

DISCUSSION PAPER SERIES

DP12454

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**INTERNATIONAL MACROECONOMICS
AND FINANCE and MONETARY
ECONOMICS AND FLUCTUATIONS**



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Discussion Paper DP12454
Published 22 November 2017
Submitted 22 November 2017

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JEL Classification: E65, F13, F42

Keywords: Brexit, European Union, policy uncertainty, synthetic control method

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Acknowledgements

We thank Ruben Dominguez Diaz for excellent research assistance. The usual disclaimer applies.

The Economic Consequences of the Brexit Vote*

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November 20, 2017

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This paper introduces a data-driven, transparent and unbiased method to calculate the economic costs of the Brexit vote in June 2016. We let a matching algorithm determine a combination of comparison economies that best resembles the growth path of the UK economy *before* the Brexit referendum. The economic cost of the Brexit vote is the difference in output between the UK economy and its synthetic doppelgänger. We show that, contrary to public perception, by the third quarter of 2017 the economic costs of the Brexit vote are already 1.3% of GDP. The cumulative costs amount to almost 20 billion pounds and are expected to grow to more than 60 billion pounds by end-2018. We provide evidence that heightened policy uncertainty has already taken a toll on investment and consumption.

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“He who wills the ends wills the means.”

Keynes, *The Economic Consequences of Mr. Churchill*

1 Introduction

On June 23, 2016 the UK electorate voted to leave the European Union. A return to Britain’s pre-1973 position outside the European institutions could prove costly in economic terms—just like Britain’s return on gold in the 1920s that Keynes referred to in the quote. But how costly exactly? Existing estimates of the costs of Brexit vary by a confusingly wide margin. It is not hard to see why. The future economic relationship between the UK and the European Union is currently being negotiated and the outcome is anybody’s guess. Different assumptions about the “deal” that Britain gets will lead to very different estimates of the economic costs. But even for comparable outcome scenarios, economists manage to arrive at conclusions that are miles apart.

That’s why we take a different route in this paper. Rather than *forecasting* the economic costs of Brexit based on a specific set of assumptions which are necessarily controversial we *measure the actual output loss* that has accumulated since the Brexit vote and can be causally attributed to the decision. We will track and update these costs over time with the novel “Brexit-Cost-Tracker” that this paper introduces. Importantly, our approach does not hinge on having the right economic model for the British, the European, or even the global economy. We do not need to forecast a particular Brexit deal, construct scenarios for the outcome of the negotiations, or make debatable assumptions about critical parameters in a theoretical model. Instead we identify the realized economic cost of the Brexit decision for the UK economy by constructing an appropriate counterfactual scenario.

To do this, we propose a transparent, unbiased and entirely-data driven approach. We let an algorithm determine which combination of other economies matches the growth trend of the UK economy before the Brexit vote with the highest possible accuracy. Which economies get picked by the algorithm and what weight they are assigned is entirely data-driven and open to replication by other researchers. The better the algorithm constructs

a close match for the UK economy as a weighted combination of other economies *before* the Brexit “treatment”, the more accurate our results will be. We use the largest possible country dataset to obtain the best match possible.

In a next step, we can use this doppelganger of the pre-Brexit UK economy to determine the costs of the Brexit decision, because it does not get “treated” with the Brexit decision. The doppelganger continues to evolve in the way the pre-Brexit economy would have in absence of the vote. In other words, it represents the counterfactual performance of the UK economy had the referendum not taken place. From here it is easy. The difference in output between the UK economy and its doppelganger captures the causal effect of the referendum decision. This so-called synthetic control method has been successfully applied to study the effects of similar one-off events such as German reunification, or the introduction of tobacco laws (Abadie et al. 2010, 2015).

What do we find? The first important result is that the economic costs of the Brexit vote are already visible and quite large. We show that, contrary to public perception, by the third quarter of 2017 the output loss due to the Brexit vote is approximately 1.3%. Cumulatively, the loss is close to 20 billion pounds. Under current forecