaty of Lisbon* (2007). The roadmap of the leave-outcome was thus not established beforehand, which generated domestic debates after the referendum on a "soft" or a "hard" Brexit and eventually as the withdrawal was approaching, the debate shifted towards a "deal" or a "no deal" Brexit (*BBC News*, 2016; *BBC News*, 2019). These debates regarding the scope of the withdrawal further strengthens the assumption that Brexit can be seen as a natural experiment as the outcome's consequences were not specified beforehand. Thus, as the referendum's outcome was both unexpected and its consequences unspecified, it can be regarded as a natural experiment.

2.2. The Long-Term: The COVID-19 Pandemic

This paper also aims at investigating the long-term impact of the Brexit referendum on household savings. As the years of 2020 and onwards were impacted by the COVID-19 pandemic, a short background on the pandemic is below presented.

The COVID-19 Pandemic

Whilst the UK was entering the transition period in its withdrawal from the European Union, a new SARS virus (SARS-CoV-2), originating from Wuhan, China, began spreading over the world. On the 11th of March 2020, the new virus was classified as a pandemic by the *WHO* (2020). Because of the spread of the virus, its high mortality and strain on healthcare systems, large parts of the world shut down. Many nations implemented nation-wide lock-downs and hard restrictions. Contagion of the virus increased and decreased in waves, and restrictions were adapted accordingly (*Centers for Disease Control and Prevention*, 2023). In the end of 2020, the first people were receiving an initial vaccine shot and in January 2023, the WHO indicated that it hoped to stop viewing the coronavirus as a pandemic by the end of 2023 (Kimball, 2023). According to the *WHO* (2023) figures, more than 6.8 million people are reported to have lost their lives in a COVID-19 infection.

The Nature of the COVID-19 Pandemic

The COVID-19 virus can be seen as a global, exogenous event because it was a new virus that rapidly spread across the globe, affecting countries and economies indiscriminately (Thomson, 2020). As such, it can be regarded as an exogenous shock, meaning that it is a factor that affects the economy from outside and is beyond the control of economic agents (*United Nations Economic and Social Commission for Western Asia*, 2015). The pandemic brought the world to a standstill, causing unprecedented disruptions to global supply chains and demand for goods and services (Ulrich Ruch and Taskin, 2022). Governments worldwide responded with support packages to stimulate demand and counteract the negative effects of the pandemic, such as unemployment (Ulrich Ruch and Taskin, 2022). The resulting supply and demand shocks, along with government responses, had profound impacts on households' savings patterns (Aladangady et al., 2022).

The COVID-19 pandemic added another exogenous shock to the UK economy and provides a unique opportunity to examine how households responded to these events. The aim with the long-run estimations in this paper is thus to investigate whether or not the initial effect of the Brexit referendum on household savings persists when the subsequent pandemic shock hits the world in 2020.

3. Literature Review

The Brexit Referendum's Impact on Economic Indicators

This thesis aims to call attention to the relationship between the Brexit referendum and the savings rate in the UK. To the best of our knowledge, there is no existing paper that has examined this macroeconomic indicator specifically. However, several previous studies have explored the impact of Brexit on macroeconomic indicators and international trade (e.g., see Hiau Looi and Alessandro, 2017; Breinlich et al., 2017; Krena and Lawless, 2022). Douch and Edwards (2021) chose to specifically look into exports in the commercial services sector employing a SCM. Fernandes and Winters (2021) studied the Brexit vote as an uncertainty shock on exports and concluded that both the volume and price decreased as a result. Jackson and Shepotylo (2018) examined welfare implications under multiple Brexit scenarios. In the same spirit, Steinberg (2019) quantified the welfare cost for British households due to the trade policy uncertainty caused by Brexit. Depending on different scenarios of Brexit – soft or hard – the consumption-equivalent welfare cost is between 0.4 and 1.2% (Steinberg, 2019). Sampson (2017) estimated the income loss for every British individual which could range from 1% to 10% after the Brexit referendum. Breinlich et al. (2020) conducted a SCM to analyze how foreign direct investments were affected by the UK's disintegration of the EU, showing that investments from EU member states in the UK has dropped by around 9%. Similarly, Springford (2022) also used the SCM when assessing the impact of Brexit on the UK's GDP. According to this paper, Brexit had a longstanding effect and caused the UK's GDP to shrink by 5.5%, investment by 11%, and goods trade by 7% in 2022 Q2 (Springford, 2022).

Another paper written by Born et al. (2019) focused on assessing the economic cost of the Brexit referendum for Britain by treating the referendum as a natural experiment. Since their paper employed a synthetic control approach to quantify the effect on a macroeconomic level, it is regarded as the main reference paper for this paper, Born et al. (2019) looked into the effect of the vote itself instead of the actual Brexit withdrawal as it had not been ironed out at the time. However, Born et al. (2019) discovered that the vote itself "has already impacted economic activity well before any policy change has occurred". Given that finding, our paper will also primarily study the effect of the referendum itself instead of the actual withdrawal since the withdrawal was not a clear cut process (for instance, the formal withdrawal was on 31 January 2020 but the actual withdrawal happened one year later, as mentioned in the previous section). Many political turns regarding the withdrawal made it difficult to guarantee exogeneity, which explains why the choice of only looking at the Brexit referendum is favorable.

Apart from the first finding, Born et al. (2019) also quantified the economic reduction for the UK, showing that its GDP experienced a loss of 1.7% to 2.5% by the year-end of 2018. The authors even broke down the GDP to the component level, i.e., imports, exports, investments, private and government consumptions, so that they could discern the referendum's effect on the development of each component. However, the authors did not investigate the referendum's impact on household savings which has a profound significance for the future wealth of households and thus a country's economy. Nevertheless, Born et al. (2019) concluded that households and enterprises reacted to the Brexit vote, showing anticipation effects of the future withdrawal. Moreover, they demonstrated that these effects persist in the long term (Born et al., 2019). This finding demonstrates that the Brexit referendum can cause persistent effects, which is one of the major reasons for the inclusion of the long-term perspective in our paper.

The Impact of Economic Shocks on Household Savings

Another branch of the previous literature studied how household savings are affected by other economic shocks, for instance economic shocks related to COVID-19. Irawan et al. (2023) found out that demand and supply shocks induced by the COVID pandemic negatively impacted household savings for farmers who sell tilapia in Indonesia. The authors also emphasized the implications of this impact: "The fall in savings will disrupt the stability of consumption of household necessities (health, food, education and clothing) in the future". Fuchs-Schündeln (2008) treated German reunification as a natural experiment to study its effect on household savings, and the results showed that residents in Eastern Germany saved more relative to people in Western Germany after the reunification shock. Iwaisako and Okada (2012) studied the effect of income shocks on the Japanese household savings rate around the 2000s. According to their findings, Japan experienced a significant acceleration in the decline of its household savings rate following the domestic banking crisis in 1997/98, but the rate of decline slowed down from around 2004/05 (Iwaisako and Okada, 2012). By using the life cycle/permanent income hypothesis (LCPIH), Iwaisako and Okada (2012) explained that a key factor contributing to the aggregate decline in savings was the income slowdown experienced by older working individuals in the early 2000s. In a paper written by Dai et al. (2021), a decline in the household savings rate in China can be detected when the WTO accession caused local labor market shocks. According to Dai et al. (2021), "households reduced their saving rate in order to smooth consumption". Aizenman and Noy (2015) studied the household savings pattern caused by previous crises and adverse income shocks, including the global financial crisis of 2008. They found out that "households respond to past shocks by increasing their saving rates, and that this effect is long-lasting" (Aizenman and Noy, 2015).

The Impact of Policy Uncertainty on Household Savings

There is a plethora of studies on the determinants of household savings rate. We limit the focus of this section to studies that have plumbed the relationship between policy uncertainty and savings behavior as multiple studies have shown that the Brexit referendum is a policy uncertainty that has economic consequences (e.g., see Born et al., 2019; Bloom et al., 2019; Chung et al., 2022). According to the findings of Giavazzi and McMahon (2012), increased political uncertainty could lead to a rise in the household savings rate. Similar empirical evidence can be found in Aaberge et al. (2017) when the authors studied urban households in China. This paper clearly demonstrated that the household savings experienced a sudden temporary increase as a result of greater political uncertainty. Giesing and Musić (2019) used the Difference-in-Difference method (DiD) to study how the saving behavior in Egypt where a regime change happened in 2011. As the discovery shows, household savings have gone up, which can be interpreted as precautionary savings behavior.

The Paper's Contribution

When it comes to the contribution of this paper, it is twofold. First, our research calls attention to an important economic indicator that to the best of our knowledge has not been researched before. Therefore, the aim is to fill the void in the existing literature by assessing the referendum's effect on this macroeconomic indicator. In addition, it is interesting to investigate how the effect evolves in the long-run, given the importance of household savings for a country's economic growth. Thus, the second layer of our contribution would be analyzing the effect with a long-term perspective, which allows us to examine whether the effect persisted during the period of COVID-19 (starting from 2020 and onwards) and the Brexit withdrawal. In this way, we will be able to observe this effect both in the short-run and long-run, adding more nuances to the analysis.

4. Theory

One important theory for household savings is the Theory of Precautionary Savings. This theory simply indicates that individuals tend to increase their savings to prepare for future uncertain events by reducing current consumptions; in other words, this theory captures the behavior of households when facing increased uncertainty (e.g., see Skinner, 1988; Carroll and Samwick, 1998; Kennickell and Lusardi, 2004; Baiardi et al., 2020).

As early as 1968, Hayne Leland recognized how household savings reacted to income uncertainty, but subsequent literature on the topic of precautionary savings due to other types of uncertainties also emerged (Baiardi et al., 2020). For example, previous researchers have attempted to study how household savings respond to uncertainties in interest rates (e.g., Sandmo, 1970; Rothschild and Stiglitz, 1971). Additionally, studies have sought to assess the impact of political uncertainties on household saving behaviors (e.g., Aaberge et al., 2017; Giesing and Musić, 2019).

Furthermore, a model was presented by Kimball (1990) to explain why individuals might choose to save money even when they do not necessarily face a certain financial risk. By introducing the concept of "prudence" in the context of savings behavior, Kimball (1990) argued that individuals engage in precautionary saving to protect themselves against uncertain future events that could have negative financial consequences. That is to say, the desire to protect oneself against such events is enough to increase household savings (Kimball, 1990; Baiardi et al., 2020).

Another relevant theory is the Permanent Income Hypothesis, coined by the renowned American economist Milton Friedman (Friedman, 1957). The theory suggests that individuals are forward-looking and make consumption decisions based on their expected average income over their lifetime instead of their current income, taking into account factors such as their current income as well as future earnings potential (Hayashi, 1985; Fuchs-Schündeln and Hassan, 2016). Accordingly, individuals save more during periods of high income in order to smooth their consumption over time, and may dissave "during periods of adverse economic shocks" (Meng, 2003).

5. Methodology

Introduction to the Synthetic Control Method and Motivation of Method

To derive the causal effect of the Brexit referendum on household savings, this paper is adopting a comparative case study, using the SCM. By comparing the development of the dependent variable in the UK to that of a synthetic counterfactual, henceforth called the Doppelganger, we estimate the effect of the 2016 referendum on household savings rate. The Doppelganger is created synthetically, using a donor pool of countries and predictors, to best mimic the trends and levels of household savings in the UK before the referendum. The Brexit referendum is regarded as a treatment and is only given to the UK. The difference between the UK and the Doppelganger in household savings post-treatment is then the estimated causal effect of the Brexit referendum on household savings rate, subject to the validity of the identifying assumptions.

In order to estimate a causal effect of Brexit on household savings, a crucial identifying assumption must hold: the Doppelganger, the synthetic control created to represent the UK in the absence of the Brexit referendum, should closely track the trends and baseline values of the UK's household savings rate in every period before the referendum (Abadie, 2021). This requirement is similar to the common trends assumption of the DiD method. Specifically, both the UK (the treated unit) and the

Doppelganger (the untreated unit) should have been exposed to the same shocks prior to the intervention, which means that the countries in the donor pool should be fairly similar to the UK (Abadie, 2021).

To evaluate the credibility of the Doppelganger, its predictor values become an important tool. The predictor values should closely match those of the UK for reliable estimates (Abadie and Gardeazabal, 2003). In other words, the Doppelganger's predictor values should "reproduce the values" of the UK's predictors (Abadie and Gardeazabal, 2003). Only when these assumptions hold, can we estimate the causal effect of Brexit on household savings in the UK with confidence (Abadie, 2021).

Moreover, the referendum being a natural experiment allows the application of the SCM, because another of the key identifying assumptions of the method is therefore sustained (Abadie, 2021). Namely, the development of the Doppelganger would be the development of the UK if the referendum had not been held. Another model assumption is therefore that there are no treatment spillover effects, meaning that the macroeconomic shock's consequences do not impact other countries as it would bias the estimates (Abadie, 2021). Finally, the unmeasured factors are allowed to vary across time but are assumed to be constant across units (Hollingsworth and Wing, 2020).

There are several advantages of the SCM compared to other comparative case studies, such as the DiD method. Firstly, the SCM's general advantage over other methods is that "a combination of units often provides a better comparison for the unit exposed to the intervention than any single unit alone" (Abadie, Diamond, & Hainmueller, 2010).

Moreover, the choice and construction of the counterfactual in the SCM is formalized and transparent. The weight of each unit and predictor is a result of a data-driven procedure and is made explicit (Abadie, 2021). Unlike other methods, there is no extrapolation in the SCM, as all unit weights sum to one, which reduces the risk of making inferences beyond the available data (Abadie, 2021). In contrast, the SCM is based on interpolation, which compares data on the factual with the counterfactual in a given time period (King & Zeng, 2006).

Furthermore, the SCM only uses pre-treatment outcomes to create the counterfactual, which limits the risk of specification searches and p-hacking (Rubin, 2007). This approach reduces the risk of post-treatment confounding effects, which arise when a predictor affects both the dependent and independent variable (Abadie et al., 2010).

Lastly, the SCM allows for more possible predictors than the DiD method, as the predictors used are only employed to create the Doppelganger and are based on pre-treatment values. This reduces the risk of bias in the estimation process and allows for a greater number of predictors to be considered (Abadie, Diamond, & Hainmueller, 2010).

Creating the Synthetic Control

In the creation of the Doppelganger, we are largely inspired by Abadie's article from 2021. The article is called "Using Synthetic Controls: Feasibility, Data Requirements, and Methodological Aspects" and is a thorough guide in the use of the SCM, published by the *Journal of Economic Literature*. Because of its extensiveness, it is chosen as the main source. This section thus aims at explaining the math behind the creation of the synthetic control that Abadie and Gardeazabal first developed in 2003 and which is elaborated on in the article from 2021. Moreover, we put the math in the case specific context of the Brexit referendum.

Assume that we observe $J + 1$ units during time periods $1, 2, \ldots, T$, and that $j = 1$ is the UK, our treated unit. The other units $j = 2, 3, \ldots, J + 1$ are untreated and constitute our donor pool of comparison countries (Abadie, 2021). All T_0 periods are before the Brexit vote, also known as the treatment. Y_{jt}^N is our dependent variable household savings for time period t for unit j without the treatment, called "the counterfactual outcome" by Abadie (2021). Y_{jt}^I is on the other hand our dependent variable household savings for time period t for unit j exposed to the treatment. Thus, the overall treatment effect (the effect of the referendum on household savings) can be estimated by:

$$\alpha_{jt} = Y_{jt}^I - Y_{jt}^N. \quad (1)$$

If the identifying assumptions hold, the estimated treatment effect should be zero before the referendum, that is $\alpha_{jt} = 0$ for T_0(Abadie, 2021). Thus, if the Doppelganger is successful it should replicate the UK's household savings rate perfectly before the Brexit referendum. After the referendum, the estimated difference in household savings rate between the UK's and the untreated Doppelganger can be expressed by $\alpha_{1t} = Y_{1t} - Y_{1t}^N$ for $t > T_0$ (Abadie, 2021). Important to note is that the estimated effect of the treatment is allowed to change as time, t, evolves.

The estimated Doppelganger is a weighted average of the countries in the donor pool. The weights, $W = (w_2, \ldots, w_{J+1})$ assigned to the countries in the donor pool (henceforth called country weights) sum to one and are non-negative (Abadie, 2021). Thus, extrapolation is avoided (Abadie, 2021). The synthetic estimator of Y_{1t}^N is thus estimated by:

$$\widehat{Y}_{jt}^N = \sum_{j=2}^{J+1} w_j Y_{jt} \quad (2)$$

The estimated treatment effect can thus be written as:

$$\widehat{\alpha}_{jt} = Y_{jt}^I - \widehat{Y}_{jt}^N \quad (3)$$

The country weights $W = (w_2, \ldots, w_{J+1})$ in equation (2) are assigned in a data driven procedure to minimize the discrepancies between the UK and the Doppelganger (Abadie and Gardeazabal, 2003; Abadie et al., 2010). In this data driven procedure, a set of k predictors of the outcome are used to predict Y_{jt} (Abadie, 2021). The set of k predictors $X_{2j}, \ldots, X_{J+1}$ can be thought of as characteristics for each of the countries $j = 1, 3, \ldots, J + 1$ before the treatment. In order for the Doppelganger to replicate the UK, the discrepancies between the UK's and the Doppelganger's characteristics, their predictor values, should be minimized (Abadie, 2021). In consequence, a $k \times J$ matrix for $X_0 = X_2, \ldots, X_{J+1}$ is created which thus constitute the pre-treatment values of the predictors for the untreated units (all countries in the donor pool except the UK) (Abadie, 2021). Moreover, a $k \times 1$ vector of the pre-treatment values of the treated unit X_1 (the UK) is created (Abadie, 2021). Thus, the

country weights $W^* = (w_2^*, \ldots, w_{J+1}^*)'$ are assigned to minimizes the distance between the treated unit's predictor values and the untreated units' predictor values (Abadie and Gardeazabal, 2003; Abadie et al., 2010), expressed in equation (4):

$$(4) \qquad \left|X_1 - X_0 W\right|$$

In the minimization procedure, it is assumed that we have a set of non-negative constants $v_1,\ldots, v_k$ that are assigned to the k predictors (Abadie, 2021). v_m thus reflects "the relative importance" that is assigned to the m:th predictor when the discrepancy between the UK and the Doppelganger $\left|X_1 - X_0 W\right|$ is minimized (Abadie, 2021). Thus, $v_1,\ldots, v_k$ reflect the predictor weights whilst $w_2, \ldots, w_{J+1}$ constitute the country weights (Abadie, 2021). Both are chosen to minimize the discrepancy between the Doppelganger and the UK's household savings rate. The discrepancy is measured by the mean square prediction error (the MSPE) that is minimized with respect to Y_{1t}^N (the household savings rate) before the treatment ($t < T_0$), subject to the restriction that the weights $W(V)$ are positive and sum to one (Abadie, 2021):

$$(5) \qquad \left|X_1 - X_0 W\right| = \sum_{m=1}^{k} v_m (X_{1m} - \sum_{j=2}^{J+1} w_j X_{jm})\text{^}2$$

Thus, the minimization of discrepancy between the Doppelganger and the UK's household savings rate depends on the optimization of country weights and the relative importance of the predictors (Abadie, 2021). Finally, the post-treatment estimation of the treatment effect can be summarized by:

$$(6) \qquad \widehat{\alpha}_{jt} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt}$$

Choice of Control Units

The choice of the control units is important as they impact the fit of the Doppelganger and hence the inference (Abadie, 2021). The units (countries) in the donor pool should exhibit similar trends as the factual (the UK) before the treatment, be unaffected by the treatment (the Brexit referendum) and not have been under a similar treatment as the factual unit (Abadie, 2021).

The donor pool used in this paper consists of 22 countries, mostly other European countries but also the US, Japan, Australia, Canada and South Korea. This is similar to Born et al. (2019) that used OECD countries to construct their Doppelganger. Our reduction in the number of countries in the donor pool was due to data unavailability, which is discussed in the subsequent data section. Still, the number of countries is sufficient to compute reliant p-values (Abadie, 2021). None of the countries has had a similar referendum as the UK under the time period of interest (*Britannica*, 2023), which permits the application of a comparative case study as the referendum is a unique treatment for the UK.

However, the UK has trade relations and economic exchanges with all selected countries, which means that there is a risk that other countries in the donor pool are indirectly affected by the treatment

and its possible macroeconomic spillover effects (*UN comtrade*, 2022).Yet, a set of placebo tests are conducted to verify the assumption that only the UK was affected by the referendum (see more under Placebo Tests).

Choice of Predictors

In the SCM, predictors are used to create the Doppelganger and should be variables that predict the dependent variable (Abadie, 2021). The weights, $v_1,...,v_k$, are assigned to the predictors in a data driven procedure that minimizes the MSPE and thus optimizes the fit of the Doppelganger (Abadie, 2021). In studies using the SCM, such as the Born et al.'s article (2019) and the Abadie and Gardeazabal's article (2003), the authors do not elaborate around the choice of predictors. We have thus chosen to begin by using a theoretical motivation for creating a pool of predictors. Secondly, we use a data driven procedure to find the combination of predictors that minimizes the MSPE and thus optimizes the fit of the Doppelganger. Hence, the combination of predictors with the smallest MSPE is the one used in the estimations. This data driven search for the optimal combination of predictors was inspired by Belaieff Kronborg and Wernsten (2021).

Loayza et al. (2000), published by the *World Bank*, have studied 150 countries during 30 years using panel data to look at the drivers of private savings (both household and corporate savings). They conclude that private savings rates show inertia and that lagged values of the dependent variable thus constitute an important predictor. Moreover, disposable income, inflation, fiscal policy, real interest rate, GNDI and demographic variables all had statistically significant impact on savings rate (Loayza et al., 2000). A more recent study specifically looking at household savings also states the importance of the lagged dependent variable, inflation, real GDPI per capita (GDPI is an income approach of GDP) and its growth rate, real deposit rate and old-age dependency ratio as variables that significantly predict household savings (Grigoli et al., 2014). In an article published in 2015 which investigates the main drivers of household savings within EU countries, the same predictors are mentioned as significant and they also underline the importance of unemployment rate and pension systems (Rocher and Stierle, 2015).

Based on this theoretical motivation and data availability, a pool of predictors was created consisting of nine variables for all 23 countries (the 22 countries in the donor pool and the UK): GDP, GDP per capita, real GDP growth rate, lagged household savings rate, household consumption, real interest rate, inflation, old-age dependency ratio and unemployment rate. We acknowledge the lack of predictors capturing fiscal policy and pension systems, which is due to data unavailability. This is something that should be improved in future studies.

To determine the combination of predictors that best minimizes the discrepancy between the UK and its Doppelganger, a loop was implemented, which exhaustively searched for the optimal combination of predictors. The objective was to achieve a minimum mean squared prediction error (MSPE) between the UK and its Doppelganger before the Brexit referendum, while ensuring that the predictor weights are positive and sum to one. A low MSPE is desirable, as it indicates a better fit of the counterfactual to the factual, validating the identifying assumptions (Abadie, 2021).

The results show that the combination of real interest rate, real GDP growth, inflation, unemployment rate, household consumption, old-age dependency ratio, and lagged values of household savings rate produce the lowest possible MSPE of 1.714689, given our donor pool of countries and predictors. The root MSPE (RMSPE) is a more easily interpretable metric, expressed in the same units as the

dependent variable. The obtained RMSPE of approximately 1.31 ($\sqrt{1.714689}$) indicates that, on average, the predicted household savings rate for the Doppelganger is approximately 1.31 percentage points different from that of the UK before the referendum. Given that the standard deviation of household savings rate in the UK is approximately 3.504, the RMSPE suggests that the Doppelganger's predicted household savings rate is about one-third of a standard deviation different from the UK's household savings rate before the referendum.

Placebo Tests

To verify that the Brexit referendum's effect on household savings in the UK was unique and different from other fluctuations during the analyzed period, a series of time and country placebo tests are conducted (Abadie, 2021). Firstly, country placebo tests are conducted where the treatment is randomly assigned to other countries in the donor pool to compare the differences in household savings pre and post-treatment to those in the UK. This technique is similar to permutation tests and was first introduced by Abadie (2010). Secondly, we conducted time placebo tests by moving the treatment date back in time to determine if there was "an absence of estimated effects prior to the intervention" (Abadie, 2021). The absence of such effects would make the estimated treatment effect more credible, in line with refutability tests and uniformity trials found in the literature (Cochran 1937; Angrist and Krueger, 1999). These placebo tests allow us to investigate if the Brexit referendum had a unique and significant impact on the UK's household savings rate compared to other countries and fluctuations during the analyzed period (Abadie, 2021).

Model Limitations

One limitation of the model is the potential for spillover effects, which occur when the treatment effect indirectly affects the donor pool countries (Abadie, 2021). Given the close trade connections and interdependencies between the UK and countries in the donor pool, changes in household savings in the UK could impact the economies of these countries, leading to biased estimates (Abadie, 2021; *UN comtrade*, 2022). Additionally, investments of British household savings in foreign markets could further impact the predictors of the countries in the donor pool (Rocher and Stierle, 2015). However, selecting economically distant countries brings the risks of overfitting and interpolation biases (Abadie, 2021). Overfitting occurs when idiosyncratic variations are matched rather than overall trends, resulting in a bad Doppelganger and unreliable estimates (Abadie et al., 2015). Interpolation bias occurs when there are insufficient similarities between the factual unit and the counterfactuals in the donor pool which causes "an incorrect adjustment for control variables" (King and Zeng, 2006). Therefore, there is a trade-off between the common trends assumption and spillover effects. However, the use of placebo tests and robustness tests can mitigate the risks of spillover effects as they critically analyze the significance and robustness of the results. The robustness of the estimates is investigated according to what Abadie et al. (2015) suggest, which is dropping countries from the donor pool that make up a significant portion of the estimated effect. If the estimates change significantly after dropping these countries, they cannot be considered robust (Abadie et al., 2015).

Another limitation of the model is the potential for idiosyncratic variations among the countries in the donor pool, violating the identifying assumption (Abadie, 2021). Country-specific fluctuations and shocks would make it difficult to create a well-fitting Doppelganger and increase the risk of overfitting (Abadie et al., 2015). Thus, large variations in the data would impact the reliability of the estimates (Abadie, 2010). In the placebo tests, units with extreme values are successively excluded to account for its effect on the main results.

6. Data

The data used in this paper is a quarterly panel of 23 countries for the time period 2003 Q1 – 2022 Q3, because the SCM requires a panel dataset with many time periods (Abadie, 2021). The main data sources from which most data was collected for this paper are the *OECD* and *Eurostat* databases.

The dataset contains the following variables: household savings rate, GDP, GDP per capita, real GDP growth, household consumption, inflation rate, old-age dependency ratio, unemployment rate and long-term interest rate.

Household savings rate measures the amount of disposable income that households save on average, and it is expressed in percentage form. GDP is a measurement of a country's economic output, which equals the total value of goods and services produced within the country in a year. In our data, GDP is expressed in million EUR. GDP per capita is expressed in USD and measures the same thing as GDP but on the citizen level. Real GDP growth refers to the rate at which a country's GDP is increasing or decreasing over time, adjusted for inflation. Household consumption illustrates the amount of disposable income that households spend on goods and services and this measurement is expressed on a national level, in million EUR. Inflation rate shows the rate at which the general level of prices for goods and services is rising over time. Old-age dependency ratio measures the share of a population that is aged 65 and over, relative to the number of people aged 15-64. Unemployment rate is the percentage of the labor force that is currently out of work but seeking employment. Long-term interest rate demonstrates the interest rate at which loans are borrowed over longer periods of time.

In terms of the household savings rate, data on Australia, Canada and Germany was collected from a dataset called OECD Economic Outlook No. 112 (Edition 2022/2). Because this dataset only has quarterly data for limited countries, data on the remaining countries was obtained from *Refinitiv Eikon Datastream* that in turn collected data on household savings rate from *OECD*, *Eurostat* and the *National Statistics Office* for certain countries. The unemployment rate for all 23 countries was also extracted from the same dataset OECD Economic Outlook No. 112 (Edition 2022/2).

From another dataset Quarterly National Accounts on *OECD*, data on GDP per capita and growth rates of real GDP were found. GDP per capita is seasonally-adjusted and the unit is US dollar based on the reference year 2015. As for the variable real GDP growth, it is also seasonally-adjusted and the percentage change is based on the previous quarter. However, this dataset does not provide data on GDP per capita for Japan during the time period 2003 Q1 – 2007 Q2. Therefore, the data for this particular period was collected from Fred Economic Data, which also used 2015 as the reference year and adjusted for seasonality.

Data on the inflation rate, the long-term interest rates and the old-age dependency ratio was collected from *OECD*. As for the latter variable, the data is not available for all the years and is only on an annual basis. Given that this ratio does not vary much from year to year, one can assume that the difference between quarters within one year is not huge either. Thus, it is reasonable to convert it to the quarterly basis, so that, for instance, the annual ratio of 21.1 for Austria in 2003 becomes the quarterly ratio for Austria in 2003 (that is, the ratio is 21.1 for all the quarters in 2003). When it comes to the long-term interest rates, the data is not available for Estonia during the time period 2003 Q1 – 2020 Q2. However, data on long-term interest rates is available from the *Bank of Estonia* on a monthly basis. Therefore, we converted it to a quarterly basis by taking the average of the long-term interest rates in EUR and EER (Estonia's currency prior to adopting Euro on 1 January 2011

according to the European Commission) before 2011 and taking the average of the long-term interest rates in EUR starting from 2011. As for the household consumption, the data was collected from Eurostat, which used million EUR as the unit of measure.

In an attempt to get a more objective picture of the data, we converted all data to deviations from 2003 similar to what Born et al. (2019) conducted in their paper, i.e., subtracting the right quarterly value in 2003 for each country and each subsequent period. In this way, one could better observe how much a value is moving from the baseline, removing certain baseline differences and eliminating seasonality. Because of these benefits, we chose to use deviations from 2003 on all our variables.

It is also worth mentioning that our choice of predictors is limited because the nature of quarterly data makes it difficult to obtain comprehensive data on the desired variables. We recognize that differences exist in terms of institutions, demography, culture and socio-economic situation in different countries, which can in turn influence the household savings rate. For instance, it is desirable to include a variable that measures the cultural attitudes towards savings or the number of children per household in each country on a quarterly basis (Rocher and Stierle, 2015), but such variables cannot be included due to data unavailability.

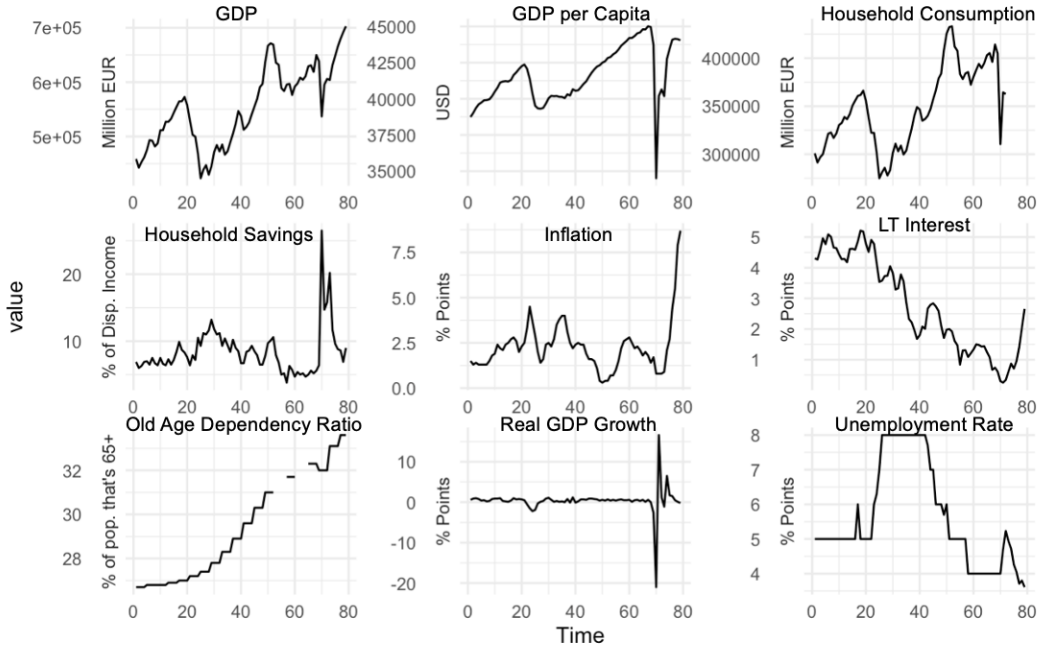
Comparability issues should also be mentioned given that there are several concerns when comparing household savings rates across countries. Firstly, differences in institutional characteristics, such as taxation methods, pension systems and social services provided by the government, can lead to a discrepancy in household savings rates even though the savings behavior is similar in chosen countries (Rocher and Stierle, 2015). Second, factors such as the existence and the size of a shadow economy as well as unrecorded remittances can contribute to estimation inaccuracy, which raises comparability issues (Rocher and Stierle, 2015). However, as our paper aims to probe changes in household savings before and after the Brexit referendum, comparability issues should not be a huge concern for our research.

Data Visualisation

To gain a better understanding of the data, the dependent variable and the eight predictors in the predictor pool are plotted for the UK. The quarters are numbered because of numerical model limitations of the SCM. Thus, we chose to use numbered quarters in all time series plots for increased consistency. Q1 in 2003 is thus time period 1 and the last quarter in our data, Q3 2022, is time period 79.

The 2008 financial crisis began in time period 20. The Brexit referendum took place in Q2 2016, which is time period 54. The pandemic began in Q1 2020, which is time period 69. From the descriptive statistics in *Figure 2*, one can conclude that the variables exhibit different fluctuations and development paths. Especially household savings, inflation and long-term interest rate seem to be rather volatile, while real GDP growth and real GDP per capita appear to be more stable throughout time except for certain dips. From the descriptive statistics, it seems as if all GDP measures, household consumption and household savings were facing large spikes or dips in the time periods around the 2008-financial crises and the COVID-19 pandemic.

Figure 2



Source: Eurostat (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

To better visualize household savings in different countries, each country's household savings rate is plotted as a time series. From *Figure 3,* there seems to be some seasonality in the data and it is clear that each of the country's baseline differs. Yet, Switzerland and Spain are two countries that face great seasonality on a quarterly basis with large jumps. In *Figure 4,* household savings expressed as deviations from 2003 is depicted. Generally, it seems to remove seasonality as well as the extent of baseline differences between the countries, which can be noticed, for instance, in the scale of the Y-axis. Despite this, Switzerland and Spain's household savings rate still exhibits large volatility compared to the other countries.

Figure 3

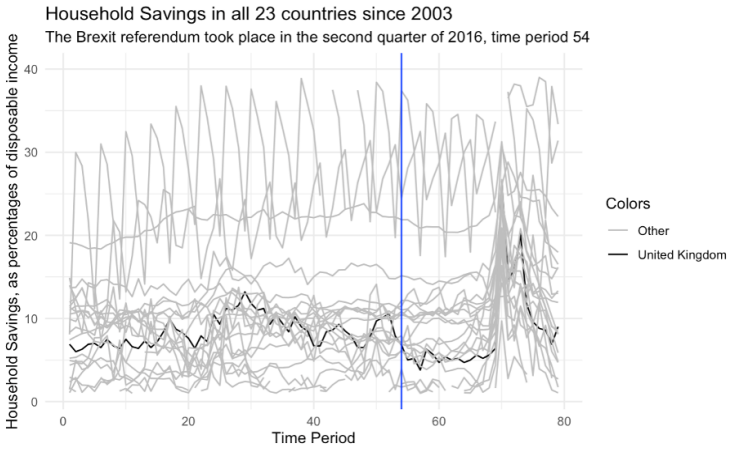
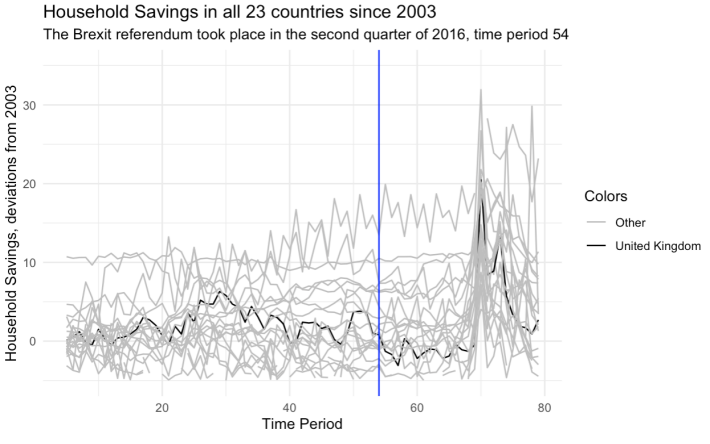


Figure 4



Source: Eurostat (2023); OECD (2023a). For both Figure 3 and 4.

As one of the baseline assumptions of the SCM is that the countries in the donor pool should face similar characteristics and trends (Abadie, 2021), Switzerland and Spain are excluded from the donor pool. In *Figure 5 and 6* one can see that conformity between the countries are improved by this removal. Thus, these two countries are excluded from all estimations in the coming result section. However, in Appendix 3 and Appendix 4, one can for completeness find estimations where they are included.

Figure 5

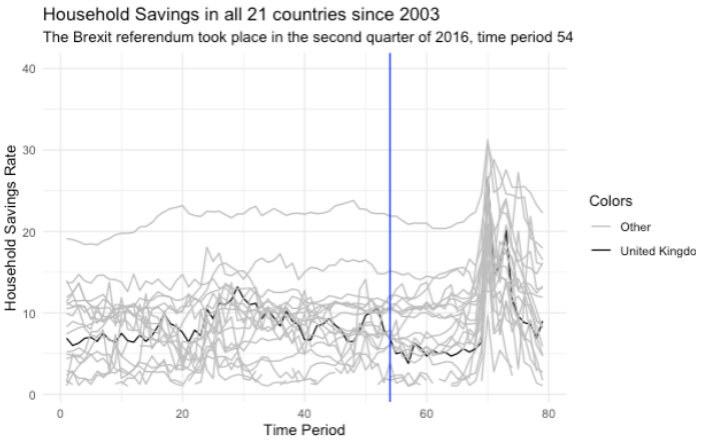
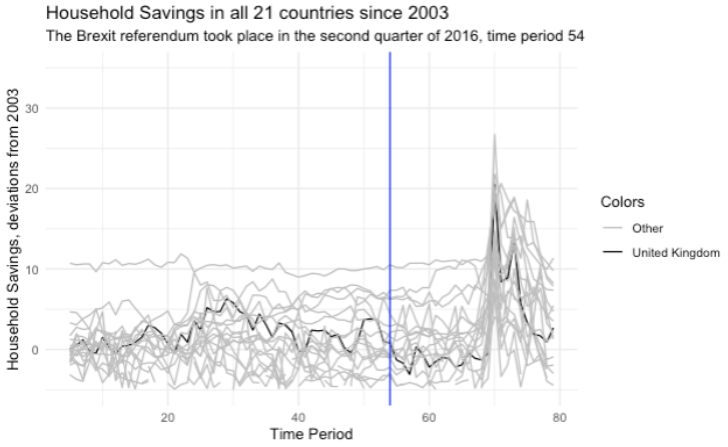


Figure 6



Source: Eurostat (2023); OECD (2023a). For both Figure 5 and 6.

7. Results

7.1. The Creation of the Doppelganger

The Doppelganger is constructed using pre-treatment values in quarter 1 to 53 for the 20 countries in the revised donor pool using our seven predictors. In the creation of the Doppelganger, each of the 20 countries is assigned a country weight and each of the predictors is assigned a predictor weight. The assignment of predictor and country weights is done to minimize the discrepancy between the Doppelganger and the UK before the treatment period. The treatment is given in time period 54, which is the second quarter in 2016.

Country Weights

The country weights assigned to the donor pool countries in the creation of the Doppelganger are summarized in *Table 1*. Sweden, Ireland, Estonia, the Czech Republic and Austria are the main contributing countries in the creation of the Doppelganger. Thus, about 28.4% of the Doppelganger is in fact Sweden, and about 23.8% is Ireland. The remaining 50 percentage points are distributed fairly equal between the three other large contributors. The country weights sum to one.

Table 1

Country Weights							
Sweden	0.284	Japan	<0.01	France	<0.01	Korea	<0.01
Ireland	0.238	United States	<0.01	Portugal	<0.01	Italy	<0.01
Estonia	0.164	Finland	<0.01	Netherlands	<0.01	Australia	<0.01
Czech Republic	0.163	Hungary	<0.01	Poland	<0.01	Canada	<0.01
Austria	0.15	Norway	<0.01	Denmark	<0.01	Germany	<0.01

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

The main contributing countries are similar to Born et al.'s Doppelganger (2019). Each of the five contributing countries are part of the EU and thus have a geographical and political proximity to the UK before the referendum. Additionally, Sweden and the Czech Republic are also countries with a national currency, despite being part of the EU's common market, just like the UK. Thus, the assigned country weights are in line with expectations.

Predictor Weights

The predictor weights used to create the Doppelganger are summarized in *Table 2*. The five predictors used from our data driven approach are long-term interest rate (named Interest Rate in the table), real GDP growth rate (named Real GDP Growth in the table), inflation, unemployment rate (named Unemployment in the table), household consumption (named HS Consumption in the table), old-age dependency ratio (named Old Age Dependency in the table) and lagged values of household savings rate (named Lagged DV in the table). The most influential predictors used in the creation of the Doppelganger is unemployment rate and real GDP growth. Household consumption is assigned zero weight in the creation of the Doppelganger. The predictor weights sum to one.

Table 2

	Interest Rate	Real GDP Growth	Inflation	Unemployment	HS Consumption	Old Age Dependency	Lagged DV
Predictor Weights	0.014	0.18	0.006	0.745	0	0.029	0.026

All values used for the predictors are deviations from 2003

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

7.2. The Short-Run Effects of the Brexit Referendum on Household Savings Rate in the UK

We begin by estimating the Brexit referendum's effect on household savings rate up until 2020 (time period 69) when the pandemic began. Then, in the next part, we add the remaining 10 quarters, from 2020 Q1 and onwards to see how the household savings further developed during the pandemic and the withdrawal from the EU.

Short-Run Effects

Firstly, the UK vis-à-vis the Doppelganger's household savings' rate trajectory are plotted as a time series in *Figure 7*. The time series begins in Q1 2003 (time period 1) and runs through Q4 2019 (time period 68) and shows the deviations in household savings rate from 2003. When one looks at the quarters before the Brexit referendum, one can see that the largest deviation from 2003 occurs in the

2008 financial crisis (which begins in time period 20) where household savings in the UK increase by six percentage points. The increase in the Doppelganger's household savings rate is not fully as large as in the UK. Moreover, in the quarters prior to the intervention, household savings in the UK remained at either similar or higher levels than the 2003 household savings rate. For the Doppelganger, the household savings rate is generally more stable and the deviations prior to the intervention are at maximum 4 percentage points higher than its 2003 values. When the Brexit referendum occurs in time period 54, the household savings in the UK drops by approximately three percentage points and reaches its minimum value in time period 58 (second quarter of 2017). However, the drop seems to begin slightly before the Brexit referendum in time period 52 (first quarter of 2016). Thus, the total drop that occurs between time period 52 and 58 is approximately 5.6 percentage points. This drop in household savings rate is the largest observed drop in the entire time series. After this initial drop, the household savings rate recovers slightly but continues to fluctuate at around 2-4 percentage points lower than its Doppelganger until the time series ends in quarter 68 (last quarter of 2019). Yet, the Doppelganger's household savings rate continues steadily after the Brexit referendum at around 2 percentage points, and increases slightly from time period 60 until 68. Overall, the UK's household savings rate not only drops around the Brexit referendum but also remains at a lower base level throughout the short-run estimations.

Figure 8 is the plotted difference between the UK and its Doppelganger's household savings rate. When one observes the quarters before the intervention, the difference between them seems to fluctuate between -2 and 2 percentage points and is thus not perfectly zero although the difference circulates around zero. Thus, the Doppelganger is not able to fully track the many fluctuations in the dependent variable although the RMSPE of approximately 1.3 is less than one third of the UK's household savings rate's standard deviation.

Figure 7

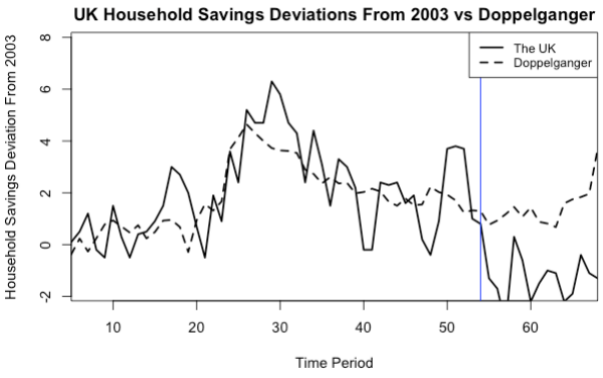
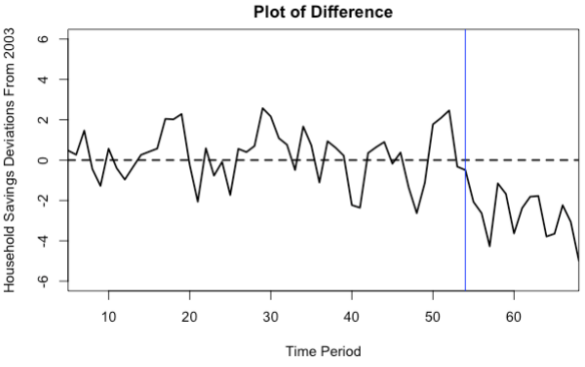


Figure 8



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 7 and 8.

Another method to assess the similarity between the UK and the Doppelganger, is to compare the average value of each predictor for both the factual and the counterfactual, as suggested by Abadie and Gardeazabal (2003). In *Table 3*, the mean value of each predictor for the UK, the Doppelganger, and the overall sample is presented, with values expressed as deviations from 2003.

Comparing the mean value of unemployment (1.655 vs 1.625 percentage points) and real GDP growth (-0.379 percentage points vs -0.380 percentage points) for the UK and the Doppelganger, respectively,

they are nearly identical. This indicates a strong fit as these two predictors are given the highest weights (92.6% in total, as shown in *Table 2*). Additionally, for all predictors except household consumption and old-age dependency ratio, the Doppelganger's mean values are more similar to the UK than those of the overall sample. However, household consumption has zero predictor weight, and old age dependency ratio has less than 3% weight, so the average difference in these two variables should not be of concern.

Table 3

Predictor Mean Values

	UK	Doppelganger	Sample Mean
Interest Rate (% Points)	-0.598	-0.406	-0.373
Real GDP Growth (% Points)	-0.379	-0.380	-0.148
Inflation (% Points)	0.860	0.114	0
Unemployment Rate (% Points)	1.655	1.625	0.539
Household Consumption (Million EUR)	60,223.660	7,191.862	42,939.210
Old Age Dependency Ratio (% of pop. that's 65+)	3.660	3.932	4.065
Lagged Household Savings Rate (% Points)	2.427	2.614	0.770

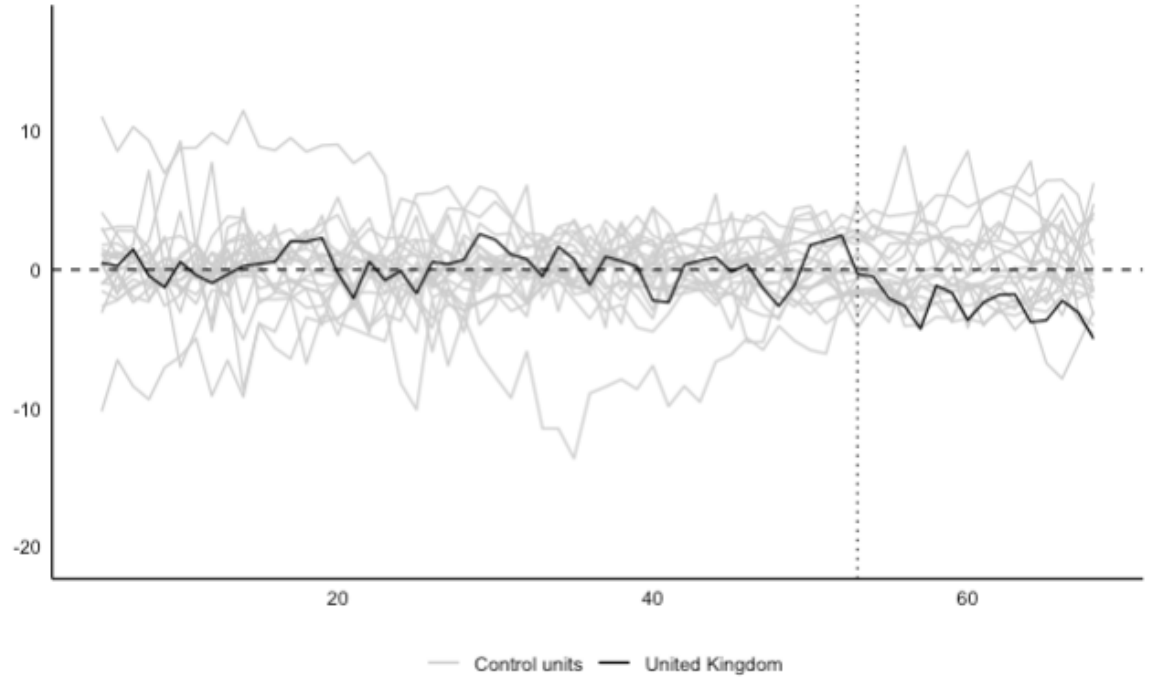
All values are deviations from 2003

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Country Placebo Tests of Short-Run Effects

To verify that the estimated effect of the Brexit referendum on household savings was any different from what other countries exhibited at the time, a set of country placebo tests, similar to what Abadie et al. (2010) and Born et al. (2019) suggest, are conducted. In the country placebo test, the treatment is assigned to the other countries in the donor pool. If the other countries' household savings rate react similarly to the UK, although they in fact were given a placebo treatment, the results cannot be verified (Abadie, 2021). The plot of the country placebo test can be seen in *Figure 9*. In *Figure 9* all 21 countries (the 20 countries in the revised donor pool and the UK) have been assigned the treatment. From the figure, the UK still seems to be one of the countries that is picking up the largest downward effect of the referendum shock in the household savings rate.

Figure 9: Country Placebo Test for All Countries

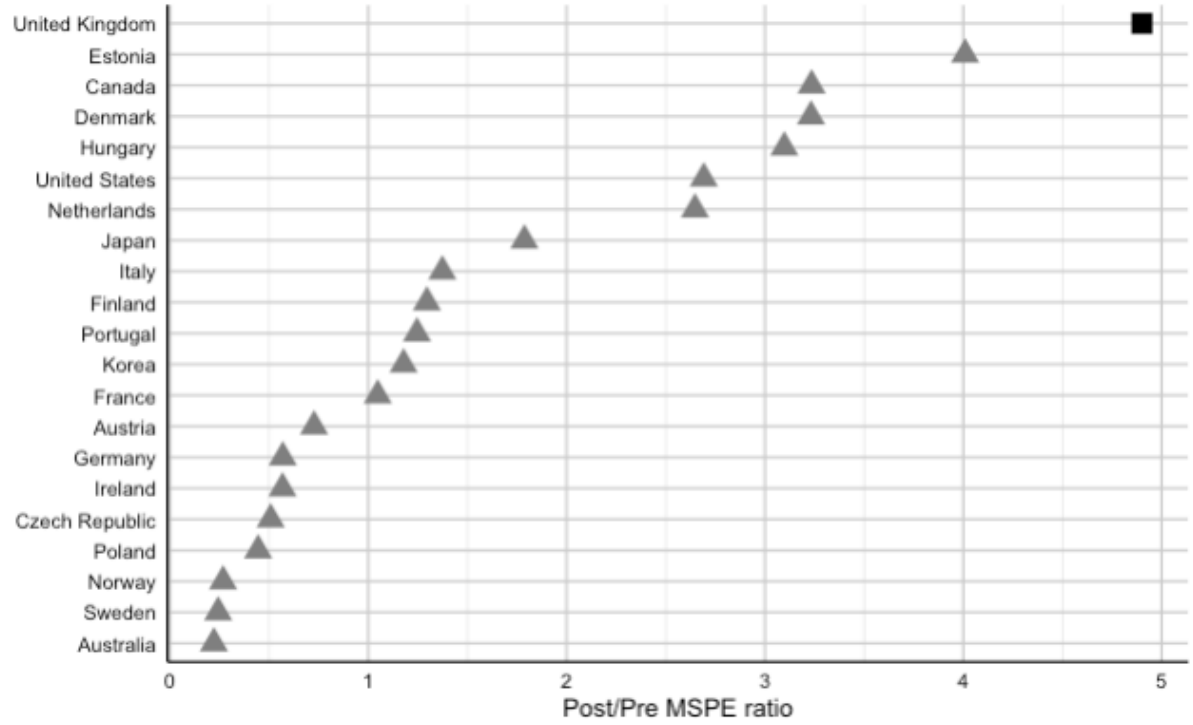


Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Yet, countries that are rather different from the UK before the treatment are less interesting to compare with post treatment (Abadie, 2021). Thus, in three other placebo runs found in Appendix 5.1, countries that have a high MSPE value before the treatment, and thus are the most dissimilar to the UK before the treatment, are excluded. In all three trials, where the MSPE is halved in each of them, the UK is still one of the countries where household savings exhibit the largest downward effect post treatment.

Moreover, the ratio of each of the countries' post and pre MSPE values of the placebo tests are plotted. A large post/pre MSPE ratio indicates a large treatment effect as the post treatment trajectory must have shifted from the pre treatment trajectory (Abadie, 2021). If other countries exhibit similar ratios as the UK (which is the only country that is not given a placebo treatment) or higher ratios than the UK, the significance of our results diminish. From *Figure 10* where the Post/Pre MSPE ratio is plotted for each of the 21 countries, one can see that the UK exhibits the largest treatment effect. Moreover, the UK's treatment effect is significantly higher than the other countries' at a 5% significance level as its p-value is approximately 0.04. Yet, especially Estonia but also Canada and Denmark seem to experience large treatment effects. To ensure that the effect they experience is not contributing to the UK's treatment effect, generating an upward bias, they are excluded in a set of robustness tests in one of the following sections.

Figure 10: MSPE Ratios of All Countries

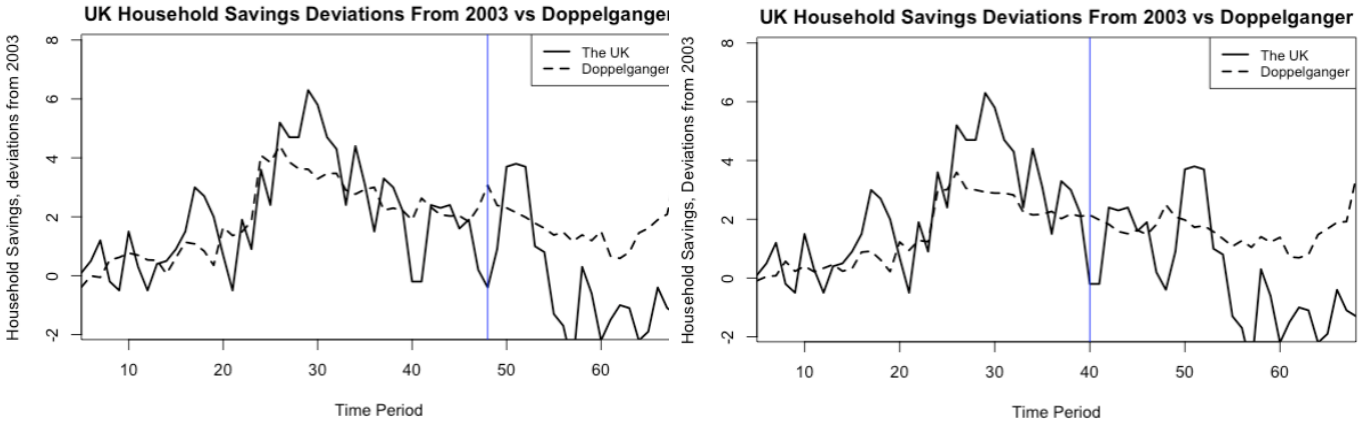


Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Time Placebo Tests of Short-Run Results

To ensure the validity of the estimated treatment effect during the intervention period, a series of time placebo tests are conducted. These tests aim to examine whether the previously observed divergence between the treated and untreated units remains consistent when the treatment date is moved to earlier periods, as suggested by Abadie (2021). Specifically, the treatment date was shifted 5 and 13 quarters back in time in the placebo tests, as depicted in *Figure 11* and *Figure 1*2. The results of these tests show that the fluctuations in the data do not significantly alter compared to the original analysis presented in *Figure 7*, suggesting that the treatment effect is specific to the intervention period. However, it is important to note that given the initial suboptimal fit between the UK and the Doppelganger, and the volatility of the dependent variable, it is difficult to assert conclusively that the treatment effect was entirely absent during other time periods.

Figure 11 (the intervention is moved to period 48) & Figure 12 (the intervention is moved to period 40)



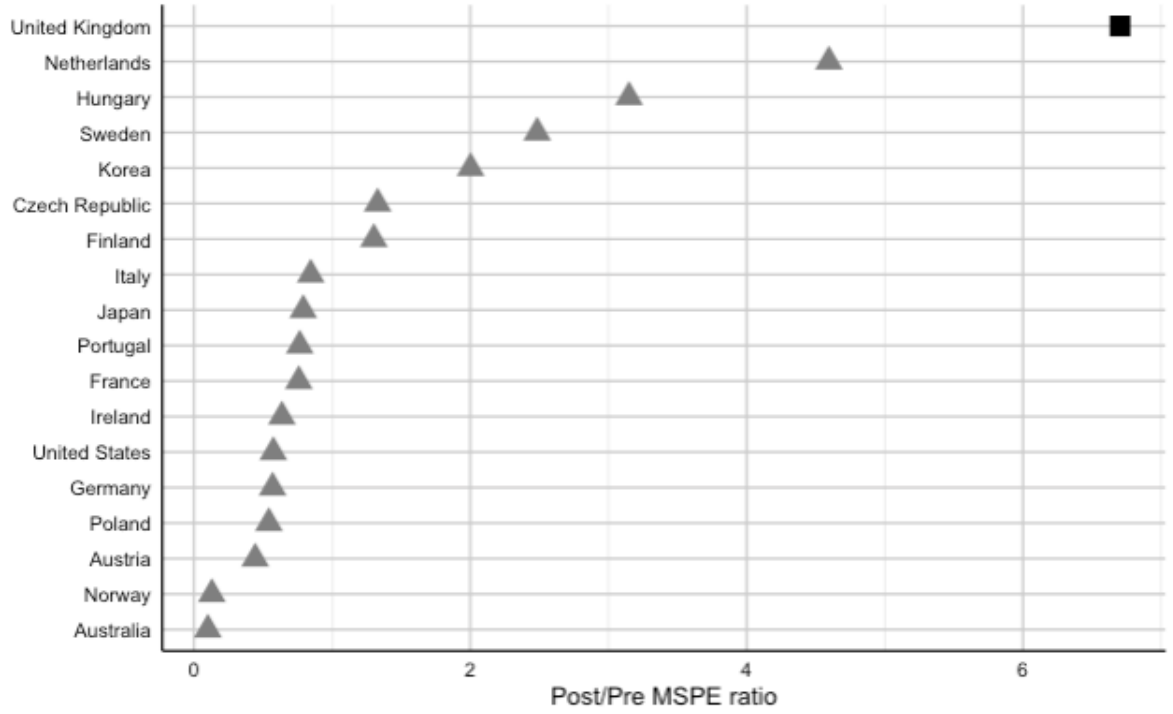
Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 11 and 12.

Robustness Tests of Short-Run Results

Similar to Born et al. (2019), a robustness test is conducted where the three donor states that exhibit the largest post/pre MSPE ratio are excluded. As Estonia, Canada and Denmark are three countries that except for the UK seem to exhibit the largest treatment effect in the country placebo tests, these countries are excluded as there is a risk that they are contributing to an upward bias of the estimates (Born et al., 2019). This risk is material as Estonia is one of the main contributing countries in the creation of the Doppelganger. For completeness, all figures and tables made for the original model specification are also created for the robustness test, which can be found in Appendix 5.1. In the creation of the Doppelganger, the US and the Czech Republic are assigned a larger weight than previously. Except for this, only minor changes are observed.

In *Figure 13,* it is observed that the UK's post/pre MSPE ratio, and thus the estimated treatment effect, increases slightly by the removal of the three states. Moreover, the p-value increases to approximately 0.056, which means that the results' significance is slightly above the 5% level. Overall, the original short-run estimates appear to be robust as the country with the largest estimated treatment effect remains the UK, and the p-value continues to indicate statistical significance. Additionally, the short-run results align with the estimates obtained when Spain and Switzerland are included, as shown in Appendix 3 and Appendix 4. This further suggests that the short-run results are robust.

Figure 13: MSPE Ratios of All Countries, Excluding Estonia, Canada and Denmark



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

7.3. The Long-Run Effects of the Brexit Referendum on Household Savings Rate in the UK

In this part, time periods 69-79 (Q1 2020 - Q2 2022) are added to the original short-run model to investigate how household savings continue to evolve on a more long-term basis after the Brexit referendum. These quarters are marked by the COVID-19 pandemic and the actual withdrawal from the EU. The aim with the long-run model is to investigate if the UK's household savings rate continues to remain lower than its Doppelganger despite the pandemic, its accompanying restrictions and support packages and the withdrawal from the EU. There are two underlying assumptions for this. Firstly, it is assumed that the COVID-19 pandemic is an exogenous, global event, affecting the UK and every country in the donor pool. Secondly, we assume that the largest impact of the UK's withdrawal from the EU will be manifested in the UK's data although we acknowledge that there is a risk of spillover effect on certain countries in the donor pool, such as Ireland.

7.3.1. Empirical Context

To gain a deeper understanding of the implications of the pandemic and the Brexit withdrawal, it hereby follows some empirical context of these events. Firstly, there is a short summary of the restrictions and fiscal support packages launched in the UK and the five countries that contributed the most in the creation of the Doppelganger: Sweden, Ireland, Estonia, the Czech Republic and Austria. Secondly, there is a short summary of the economic impact that the Brexit withdrawal is estimated to have had on the British economy.

COVID-19 Restrictions

The UK had three nationwide lockdowns because of the pandemic (*Institute for Government*, 2022). The Czech Republic had two nationwide lockdowns whilst Ireland had three (*University of Ostrava*, 2023; *Loughlin, 2022*). In Sweden there was no legally imposed lockdown although people were encouraged to stay home and bars and restaurants had shorter opening hours (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022h). In Austria, people experienced four lockdowns, with the latest national lockdown in November 2021 (Austria to go into full lockdown as COVID surges, 2021). In Estonia, there was one nationwide lockdown in 2021 (ERR News, 2021). In Ireland, there were three national lockdowns (Carroll, 2020; *BBC News*, 2020; Moloney et al., 2020). In all six countries, workplaces and schools closed (in Sweden only high-schools and universities closed) and people worked and studied from home. In each of the countries except Sweden and Estonia, public transport was at least partly closed or subjected to certain changes due to the pandemic. Public events were canceled in Ireland, Sweden, Austria, Estonia and the UK (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022a; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022b; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022g; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022h; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022i; *University of Ostrava*, 2023).

In between lockdowns and contagion spikes, there were rules of how many people that were allowed to meet up, in order to minimize spread of the virus. In the UK, there was the rule of six which meant that no more than six people were allowed to meet up (*Institute for Government*, 2022). In Ireland there was a rule of ten and in Sweden there was a rule of fifty, given possibilities for social distancing (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022g; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022h). Each of the countries also required self-isolation upon infection. The countries closed their borders and incoming visitors from high-risk countries were required to quarantine. There were also restrictions on internal movement in each of the six countries (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022a; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022b; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022g; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022h; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022i; *University of Ostrava*, 2023). In Ireland, the UK and the Czech Republic face masks became compulsory in public indoor venues (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022g; *Institute for Government*, 2022; *University of Ostrava*, 2023).

When the world began opening up during 2021 as vaccinations picked up pace, access to many indoor venues and events such as stores, restaurants and bars were conditioned upon a negative covid-test result or proof of vaccination (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022g; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022h; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022i; *University of Ostrava*, 2023). All these restrictions and general fear of contagion resulted in a contraction of demand for goods and services previously consumed with ease (Ulrich Ruch and Taskin, 2022). Simultaneously, industries where work could not be performed remotely caused unreliable supply chains and hence a supply shock (Ulrich Ruch and Taskin, 2022). Thus, the possibilities for consumption were reduced and governments launched historical support packages to stimulate the economy.

COVID-19 Government Support

All six countries issued large support packages to support the business sector and households during the pandemic. The UK's total government support constituted approximately 6.4% of their annual

GDP in 2020, whilst the government support constituted 4% of Czech Republic's, 5.4% of Ireland's, 8.5% of Estonia's, 12.6% of Austria's and 12% of Sweden's GDP in 2020 (Pope and Hourston, 2022; *IMF*, 2022). In the UK, almost 60% of the government support went to individuals whilst the remaining 40% went to businesses. Two thirds of the British government support was distributed during 2020 (Pope and Hourston, 2022).

Government support was packaged in several wide-ranging schemes, benefitting many people. One of the largest schemes in each of the countries was compensation of furloughed workers. In the UK, 11.7 million jobs were supported and furloughed workers were able to retain up to 80% of their salaries (Pope and Hourston, 2022). In the Czech Republic, the government was replacing 50-60% of lost salaries (*IMF*, 2022). Ireland launched The "Pandemic Unemployment Payment" and the "Employment Wage Support Scheme" which allowed for a weekly €350 compensation for every unemployed week and €203 for every week where there had been a 30% reduction of working hours (*IMF*, 2022). In Sweden, unemployment insurances were increased and the social security contribution requirements of employers were lowered (*IMF*, 2022). At least 50% of lost salaries was replaced by the government in Austria, while Estonia granted grace periods for households regarding, for instance, mortgage loans (*IMF*, 2022).

Moreover, self-employed people were especially supported in all countries and VAT and/or other taxes were either temporarily lowered or postponed in each of the countries (Pope and Hourston, 2022; *IMF*, 2022). The Czech Republic gave a daily lump sum of 370 Czech korunas (about €15) for each day spent in quarantine, and the UK offered £500 lump sum for people asked to self-quarantine (Pope and Hourston, 2022; *IMF*, 2022). Ireland launched credit guarantees and reduced taxes to a value of €5 billion (*IMF*, 2022). The Czech Republic and Sweden offered rent support for certain households and businesses (Pope and Hourston, 2022; *IMF*, 2022). The UK increased its Universal Credit and also initiated a one-off extra payment amounting to £500 which 5.8 million people were given (Pope and Hourston, 2022).

The above presented examples of government support are non-exhaustive. To gain a better understanding of the magnitude and impact of the support packages, they are hereby related to statistical figures from *Eurostat* and the *Office for National Statistics*. When comparing change in household income to the previous year, 34.8% of the population in the Czech Republic and 32.3% of the population in Sweden, and 20.9% of the population in Ireland reported higher income in 2021 compared to 2020 which is to be compared with the EU average of 17.5% (see Appendix 5.2) (*Eurostat*, 2022). In the entire EU, household income had a relatively small increase in 2020 of 0.4% and an unusually large increase in 2021 of 2.6% (*Eurostat,* no date). In the UK, households' median disposable income increased by 2.3% in 2020 and by 2% in 2021 (Croal, 2022). Thus, households seem to generally have had increasing incomes in each of the four countries, despite the pandemic and the economic downturn.

The Brexit Withdrawal

As the COVID-19 pandemic unfolded, the UK began the process of withdrawing from the EU. The withdrawal had in itself economic consequences, which were compounded by the impact of the pandemic. The disruption to supply chains and trade was particularly pronounced and led to a 3% greater drop in trade compared to similar countries such as Germany, France, the US, and Canada (Tsoukalis and Spisak, 2023). Additionally, the estimated shortfall in business investments was 19%, and the UK had the lowest GDP growth rate amongst the G7 countries (Tsoukalis and Spisak, 2023). Tax revenues also decreased by £40 billion according to Springford (2022). *The Office for Budget*

Responsibility's forecasts in March 2023 indicate that the long-term effects of Brexit will lead to a reduction in British GDP per capita of 4%, as well as a 15% decrease in both British imports and exports.

7.3.2. The Long-Run Estimations

With the empirical context in mind, the ten time periods are now added to the original model. The trajectory of the household savings rate for the UK vis-à-vis the Doppelganger can be seen in *Figure 14*. In period 69-71 when the pandemic began (the two first quarters of 2020), it seems like the household savings rate in both the UK and the Doppelganger had a historically high spike. The household savings rate in the UK increases by about 20 percentage points whilst the Doppelganger's household savings rate increases by about ten percentage points. Thus, when the pandemic begins, the household savings rate in the UK surpasses its Doppelganger after having remained at a lower base level for 15 quarters. After the initial spike, the UK aligns quite well with its Doppelganger and both exhibit a second, smaller spike in time period 73. The UK seems to face a faster drop in household savings rate after the second, smaller spike although both align quite well towards time period 78. From *Figure 15* one can thus summarize the estimations by stating that the dip in the UK's household savings rate seen after the referendum remains up until the pandemic begins. Then, the UK seems to face a greater spike than its Doppelganger and further on align quite well with its Doppelganger's trajectory. Once again, one should be aware that the Doppelganger fit is suboptimal before the Brexit Referendum which implies that it is difficult to draw strong conclusions.

Figure 14

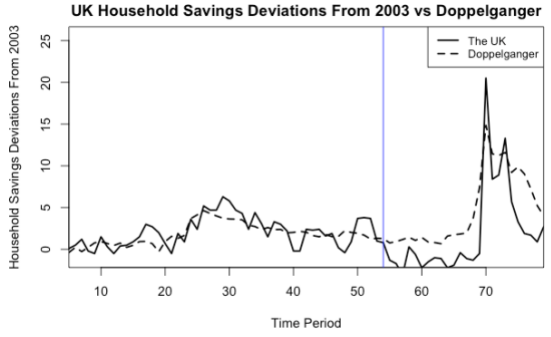
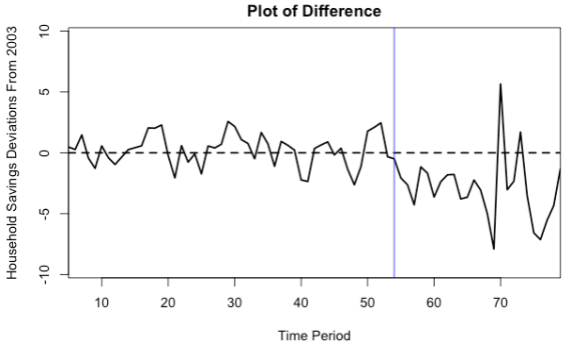


Figure 15



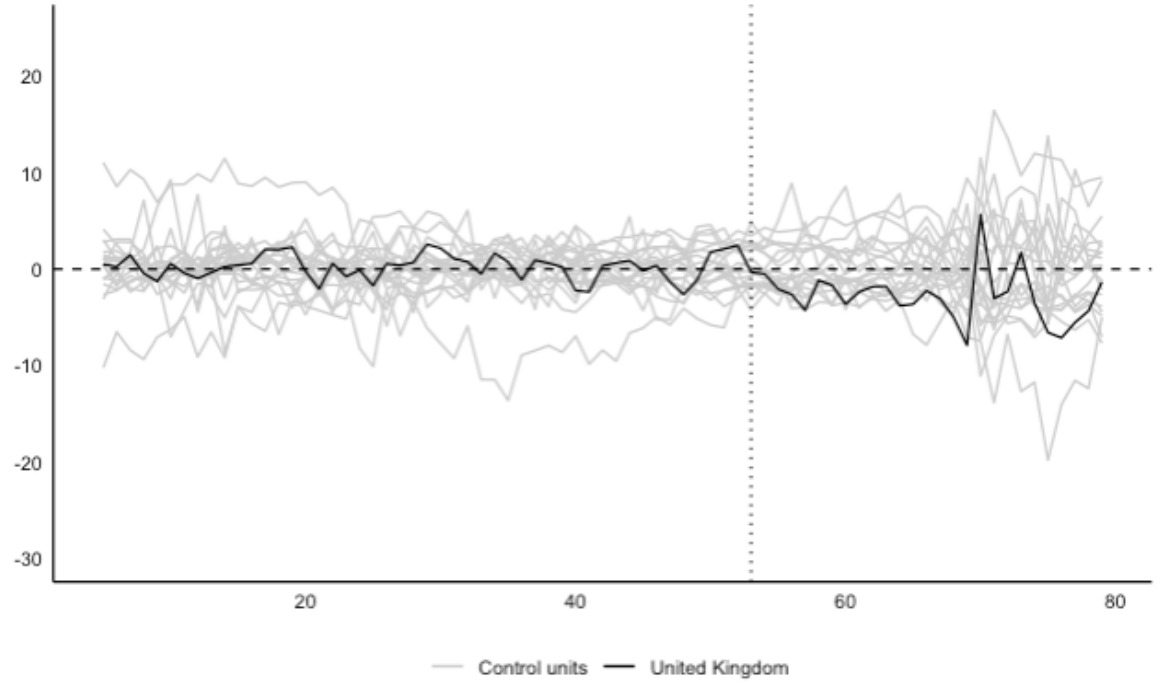
Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 14 and 15.

Country Placebo Tests of Long-Run Effects

In the country placebo tests, where a placebo treatment is assigned to the donor states, the UK remains one of the countries that exhibit the largest downward effect on household savings rate after the Brexit referendum (see *Figure 16*). Moreover, the effect seems to last amongst the lowest among the donor states up until the pandemic in time period 69 begins where it has a spike, similar to other countries. Yet, the spike seems relatively high compared to other countries when its low starting point is considered.[1]

[1] When countries that are fairly dissimilar to the UK before the Brexit referendum are excluded (see Appendix 5.2), the UK remains one of the countries where the treatment has the largest negative impact and one of the countries where the pandemic has the largest positive impact.

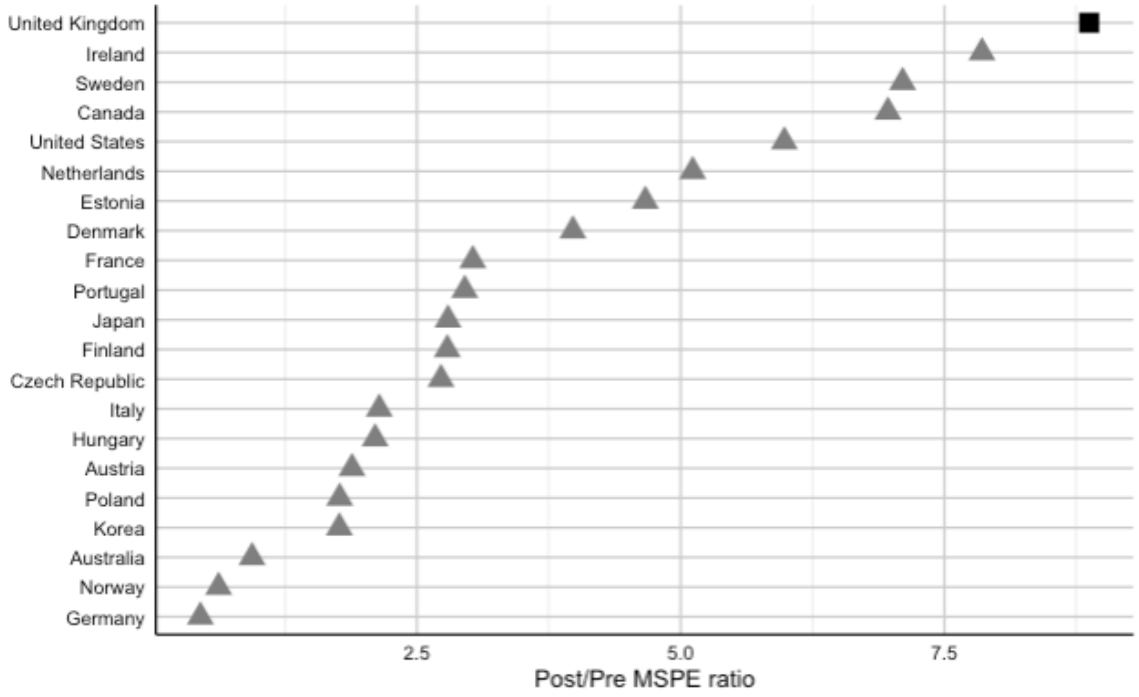
Figure 16: Country Placebo Test for All Countries



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Interestingly, when we look at the post/pre MSPE ratio in *Figure 17*, the UK is still the country that has the largest post/pre MSPE ratio. Thus, when the post intervention period is extended, the UK's household savings ratio is still the one that has faced the greatest change. The Post/Pre MSPE value increases, which is reasonable considering the large spike in household savings rate seen in the final ten quarters. It also seems as if Ireland, Sweden and Canada, amongst other countries, have faced relatively large changes in their household savings rate after the intervention date compared to before it. Thus, the relatively large downward treatment effect seen in the Short-Run Results seems to last when the final ten quarters are included. Moreover, the results are still significant (the fisher p-value is approximately 0.0476). Thus, when the pandemic years are included, the treatment effect is still distinguishable which means that the treatment effect seems to last in the long-run.

Figure 17: MSPE Ratios of All Countries

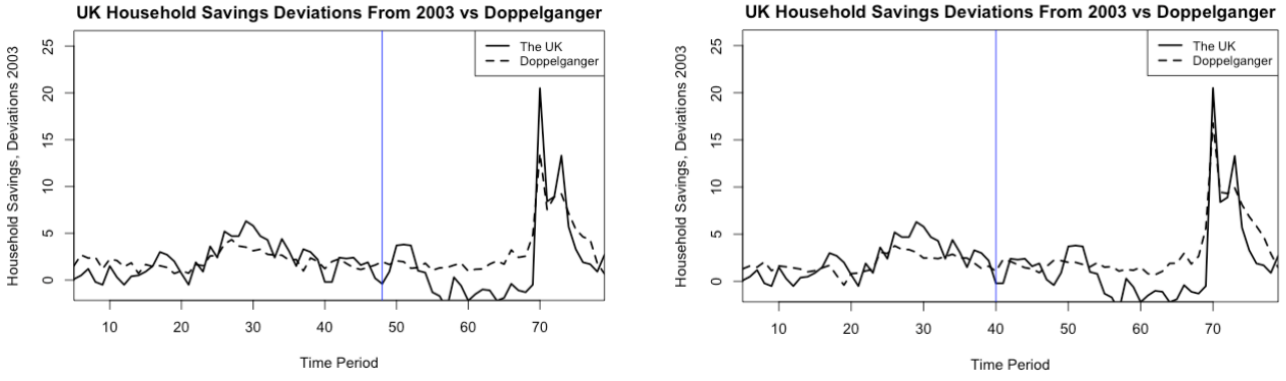


Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Time Placebo Tests of Long-Run Results

As in the short-run time placebo tests, the treatment date is moved back first 5 quarters in *Figure 18* and then 13 quarters in *Figure 19*. From these tests, the fluctuations compared to *Figure 14* do not seem to alter, indicating that the treatment effect is not moved back in time when a placebo treatment is given in other time periods. Thus, the estimates seem to hold for the time placebo tests. Yet, as the fit between the UK and the Doppelganger is suboptimal, it is difficult to certainly state that the treatment effect is not moved.

Figure 18 (the intervention is moved to period 48) & Figure 19 (the intervention is moved to period 40)



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 18 and 19.

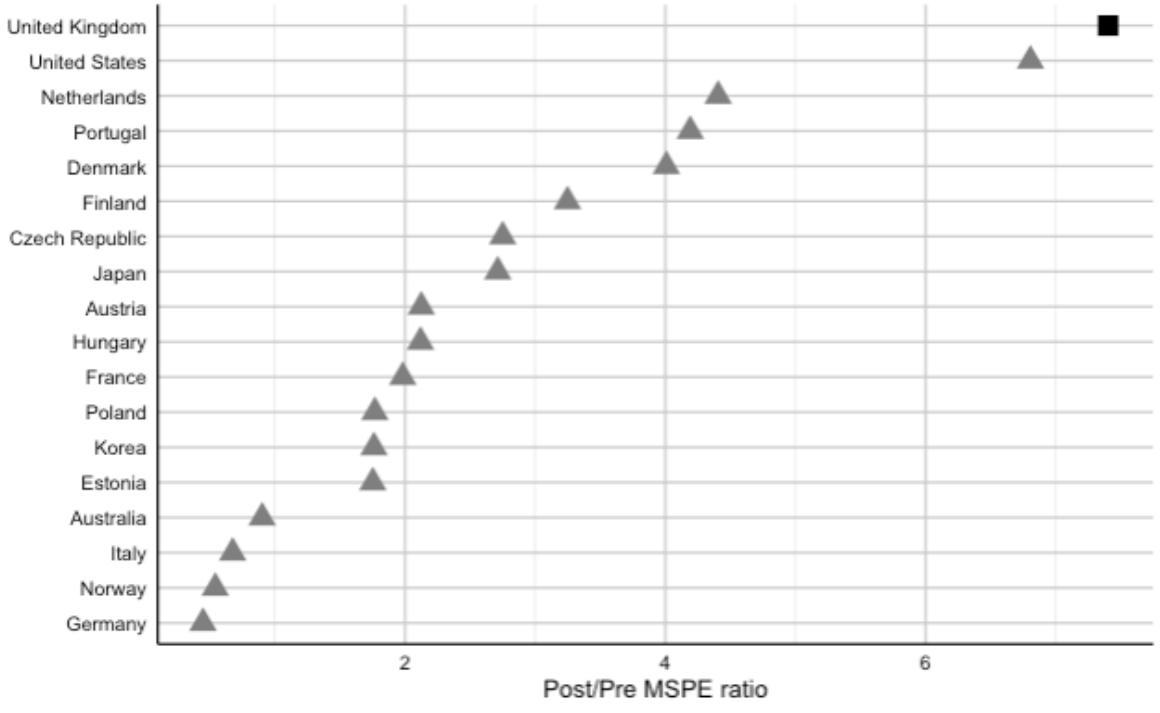
Robustness Tests of Long-Run Results

As both Ireland and Sweden are assigned large country weights in the creation of the Doppelganger and exhibit relatively large treatment effects, they are excluded in a robustness test together with Canada which also exhibits a large treatment effect. These countries are excluded as there is a risk that they are contributing to an upward bias of the estimates (Born et al., 2019). Furthermore, the robustness test becomes increasingly relevant as there is a risk of spillover effects, especially between the UK and Ireland during the Brexit withdrawal, considering their geographical and economical proximity. By excluding Irealnd, it thus becomes interesting to see how the results alter. The relevance of the robustness test is further amplified by the fact that the long-run model specification where Spain and Switzerland are included, shown in Appendix 3 and Appendix 4, did not show significant, long-term results.

For completeness, all figures and tables made for the original long-run model specification are also constructed for the robustness test, which can be found in Appendix 5.2. In the creation of the new Doppelganger, when Ireland, Sweden, and Canada are excluded from the donor pool, the US, Germany, Finland and the United States are assigned a larger weight than previously. Except for this, only minor changes are observed.

In *Figure 20,* it is observed that the UK's post/pre MSPE ratio, and thus estimated treatment effect, decreases slightly by the removal of the three states. This indicates that the three excluded states previously contributed to an upward bias. Moreover, the p-value approaches 0.06, which means that the results' significance is slightly above the 5% level. Overall, the original long-term estimates appear to be robust since the UK still exhibits the largest estimated treatment effect, and the p-value remains close to the conventional significance level of five percent.

Figure 20: MSPE Ratios of All Countries, Excluding Ireland, Sweden and Canada



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

8. Discussion

8.1. The Reliability of the Results

The fit between the UK and its Doppelganger prior to the Brexit referendum is imperfect, as mentioned earlier. The Doppelganger fails to completely replicate all the fluctuations in the UK's household savings rate, as depicted in *Figures 7* and *8*. This imperfect fit reduces the reliability of our estimates, as the underlying assumptions are not fully satisfied (Abadie, 2021). There are various potential reasons for the flawed fit. Firstly, the donor pool countries may be too dissimilar from the UK, hindering the Doppelganger's potential fit (Abadie, 2021). However, the donor pool countries used in this study are the same as those used by Born et al. (2019), who achieved a better fit. It is worth noting that they included eight more countries than this study, which could be one reason for their better fit. Nevertheless, the countries not included in this study were all assigned less than 1% weight in the construction of the Doppelganger by Born et al. (2019). Secondly, the large variations observed in the dependent variable could be another more plausible reason for the suboptimal fit (Abadie, 2021). As seen in *Figure 2*, household savings is a macroeconomic metric that exhibits much volatility compared to many others, which remain in the "Deviations from 2003" version. The significant variance of the dependent variable could indicate idiosyncratic variations, making it challenging to construct a well-fitting Doppelganger (Abadie, 2021; Rocher and Stierle, 2015). However, it should be acknowledged that the fit could be improved by incorporating more predictors, which were not included in this study due to data unavailability.

There are several reasons why the imperfect fit between the UK and its Doppelganger may not be a major problem. Firstly, the Doppelganger generally exhibits the same trend in household savings rate as the UK, albeit with some variations in magnitude. Secondly, although the difference between the UK and the Doppelganger in *Figure 8* is not perfectly zero, it is still relatively small. Thirdly, the UK consistently shows one of the largest treatment effects in the placebo tests, which confirms the causal impact of the Brexit referendum on household savings. Therefore, while the fit issue should be acknowledged, it does not appear to significantly undermine the reliability of the results.

8.2. Discussion of the Short-Run Results

The short-term result shows a decreasing trend in the British household savings rate that began before the Brexit referendum in time period 52 (first quarter of 2016). The results' implications are first discussed from a theoretical point of view and are then related to previous research.

Firstly, the household savings rate is estimated to have begun to decline already in the first quarter of 2016. According to the concept of "prudence" described by Kimball (1990), people react precautionary when uncertainty increases. The economic policy uncertainty index began to increase already in the first quarter of 2016 when the Brexit referendum date was announced (Walker, 2021; Baker et al., 2023). Thus, it is reasonable that households reacted in caution already before the referendum as policy uncertainty arised.

However, the short-term result is contradictory to the precautionary savings theory. Instead of increasing savings as uncertainty increased, households began to dissave. Moreover, the seen dissaving pattern is not in line with the findings of Giavazzi and McMahon (2012), Aaberge et al. (2017) nor Giesing and Musić (2019) which all show how household savings increase in response to increased political uncertainty.

Yet, there are two reasons for dissaving behavior according to The Permanent Income Hypothesis. Firstly, individuals may dissave if they expected an increase in their total lifetime income. This is contradictory to the rise in economic policy uncertainty, as economic confidence at the time was low (Baker et al., 2023). Secondly, individuals would dissave in times of low income, which is induced by economic shocks, in order to smooth their consumption over time. Born et al. (2019), Breinlich et al. (2020) and Fernandes and Winters (2021) have already established that the Brexit referendum was a policy shock that caused an economic contraction. Hence, the short-term result indicating a dissaving pattern among households in the UK is in conformity with the PIH theory because savings decreased as the economy contracted. Thus, households seem to have perceived the Brexit referendum as a low-point in their lifetime income, explaining the decreased savings rate. Furthermore, it could be argued that the economic and political uncertainty were already perceived before the referendum, explaining the dissaving pattern before the actual vote. This early dissaving pattern seems to be in line with the findings of Born et al. (2019) who also identified an anticipation effect among households. While Born et al. (2019) regarded the economic decline after the referendum as an anticipation effect before the actual withdrawal, which our findings support, our paper further identified the dissaving pattern as an anticipation effect even before the referendum. Moreover, the shrinking consumption and investments in Britain as a result of the referendum implies that the Brexit vote has had a deteriorating effect on the British economy (Born et al., 2019). Our finding of the decreased household savings supports that notion.

However, Born et al. (2019) found private consumption to be one of the most sensitive indicators that reacted “almost immediately after the Brexit vote” and served as a major driver behind the decline in GDP (Born et al., 2019). One could thus ask why private consumption dropped despite the smoothing effect owing to the decreased savings?

One possible answer is that the smoothing effect cannot fully offset the effect of rising consumer prices induced by the vote, for instance, every household in the UK experienced approximately £400 consumption loss on average during the post-referendum period (Born et al., 2019; Breinlich et al., 2017). That is, the smoothing effect of saving less may not be large enough to neutralize the effect of rising consumer prices fully, thus, leading to a decline in consumption for British households. Therefore, our results do not seem contradictory to the findings of Born et al. (2019). In addition, we already know that the UK exhibited a below-average savings rate historically from Appendix 1 (OECD, 2023f), which means that the nation can be more vulnerable to economic shocks. Consequently, it is fair to assume that this may also be a reason why the smoothing effect cannot fully neutralize the consumption loss caused by rising prices. Another reason may be that the referendum caused a decline in household income for British households, which can also explain the drop in consumption (Sampson, 2017; Born et al., 2019). As households received less income, it is reasonable that they could not sustain the same level of consumption as before, hence the decreasing consumption after the referendum.

In short, the short-term result entails that the Brexit referendum affected the household savings rate negatively which aligns with the PIH as well as previous studies which revealed that the Brexit referendum has a negative impact on economic indicators. Our research makes a valuable contribution to the current literature by examining a vital economic indicator that has been neglected in the study of the impact of the Brexit referendum. Furthermore, our findings affirm the overarching conclusion that the referendum has had an adverse effect on the British economy.

8.3. Discussion of the Long-Run Results

In the long-term, the pandemic shock hit at the beginning of 2020, i.e. the time period 69. A clear result is that the household savings rate skyrocketed for both the UK and the Doppelganger.

Due to the exogenous nature of the pandemic shock, it is righteous to claim that this shock could elevate the overall uncertainty (Thomson, 2020). This statement can be further supported by certain changes in COVID policies, because these changes are a clear indication of the exogenous and unpredictable nature of the pandemic. Hence, the observed increase in the savings rate can be interpreted as corroborating evidence for the Precautionary Savings Theory as the theory states that households should be inclined to save more to be better prepared for a volatile future during times of uncertainty. Furthermore, the long-term result is also in conformity with many other previous studies that found that increased uncertainty, shocks and crises can elicit an upsurge in the savings rate of households (Giavazzi and McMahon, 2012; Aizenman and Noy, 2015; Aaberge et al., 2017).

Apart from the reason that an uncertain future caused the heightened savings rate for British households, government support may also shed light on this sudden increase in the household savings rate. We already know that households obtained higher incomes during 2020 because of government support packages, so this period can be regarded as a period of high income. Additionally, the incremental income obtained from government support is not a regular income source, so it can be regarded as an extra amount on top of their previously calculated lifetime wealth. Since households should increase savings in times of high income according to the PIH, the long-term result is also in line with the PIH.

Despite the challenges faced by the UK in 2020, including the unpredictable pandemic and the transition period of the Brexit withdrawal, it is important to note that the long-term effects of the referendum are still significant. While it may be difficult to disentangle the effects of multiple shocks on the UK economy, research by Born et al. (2019) and Springford (2022) suggests that the initial treatment effect has not dissipated. However, it is worth noting that the downward effect of the referendum appears to have been overshadowed by larger shocks, such as the pandemic and the Brexit withdrawal, as evidenced by the significant increase in the household savings rate in the UK.

In summary, the long-term result exhibits a sudden increase in the household savings rate in the UK, which can be explained by both the Precautionary Savings Theory and the PIH. Though the negative effect caused by the referendum is still significant in the long run, the savings rate grew rapidly for British households because of the effects of the pandemic shock and the transition period.

9. Conclusion

This paper has regarded the Brexit referendum as a policy shock to investigate its effect on British households' savings rate. In conclusion, the Brexit referendum had a negative impact on British household savings rate which began the same quarter as the announcement of the Brexit referendum. The effect is persistent until the COVID-19 pandemic begins in 2020 where it exhibits a large spike. Despite the spike in association with the pandemic and the Brexit withdrawal, the Brexit referendum seems to have had a persistent long-run negative effect on households' savings rate. The paper's findings are in line with previous research and economic theory.

To further strengthen the paper's findings, future research should expand the analysis by including more predictors such as fiscal policy, retirement systems, and youth dependency ratio. Additionally, it would be interesting to see how households in different socio-economic areas reacted, as historical savings rate is a critical determinant of present savings rate. Further research would also benefit from a regional breakdown of the analysis to better understand spillover effects.

Finally, future research should aim to separate the effects of the pandemic and the Brexit withdrawal on household savings rate. Given the launch of historic support packages and restrictions during the pandemic and the UK's withdrawal from the EU, it is essential to distinguish these effects.

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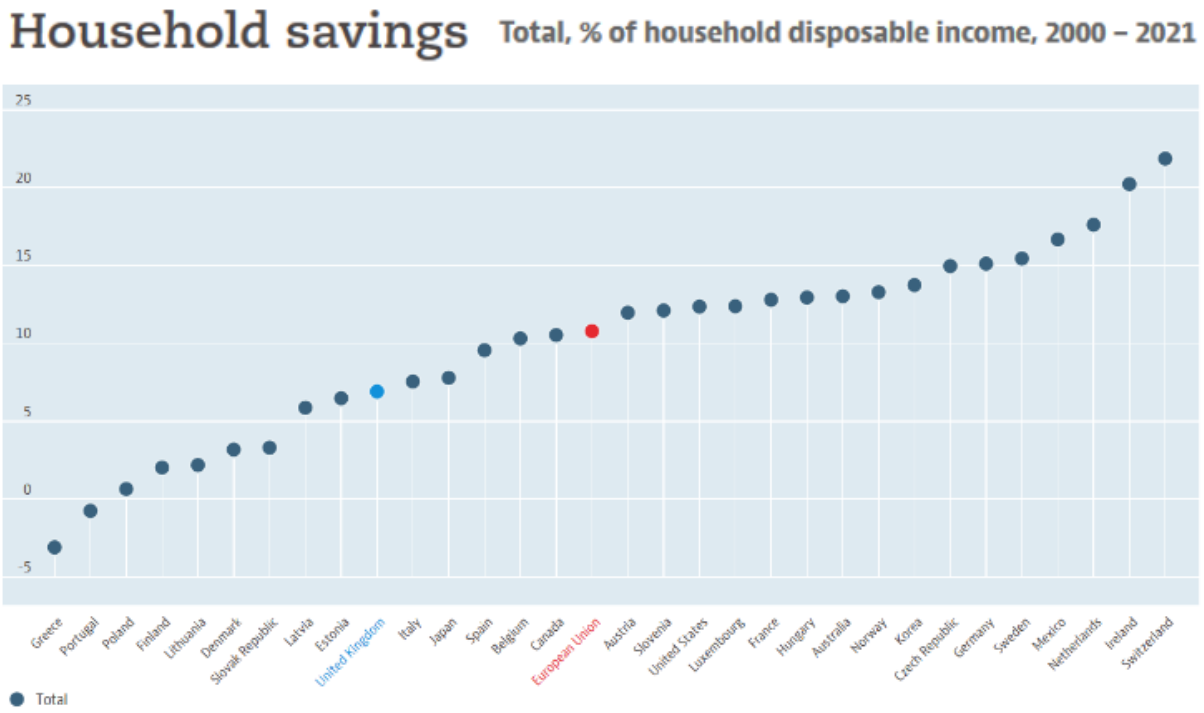
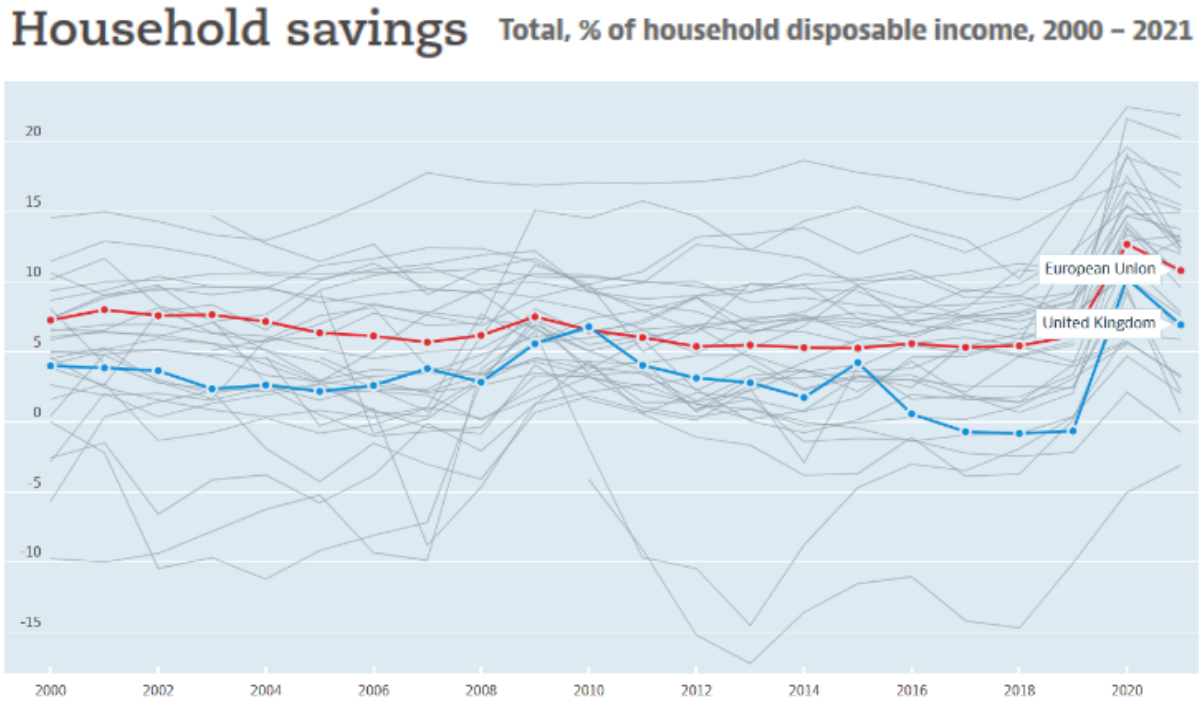
11. Appendix

Appendix 1: The Household Savings Rate in the UK vis-à-vis the EU

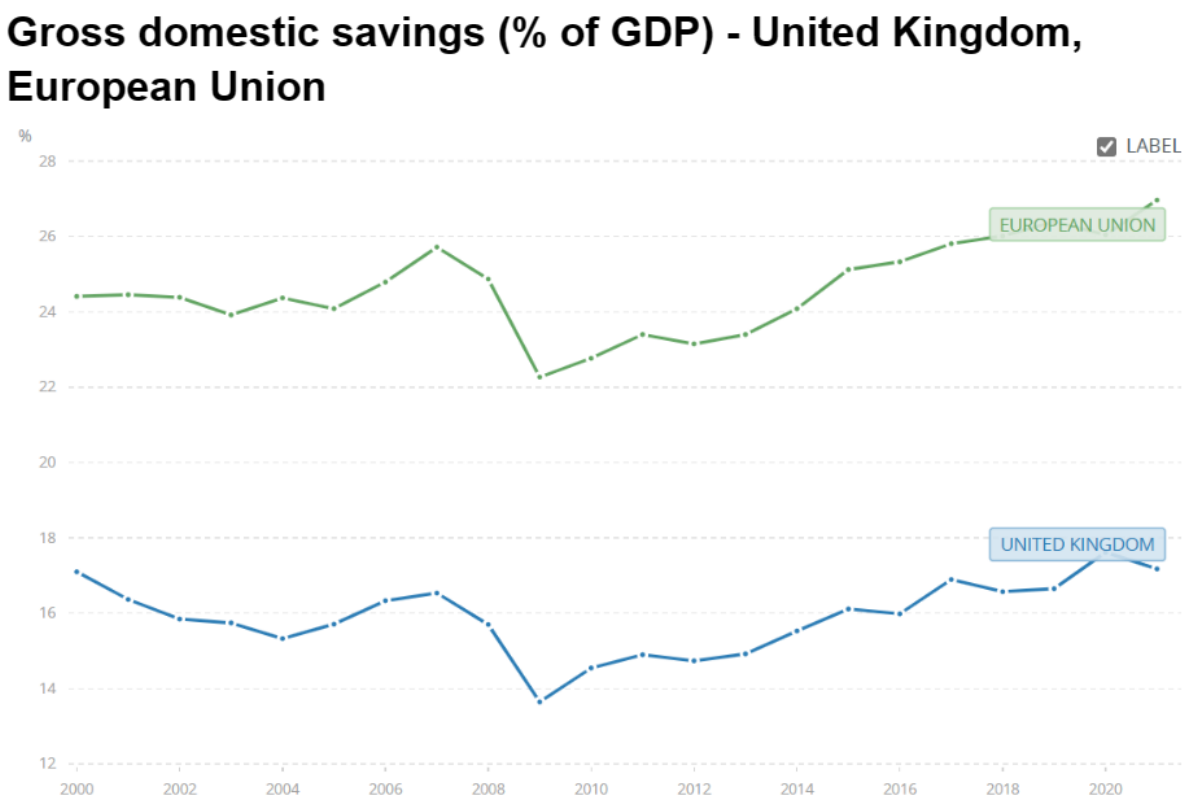


Source: OECD (2023f).



Source: OECD (2023f).

Appendix 2: Gross Domestic Savings in the UK vis-à-vis the EU



Source: World Bank (2021).

Appendix 3: Estimates when Spain and Switzerland are Included in the Donor Pool

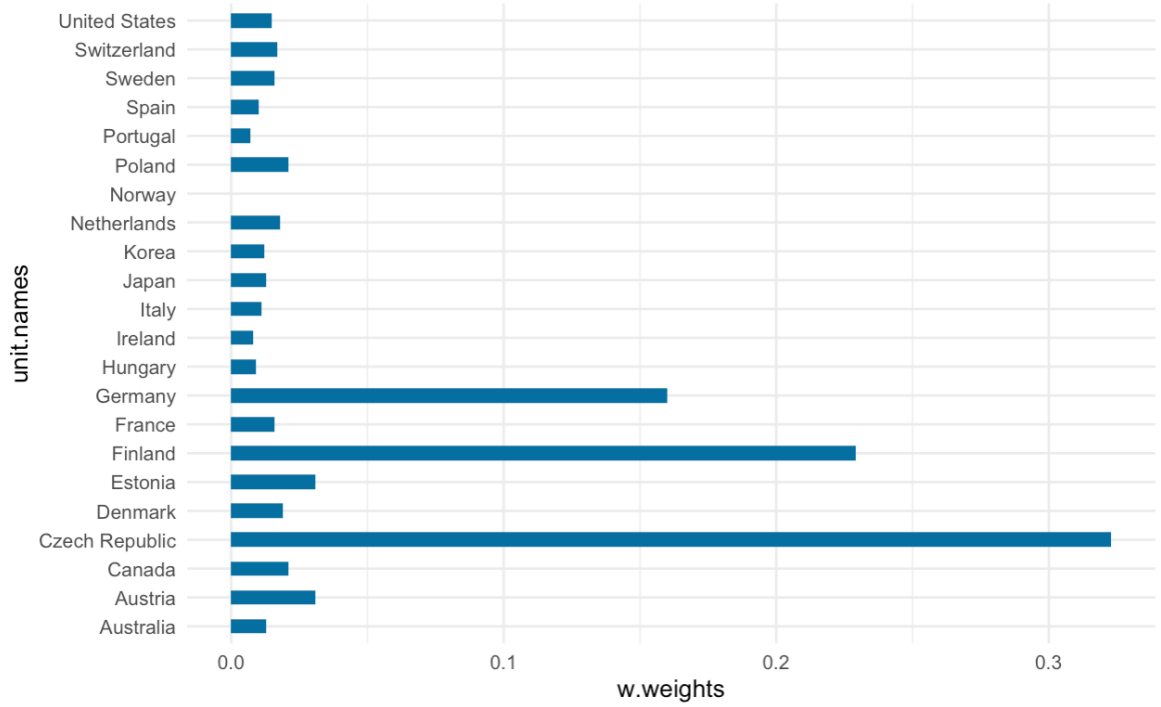
The Creation of the Doppelganger, When Spain and Switzerland are Included in the Donor Pool

The Doppelganger is constructed using pre-treatment values in quarter 1 to 53 for our 22 countries in the donor pool using our four predictors. In the creation of the Doppelganger, each of the 22 countries is assigned a country weight and each of the predictors is assigned a predictor weight. The assignment of predictor and country weights are done to minimize the discrepancy between the Doppelganger and the UK before the treatment period. The treatment is given in time period 54, Q2 in 2016.

Country Weights

The country weights assigned to the donor pool countries in the creation of the Doppelganger are visualized in *Figure 1*. The Czech Republic, Finland and Germany are the countries which have contributed the most to the creation of the Doppelganger. Thus, about 34% of the Doppelganger is in fact the Czech Republic, about 20% Finland and about 16% Germany. The remaining 30 percentage points are distributed fairly equal between the remaining countries. The country weights sum to one.

Figure 1



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Predictor Weights

The predictor weights used to create the Doppelganger are summarized in *Table 1*. The most influential predictor used in the creation of the Doppelganger is long-term interest rate. GDP per capita is assigned zero weight in the creation of the Doppelganger. The predictor weights sum to one.

Table 1

	Inflation	Interest Rate	GDP/capita	Lagged DV
Predictor Weights	0.249	0.398	0	0.354

All values used for the predictors are deviations from 2003

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

The Short-Run Effects of the Brexit Referendum on Household Savings Rate in the UK

We begin by estimating the Brexit referendum's effect on household savings up until 2020 (time period 69) when the pandemic began. Then, in the next part, we add the remaining 10 quarters, from 2020 Q1 and onwards to see how the household savings further developed during the pandemic.

Short-Run Effects

Firstly, the UK vis-à-vis the Doppelganger's household savings' rate trajectory are plotted as a time series in *Figure 2*. The time series begins Q1 2003 (time period 1) and runs through Q4 2019 (time

period 68) and shows the deviations in household savings rate from 2003. When one looks at the quarters before the Brexit referendum, one can see that the largest deviation from 2003 occurs in the 2008 financial crisis (which begins in time period 20) where household savings in the UK increase by six percentage points. The increase in the Doppelganger's household savings rate is not as large. Moreover, in the quarters prior to the intervention, household savings in the UK remained at either similar or higher levels than the 2003 household savings rate. For the Doppelganger, the household savings rate is more stable and the deviations prior to the intervention are between 1-4 percentage points higher than its 2003 values. When the Brexit referendum occurs in time period 54, the household savings in the UK drops by approximately three percentage points and reaches its minimum value in time period 58. However, the drop seems to begin slightly before the Brexit referendum in time period 52 (first quarter of 2016). Thus, the total drop that occurs between time period 52 and 58 is approximately 5.6 percentage points. This drop in household savings rate is the largest observed drop in the entire time series. After this initial drop, the household savings rate recovers slightly but continues to fluctuate around 2-4 percentage points lower than its Doppelganger until the time series ends in quarter 68 (last quarter of 2019). Yet, the Doppelganger's household savings rate continues steadily after the Brexit referendum at around 2 percentage points, and increases slightly from time period 60 until 68. This indicates that the UK's household savings not only drops around the Brexit referendum but also remains at a lower base level throughout the short-run estimations.

Figure 3 is the plotted difference between the UK and its Doppelganger's household savings rate. When one observes the quarters before the intervention, the difference between them seems to fluctuate between -2 and 3 percentage points and is thus not perfectly zero although the difference circulates around zero. Thus, the Doppelganger is not able to fully track the many fluctuations in the dependent variable although the RMSPE of 1.401 is less than half a standard deviation of UK's household savings.

Figure 2

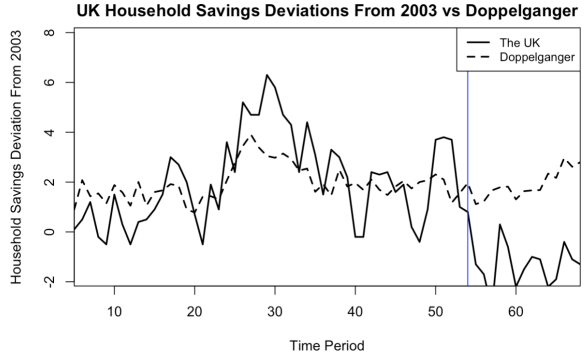
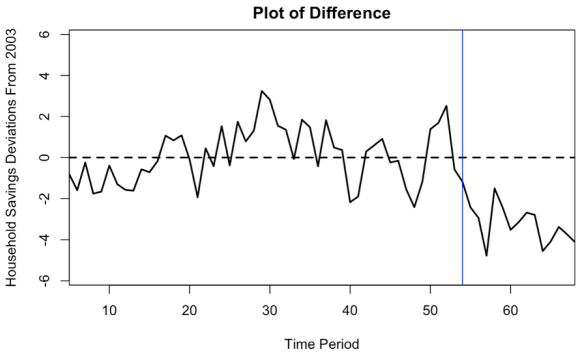


Figure 3



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 2 and 3.

An additional way to evaluate the fit between the UK and the Doppelganger is by comparing the average value of each of the predictors for the UK and the Doppelganger (Gardeazabal, 2003). The UK is in *Table 2* called "Treated" and the Doppelganger is called "Synthetic" (the consistency of labels is something we intend to fix later on in our work). One can also see the general sample mean in the third column. From *Table 2* the average value of each of the predictors except GDP per capita

are the same, using three decimals. However, the Doppelganger's average GDP per capita is more similar to the sample mean than to the UK. Yet, GDP per capita was assigned zero predictor weight. Accordingly, the mean discrepancy in GDP per capita between the UK and its Doppelganger is not a concern.

Table 2

Predictor Mean Values

	UK	Doppelganger	Sample Mean
Inflation	0.860	0.860	-0.043
Interest Rate	-0.598	-0.598	-0.362
GDP/capita	4,570.698	6,656.746	6,176.709
Lagged Household Savings Rate	2.400	2.400	1.556

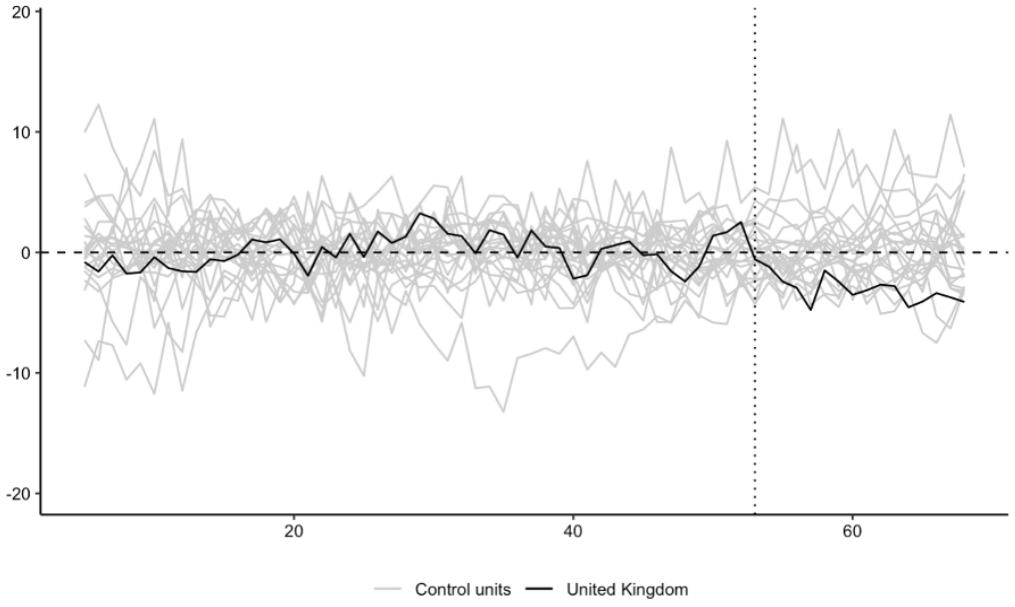
All values are deviations from 2003

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Country Placebo Tests of Short-Run Effects

To verify that the estimated effect of the Brexit referendum on household savings was any different from what other countries exhibited at the time, a set of country placebo tests similar to what Abadie et al. (2010) and to Born et al. (2019) conducted. In the country placebo test, the treatment is assigned to the other countries in the donor pool. If the other countries' household savings rate react similarly to the UK, although they in fact were given a placebo treatment, the results cannot be verified (Abadie, 2021). The plot of the country placebo test can be seen in *Figure 4*. In *Figure 4* all 23 countries have been assigned the treatment. From the figure, the UK still seems to be one of the countries that is picking up the largest downward effect of the referendum shock in the household savings rate.

Figure 4: Country Placebo Test for All Countries

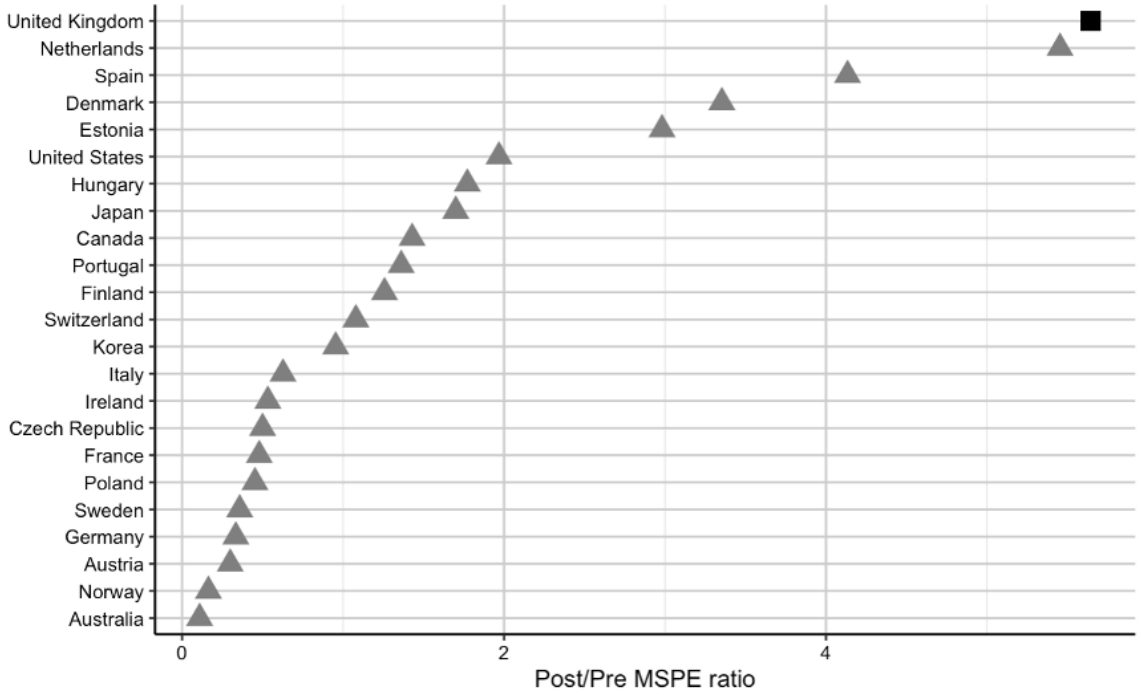


Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Yet, countries that are rather different from the UK before the treatment are less interesting to compare with post treatment (Abadie, 2021). Thus, in three other placebo runs found in Appendix 4.1, countries that have a high MSPE value before the treatment and thus are the most dissimilar to the UK before the treatment are excluded. In all three trials, where the MSPE is halved in each of them, the UK is still one of the countries where household savings exhibit the largest downward effect post treatment.

Moreover, the ratio of each of the countries' post and pre MSPE values of the placebo tests are plotted. A large post/pre MSPE ratio indicates a large treatment effect (Abadie, 2021). If other countries exhibit similar ratios as the UK (which is the only country that is not given a placebo treatment) or higher ratios than the UK, the significance of our results diminish. From *Figure 5* where the Post/Pre MSPE ratio is plotted for each of the 23 countries, one can see that the UK exhibits the largest treatment effect. Moreover, the UK's treatment effect is significantly higher than the other countries' at a 5% significance level as its p-value is approximately 0.04. Yet, especially the Netherlands but also Spain and Denmark seem to experience large treatment effects. To ensure that the effect they experience is not contributing to the UK's treatment effect, generating an upward bias, they are excluded in a set of robustness tests in one of the following sections.

Figure 5



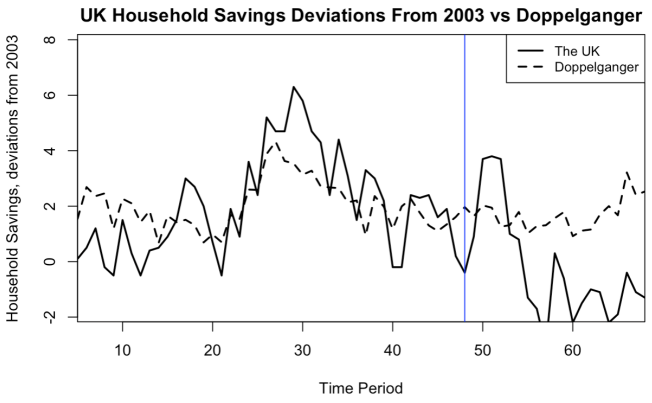
Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

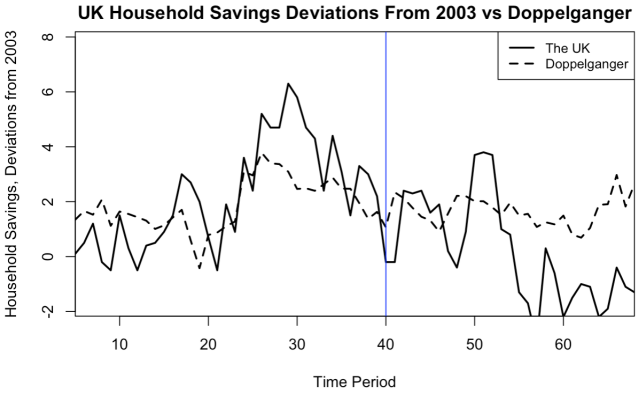
Time Placebo Tests of Short-Run Results

To investigate if our estimated treatment effect is not seen in other time periods than when the intervention, the Brexit referendum, occurred, a set of time placebo tests are conducted. In these tests, the treatment date is moved back in time, similar to what Abadie (2021) suggests. If the previously estimated divergence is moved when the treatment date is moved back in time, the reliability of our estimates is questionable. In these time placebo tests (see *Figure 6* and *Figure 7*), the treatment date is

moved first 5 quarters back and then 13 quarters back. From these tests, the fluctuations compared to *Figure 2* do not seem to alter, indicating that the treatment effect is not moved back in time when a placebo treatment is given in other time periods. Thus, the estimates seem reliable. Yet, as the fit between the UK and the Doppelganger is suboptimal from the beginning and that the dependent variable exhibits great volatility, it is difficult to certainly state that the treatment effect is not at all moved.

Figure 6 (the intervention is moved to period 48) & Figure 7 (the intervention is moved to period 40)





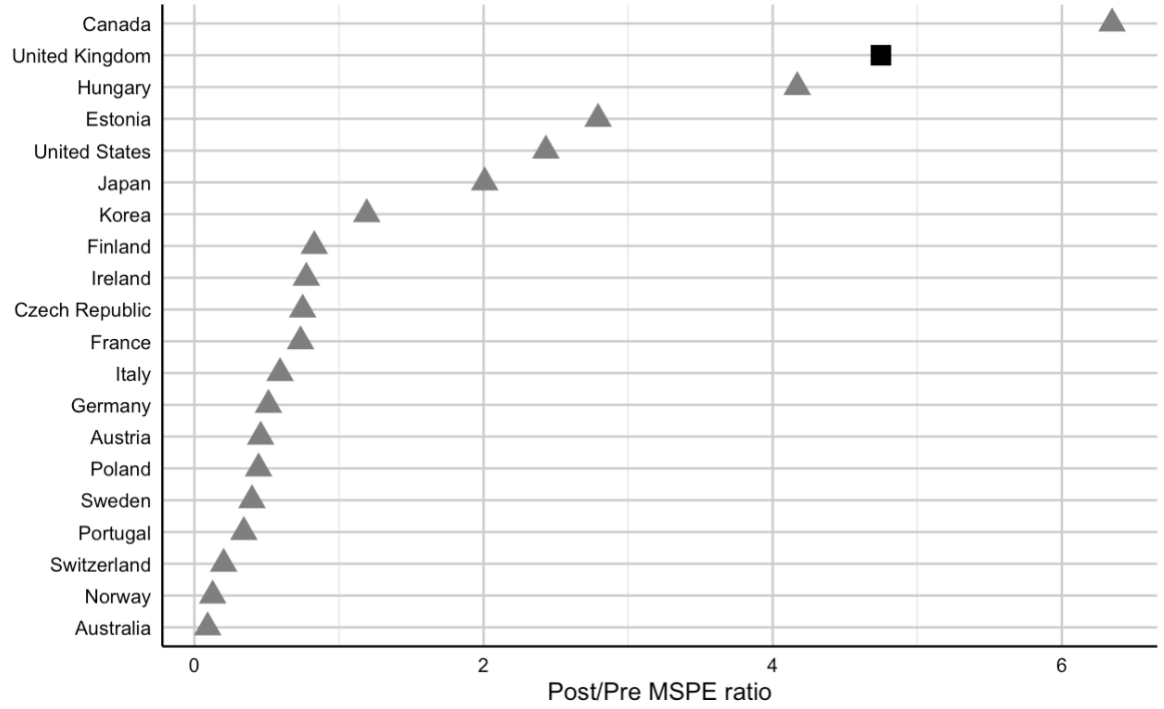
Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 6 and 7.

Robustness Tests of Short-Run Results

Similar to Born et al. (2019), a set of robustness tests are performed where the three donor states that exhibit the largest post/pre MSPE ratio are excluded. As the Netherlands, Spain and Denmark are three countries that except for the UK seem to exhibit the largest treatment effect in the country placebo tests, these countries are excluded as there is a risk that they are contributing to an upward bias of the estimates (Born et al., 2019). For completeness, all figures and tables made for the original model specification are also constructed for the robustness test, which can be found in Appendix 4.1 However, only small changes are observed as the three excluded countries were assigned small country weights in the original model specification.

Yet, the UK's post/pre MSPE ratio, and thus estimated treatment effect, decreases slightly by the removal of the three states which indicate that the three excluded states contributed to an upward bias in the original model specification (see *Figure 8*). Moreover, the p-value increases to 0.10, which means that the results no longer are significant at the 5% level. Overall, the original estimates seem fairly robust as the UK still is one of the countries with the largest estimated treatment effect and the p-value still indicates significance.

Figure 8



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Long-Run Effects

In this part, time periods 69-79 (Q1 2020 - Q2 2022) are added to the original short-run model to investigate how household savings continue to evolve on a more long-term basis after the Brexit referendum. These quarters are marked by the COVID-19 pandemic and are thus called the pandemic years. The aim with the long-run model is to investigate if the UK's household savings rate continues to remain lower than its Doppelganger despite the pandemic and its accompanying restrictions and support packages. The underlying assumption is that the COVID-19 pandemic is an exogenous, global event, affecting the UK and every country in the donor pool.

Empirical Context

To gain a deeper understanding of the implications of the pandemic, it hereby follows a short summary of the restrictions and fiscal support packages launched in the UK and the three countries that contributed the most in the creation of the Doppelganger: Germany, Finland and the Czech Republic.

COVID-19 Restrictions

The UK had three nation-wide lockdowns because of the pandemic (*Institute for Government*, 2022). The Czech Republic had two nationwide lockdowns whilst Germany had one (*University of Ostrava*, 2023; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022d). However, the German "bundesländer" imposed several lockdowns on a regional level (*Ask About*: *The Oxford COVID-19 Government Response Tracker,* 2022d). In Finland there was no legally imposed lockdown although people were encouraged to stay home and bars and restaurants were closed (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022c). In all four countries, workplaces and schools closed (in Finland early childhood education and pre-primary education were still kept open)

and people worked and studied from home. In each of the countries except Finland, public transport was at least partly closed. Public events were canceled in Germany, Finland and the UK (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022c; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022d; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022i; *University of Ostrava*, 2023).

In between lockdowns and contagion spikes, there were rules of how many people that were allowed to meet up, in order to minimize spread of the virus. In the UK, there was the rule of six which meant that no more than six people were allowed to meet up (*Institute for Government*, 2022). In Finland there was a rule of ten and in Germany there was a rule of ten and then of five (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022c; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022d). Each of the four countries also had legal requirements to self-isolate upon infection. The countries closed their borders and incoming visitors from high-risk countries were required to quarantine. There were also restrictions on internal movement in each of the four countries (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022c; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022d; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022i; *University of Ostrava*, 2023). In Germany, the UK and the Czech Republic face masks became compulsory in public indoor venues (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022d; *Institute for Government*, 2022; *University of Ostrava*, 2023).

When the world began opening up during 2021 as vaccinations picked up pace, access to many indoor venues and events such as stores, restaurants and bars were conditioned upon a negative COVID-test result or proof of vaccination (*Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022c; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022d; *Ask About*: *The Oxford COVID-19 Government Response Tracker*, 2022i; *University of Ostrava*, 2023). All these restrictions and general fear of contagion resulted in a contraction of demand for goods and services previously consumed with ease (Ulrich Ruch and Taskin, 2022). Simultaneously, industries where work could not be performed remotely caused unreliable supply chains and hence a supply shock (Ulrich Ruch and Taskin, 2022). Thus, the possibilities for consumption were reduced and governments launched historical support packages to stimulate the economy.

COVID-19 Government Support

All four countries issued large support packages to support the business sector and households during the pandemic. The UK's total government support constituted approximately 6.4% of their annual GDP in 2020, whilst the government support constituted 4% of Czech Republic's, 10.7% of Germany's and 3% of Finland's GDP in 2020 (Pope and Hourston, 2022; *IMF*, 2022). In the UK, almost 60% of the government support went to individuals whilst the remaining 40% went to businesses. Two thirds of the British government support was distributed during 2020 (Pope and Hourston, 2022).

Government support was packaged in several wide-ranging schemes, benefitting many people. One of the largest schemes in each of the four countries was compensation of furloughed workers. In the UK, 11.7 million jobs were supported and furloughed workers were able to retain up to 80% of their salaries (Pope and Hourston, 2022). In Germany, it was called Kurzarbeitergeld which allowed for a 60-67% wage compensation for reduced working hours (*IMF*, 2022). In the Czech Republic, the government was replacing 50-60% of lost salaries (*IMF*, 2022). In Finland, unemployment insurances were increased and the requirements for funds were lowered (*IMF*, 2022).

Moreover, self-employed people were especially supported in all countries and VAT and/or other taxes were either temporarily lowered or postponed in each of the four countries (Pope and Hourston, 2022; *IMF*, 2022). The Czech Republic gave a daily lump sum of 370 Czech korunas (about €15) for each day spent in quarantine, and the UK offered £500 lump sum for people asked to self-quarantine (Pope and Hourston, 2022; *IMF*, 2022). Germany expanded children benefits and similar to Finland they also expanded parental allowances (*IMF*, 2022). The Czech Republic offered rent support for households and businesses (Pope and Hourston, 2022; *IMF*, 2022). The UK increased its Universal Credit and also initiated a one-off extra payment amounting to £500 which 5.8 million people were given (Pope and Hourston, 2022).

The above presented examples of government support are non-exhaustive. To gain a better understanding of the magnitude and impact of the support packages, they are hereby related to statistical figures from Eurostat and the Office for National Statistics. When comparing change in household income to the previous year , 34.8% of the population in the Czech Republic and 25.6% of the population in Germany, reported higher income in 2021 than compared to 2020 which is to be compared with the EU average of 17.5% (see Appendix 5.1) (*Eurostat*, 2022). In the entire EU, household income had a relatively small increase in 2020 of 0.4% and an unusually large increase in 2021 of 2.6% (*Eurostat,* no date). In the UK, households' median disposable income increased by 2.3% in 2020 and by 2% in 2021 (Croal, 2022). Thus, households seemed to generally have increasing incomes in each of the four countries, despite the pandemic and the economic downturn.

Long-Run Estimations

With the empirical context in mind, the pandemic time periods are now added to the original model. The UK's and the Doppelganger's trajectory for the household savings rate can be seen in *Figure 9*. In period 69-71 when the pandemic began, it seems as if the household savings rate in both the UK and the Doppelganger had a historically high spike. The household savings rate in the UK increases by about 20 percentage points whilst the Doppelganger's household savings rate increases by about seven percentage points. Thus, when the pandemic begins, the household savings rate in the UK surpasses its Doppelganger after having remained at a lower base level for 15 quarters. After the initial spike, the UK aligns quite well with its Doppelganger and both exhibit a second, smaller spike in time period 73. The UK seems to face a faster drop in household savings rate after the second, smaller spike although both align quite well towards time period 78. From *Figure 10* one can thus summarize the estimations by stating that the dip in UK's household savings seen after the referendum remains up until the pandemic begins. Then, the UK seems to face a greater spike than its Doppelganger and then align quite well with its Doppelganger's trajectory. Once again, one should be aware that the Doppelganger fit is suboptimal before the Brexit Referendum which implies that it is difficult to draw strong conclusions.

Figure 9

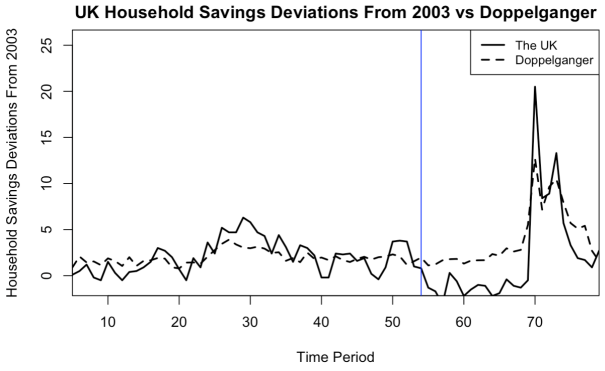
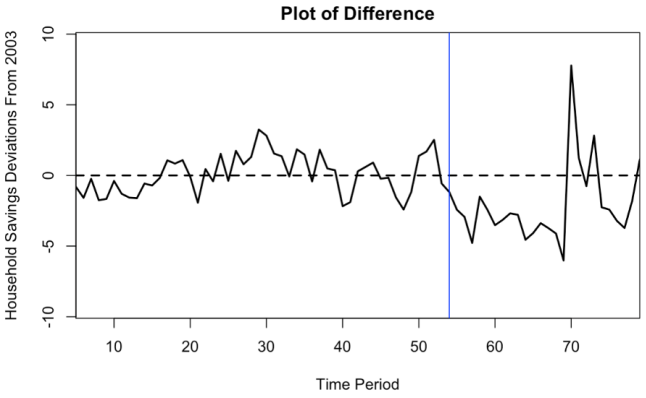


Figure 10

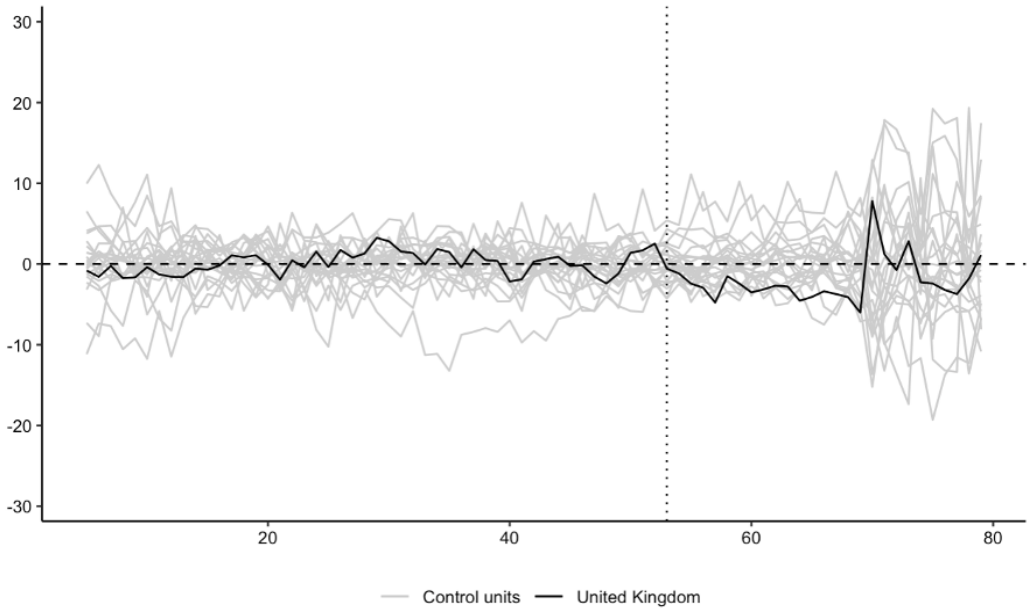


Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 9 and 10.

Country Placebo Tests of Long-Run Estimations

In the country placebo tests, where a placebo treatment is assigned to the donor states, the UK remains one of the countries that exhibit the largest downward effect on household savings rate after the Brexit referendum (see *Figure 11*). Moreover, the effect seems to last up amongst the lowest among the donor states up until the pandemic in time period 69 where it has a spike, similar to other countries. The spike seems relatively high compared to the other countries when its low starting point is considered.[2]

Figure 11

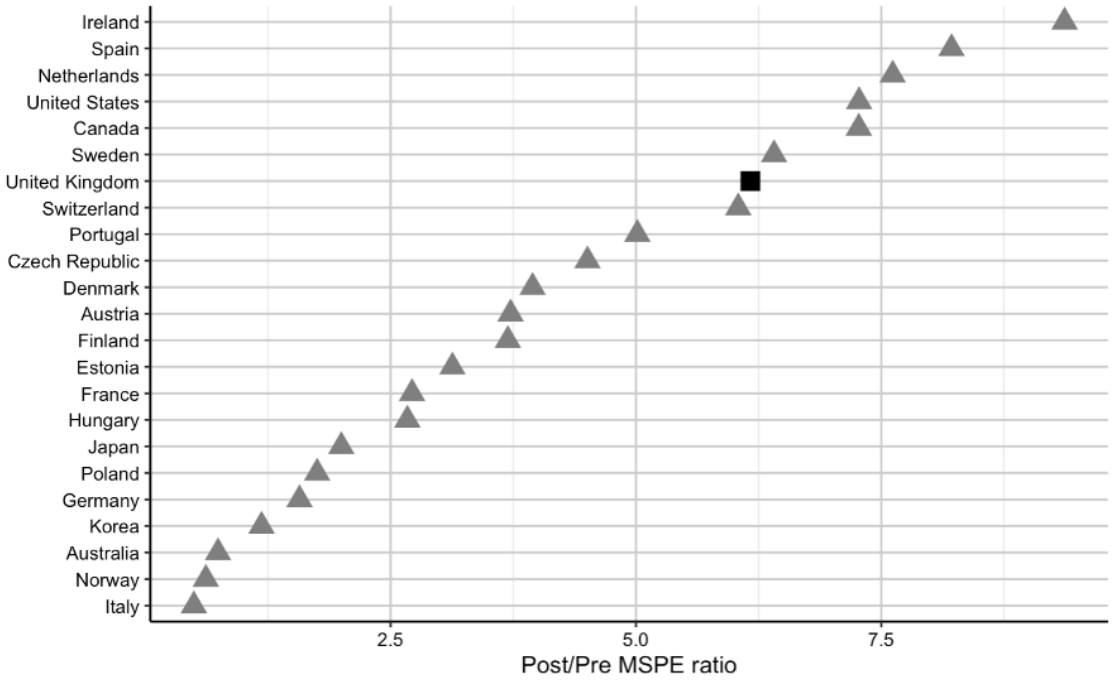


Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

[2] When countries that are fairly dissimilar to the UK before the Brexit referendum are excluded (see Appendix 4.2), the UK remains one of the countries where the treatment has the largest negative impact and one of the countries where the pandemic has the largest positive impact.

Interestingly, when we look at the post/pre MSPE ratio in *Figure 12*, the UK is no longer the country that has the largest post/pre MSPE ratio. Thus, when the post intervention period is extended, the UK's household savings ratio is no longer the one that faced the greatest change. It seems as if Ireland, Spain and the Netherlands, amongst other countries, have faced greater changes in their household savings rate compared to the UK. Thus, the relatively large downward treatment effect seen in the Short-Run Results does not seem to last when the pandemic years are included. Moreover, the results are no longer significant (fisher p-value is 0.304).

Figure 12



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Time Placebo Tests of Long-Run Estimations

As in the short-run time placebo tests, the treatment date is moved back first 5 quarters in *Figure 13* and then 13 quarters in *Figure 14*. From these tests, the fluctuations compared to *Figure 9* do not seem to alter, indicating that the treatment effect is not moved back in time when a placebo treatment is given in other time periods. Thus, the estimates seem to hold for the time placebo tests. Yet, as the fit between the UK and the Doppelganger is rather poor in the long-term model estimation too, it is difficult to certainly state that the treatment effect is not moved.

Figure 13

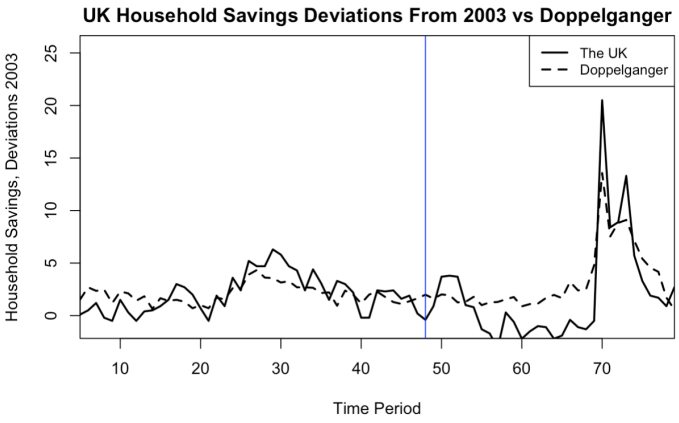
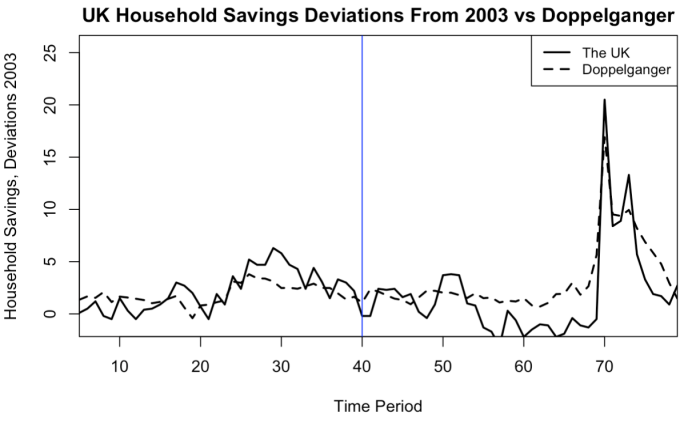


Figure 14



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 13 and 14.

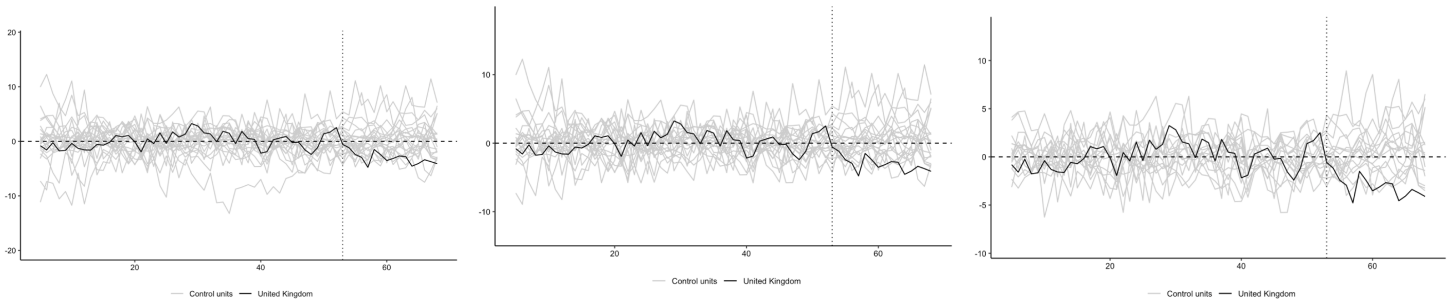
Appendix 4: Supplementary Placebo and Robustness Figures and Tables, when Spain and Switzerland are Included in the Donor Pool

Appendix 4.1 Complementary Figures and Tables for Short-Run Results When Spain and Switzerland are Included

Country Placebo Tests Where Countries with High MSPE-Values are Excluded

As countries that are rather different from the UK before the treatment are less interesting to compare with post treatment (Abadie, 2021), three other placeboruns are made where countries that have a high MSPE before the treatment are excluded. In all three trials, where the MSPE is halved in each of them, the UK still seems to be one of the countries where household savings exhibit the largest downward effect post treatment.

Figure 1a (MSPE limit = 20), 1b (MSPE limit = 10) and 1c (MSPE limit = 5)



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For Figure 1a, 1b and 1c.

Robustness Test of Short-Run Results

As a rather large treatment effect was observed for Denmark, the Netherlands and Spain, these were excluded in a robustness. The estimates in *Figure 2 and 3* are not visually changing compared to when the three countries were included, indicating robustness of the primary results. The MSPE increases slightly to approximately 2.005.

Figure 2

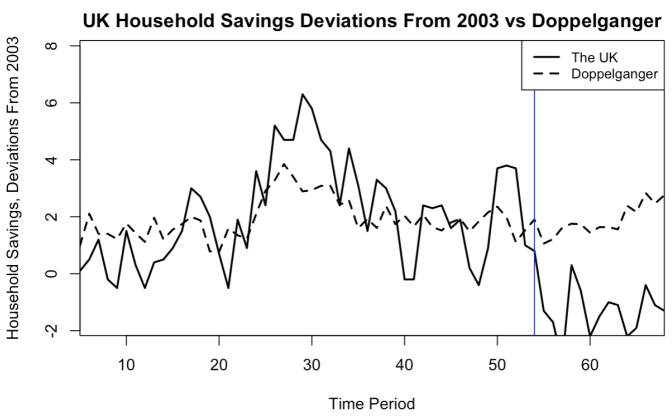
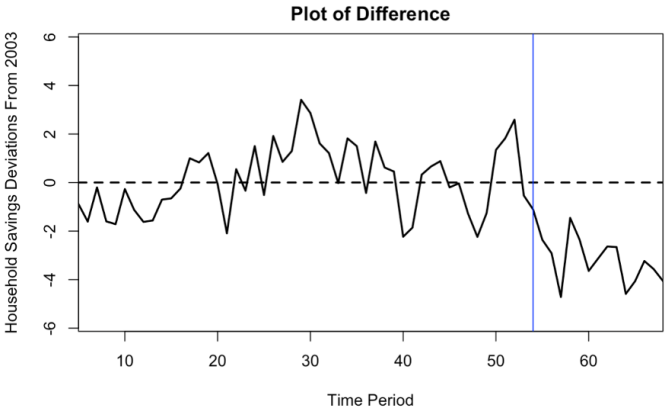


Figure 3



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 2 and 3.

Although the MSPE slightly increased, and thus the fit of the Doppelganger worsens, the difference between the average predictor values seem rather unaffected.

Table 1

Predictor Mean Values

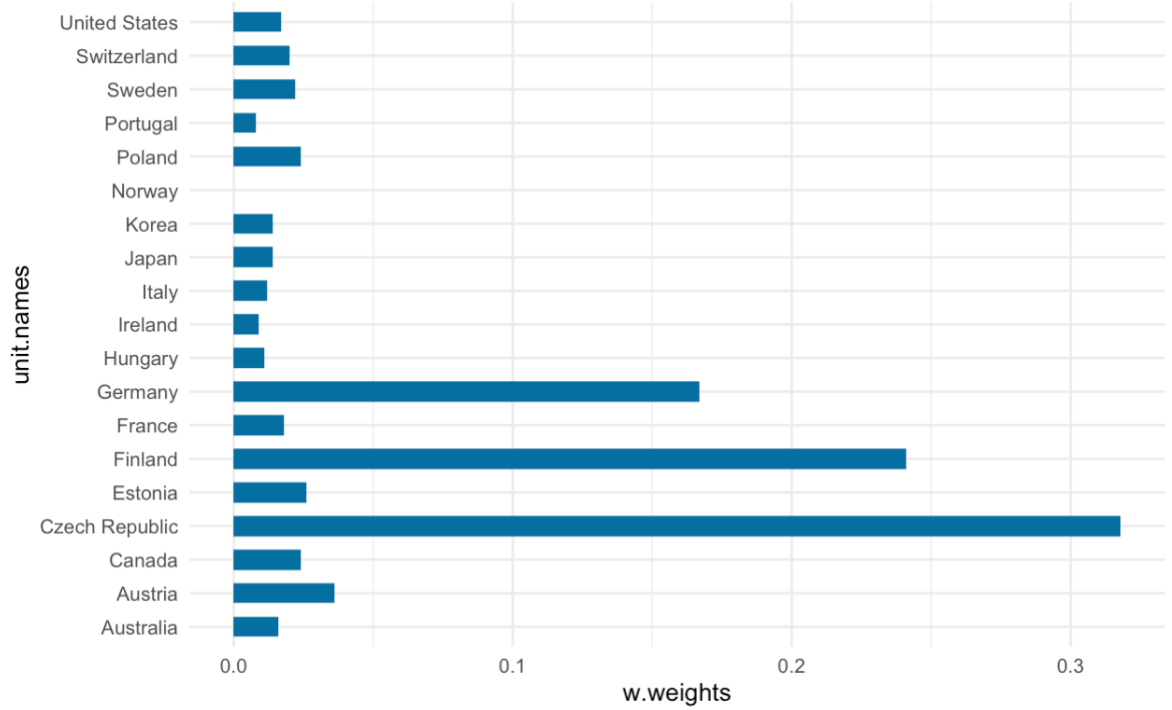
	UK	Doppelganger	Sample Mean
Inflation	0.860	0.860	0.016
Interest Rate	-0.598	-0.598	-0.331
GDP/capita	4,570.698	6,697.313	6,325.275
Lagged Household Savings Rate	2.427	2.427	1.208

All values are deviations from 2003

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Naturally, the country weights slightly alter as the three countries are excluded. Yet, there are no large differences as none of the three excluded countries were assigned large weights previously.

Figure 4



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Moreover, the predictor weights alter slightly but no large differences can be observed.

Table 2

	Inflation	Interest Rate	GDP/capita	Lagged DV
Predictor Weights	0.25	0.401	0	0.348

All values used for the predictors are deviations from 2003

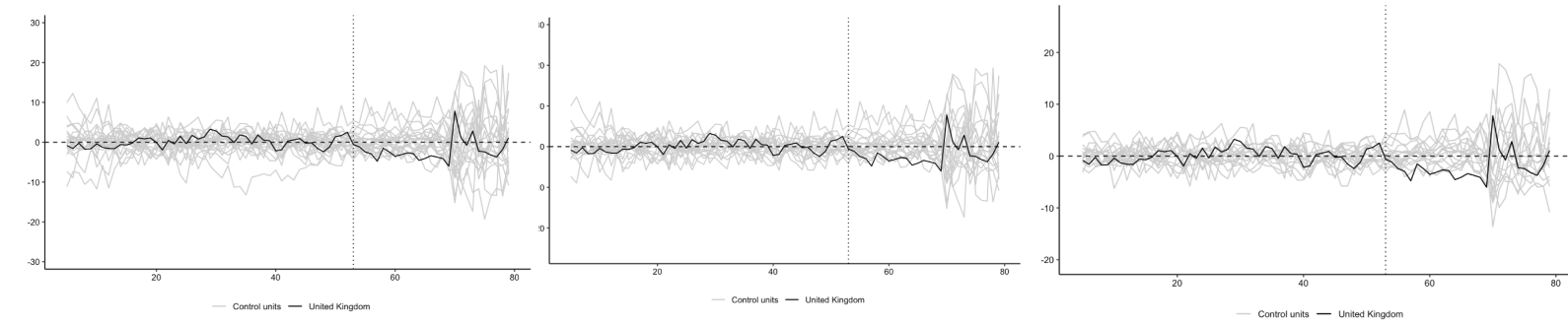
Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Appendix 4.2 Complementary Figures and Tables for Long-Run Results When Spain and Switzerland are Included

Country Placebo Tests Where Countries with High MSPE-Values are Excluded

When we exclude countries which are fairly dissimilar to the UK before the Brexit referendum similar to what Abadie (2021) suggests, the UK remains one of the countries where the treatment has the largest negative impact. In all three trials, the base-level of household savings rate remains lower up until the pandemic begins in quarter 69 where it has a spike.

Figure 5a (MSPE limit = 20), 5b (MSPE limit = 10) and 5c (MSPE limit = 5)



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For Figure 5a, 5b and 5c.

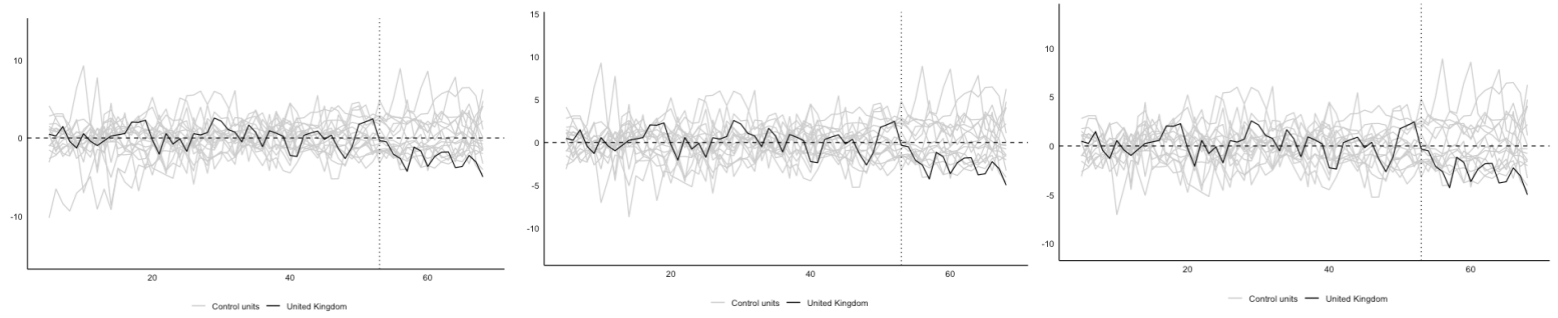
Appendix 5: Supplementary Placebo and Robustness Figures and Tables, for the Result Section

Appendix 5.1 Complementary Figures and Tables for Short-Run Results

Country Placebo Tests Where Countries with High MSPE-Values are Excluded

As countries that are rather different from the UK before the treatment are less interesting to compare with post treatment (Abadie, 2021), three other placebo runs are made where countries that have a high MSPE before the treatment are excluded. In all three trials, where the MSPE is halved in each of them, seen in *Figure 1a, 1b* and *1c* respectively, the UK still seems to be one of the countries where household savings exhibit the largest downward effect post treatment.

Figure 1a (MSPE limit = 20), 1b (MSPE limit = 10) and 1c (MSPE limit = 5)



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For Figure 1a, 1b and 1c.

Robustness Test of Short-Run Results

As a rather large treatment effect was observed for Denmark, the Netherlands and Spain, these were excluded in a robustness test. The estimates in *Figure 2 and 3* are not visually changing compared to when the three countries were included, indicating robustness of the primary results. The MSPE

increases slightly to approximately 1.74 (compared to approximately 1.71 in the original model specification).

Figure 2

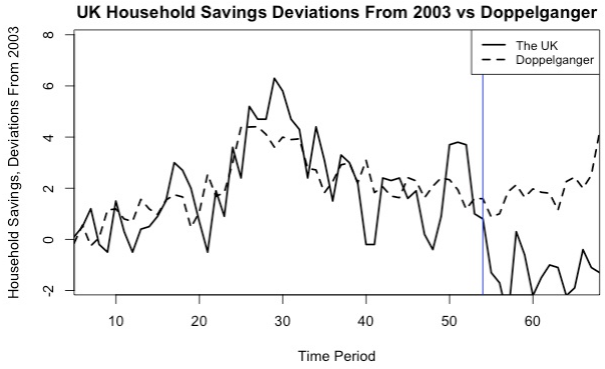
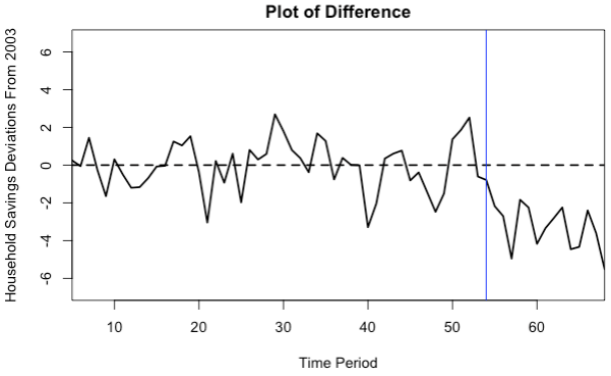


Figure 3



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 2 and 3.

Although the MSPE slightly increased, and thus the fit of the Doppelganger worsens, the difference between the average predictor values seem rather unaffected, seen in *Table 1*.

Table 1

Predictor Mean Values

	UK	Doppelganger	Sample Mean
Interest Rate	-0.598	-0.392	-0.307
Real GDP Growth	-0.379	-0.274	-0.103
Inflation	0.860	0.143	-0.063
Unemployment Rate	1.655	1.603	0.593
Household Consumption	60,223.660	22,377.720	46,632.530
Old Age Dependency Ratio	3.660	3.978	3.985
Lagged Household Savings Rate	2.427	2.800	0.953

All values are deviations from 2003

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Naturally, the country weights alter as the three countries are excluded. The US and the Czech Republic are assigned larger weights, which can be seen in *Table 2*. Despite this, there are no major differences.

Table 2

Country Weights

Sweden	0.233	Japan	<0.01	Portugal	<0.01	Australia	<0.01
Ireland	0.260	Finland	<0.01	Netherlands	<0.01	Germany	<0.01
United States	0.039	Hungary	<0.01	Poland	<0.01		
Czech Republic	0.373	Norway	<0.01	Korea	<0.01		
Austria	0.096	France	<0.01	Italy	<0.01		

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Moreover, the predictor weights alter too (see *Table 3*). Unemployment rate is assigned an even larger predictor weight.

Table 3

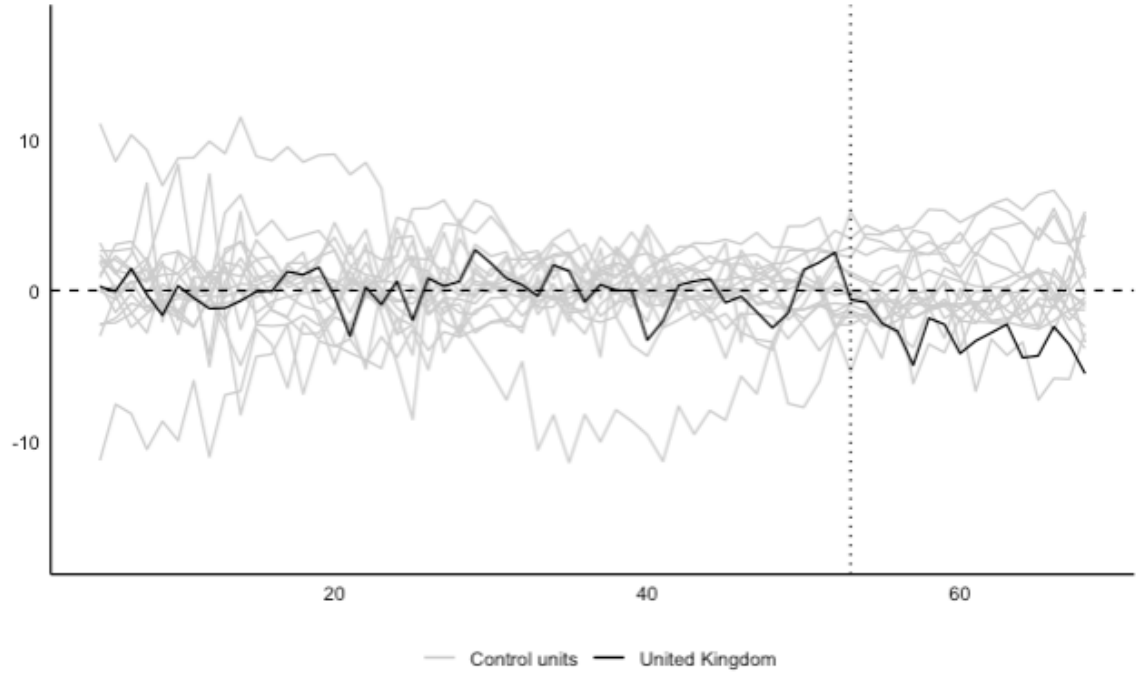
	Interest Rate	Real GDP Growth	Inflation	Unemployment	HS Consumption	Old Age Dependency	Laged DV
Predictor Weights	0.025	0.003	0.011	0.931	0.002	0.021	0.007

All values used for the predictors are deviations from 2003

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

As for the country placebo tests, the UK remains one of the countries with the largest estimated treatment effect which can be seen in *Figure 4*.

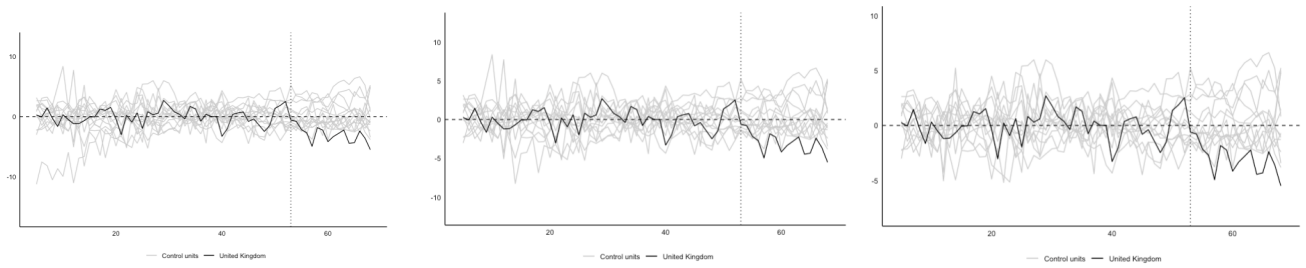
Figure 4



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

This remains the case when countries that are dissimilar to the UK before the treatment and thus have a high MSPE value are excluded. This can be seen in *Figure 5a, 5b* and *5c*.

Figure 5a (MSPE limit = 20), 5b (MSPE limit = 10) and 5c (MSPE limit = 5)

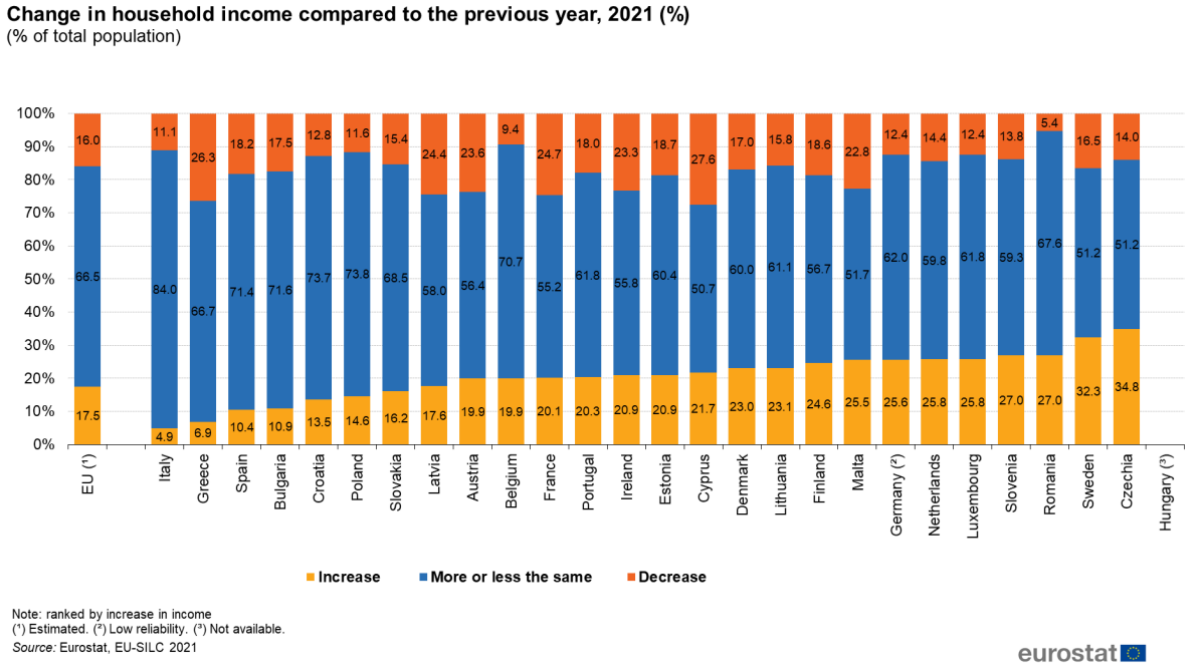


Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For Figure 5a, 5b and 5c.

Appendix 5.2 Complementary Tables and Figures for Long-Run Results

Change in Household Income Compared to Previous Year

Figure 6

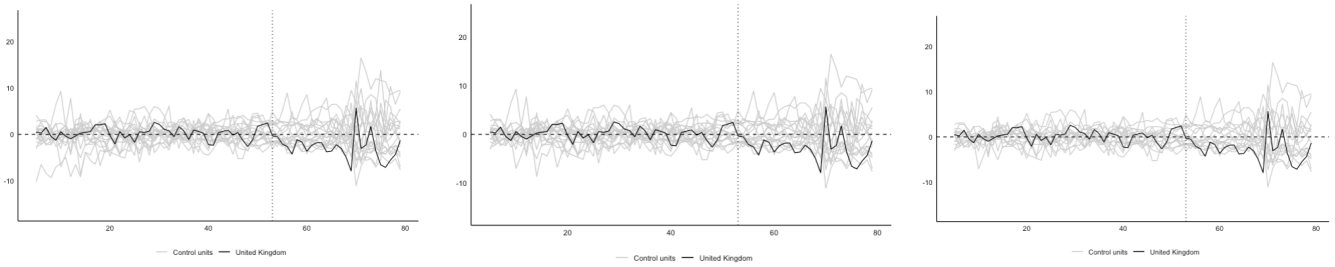


Source: Eurostat (2021).

Country Placebo Tests Where Countries with High MSPE-Values are Excluded

When we exclude countries which are fairly dissimilar to the UK before the Brexit referendum similar to what Abadie (2021) suggests, the UK remains one of the countries where the treatment has the largest negative impact. In all three trials, the base-level of household savings rate remains lower up until the pandemic begins in quarter 69 where it has a spike. This is visualized in *Figure 7a, 7b* and *7c.*

Figure 7a (MSPE limit = 20), 7b (MSPE limit = 10) and 7c (MSPE limit = 5)



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For Figure 7a, 7b and 7c.

Robustness Test of Long-Run Results

As a rather large treatment effect was observed for Ireland, Sweden and Canada, these were excluded in a robustness test. The estimates in *Figure 8* and *9* are not visually changing compared to when the three countries were included, indicating robustness of the primary results. The MSPE increases slightly to approximately 2.129.

Figure 8

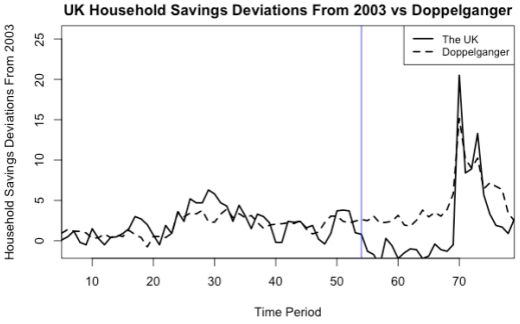
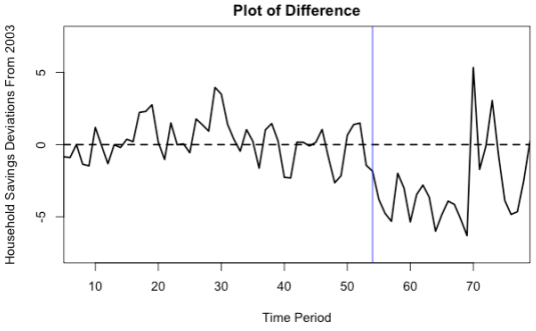


Figure 9



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For both Figure 8 and 9.

Despite the increased MSPE value, and thus worse fit of the Doppelganger, the difference between the average predictor values remains rather small. The mean value difference between the UK and the Doppelganger improves for long-term interest rate, inflation, and lagged household savings rate and worsens for unemployment rate compared to the original Doppelganger.

Table 4

Predictor Mean Values

	UK	Doppelganger	Sample Mean
Interest Rate	-0.598	-0.587	-0.325
Real GDP Growth	-0.379	-0.290	-0.143
Inflation	0.860	0.853	0.192
Unemployment Rate	1.655	-0.089	0.235
Household Consumption	60,223.660	59,792.360	46,151.770
Old Age Dependency Ratio	3.660	4.925	4.139
Lagged Household Savings Rate	2.427	2.416	0.293

All values are deviations from 2003

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Naturally, the country weights alter as the three countries are excluded. Germany, Denmark, the United States and Finland are assigned larger weights which can be seen in *Table 5*.

Table 5

Country Weights

Estonia	0.243	Czech Republic	0.091	France	<0.01	Italy	<0.01
Germany	0.215	Finland	0.016	Portugal	<0.01	Australia	<0.01
Denmark	0.167	Japan	<0.01	Netherlands	<0.01		
Austria	0.158	Hungary	<0.01	Poland	<0.01		
United States	0.109	Norway	<0.01	Korea	<0.01		

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

Moreover, the predictor weights alter too (see *Table 6*). Long-term interest rate, inflation, household consumption and lagged values of household savings rate are assigned a larger weight compared to the original Doppelganger.

Table 6

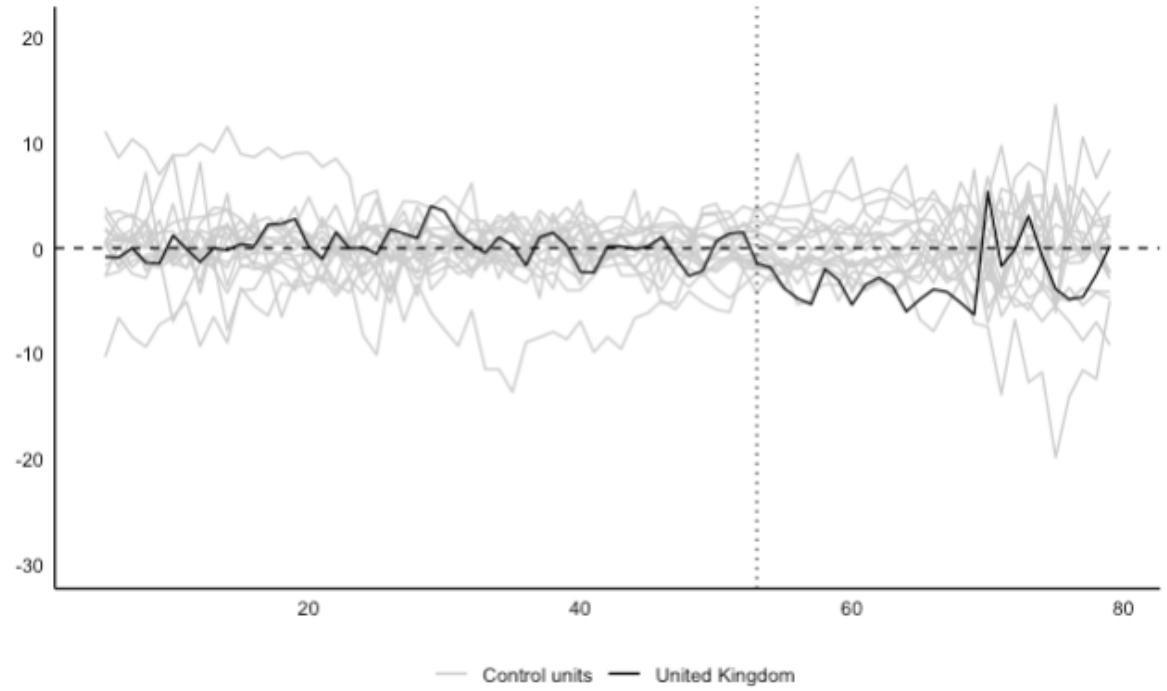
	Interest Rate	Real GDP Growth	Inflation	Unemployment	HS Consumption	Old Age Dependency	Laged DV
Predictor Weights	0.289	0.006	0.249	0.002	0.129	0	0.325

All values used for the predictors are deviations from 2003

Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

As for the country placebo tests, the UK remains one of the countries with the largest estimated treatment effect and with a relatively large spike when the pandemic begins which can be seen in *Figure 10*.

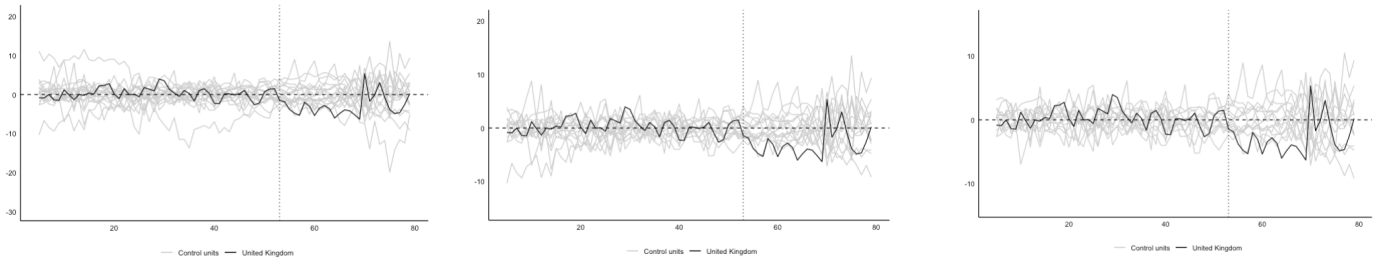
Figure 10



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e).

This remains the case when countries that are dissimilar to the UK before the treatment and thus have a high MSPE value are excluded.

Figure 11a (MSPE limit = 20), 11b (MSPE limit = 10) and 11c (MSPE limit = 5)



Source: Bank of Estonia (n.d.); Eurostat (2023); JP. Cabinet Office (2023); OECD (2023a); OECD (2023b); OECD (2023c); OECD (2023d); OECD (2023e). For Figure 11a, 11b and 11c.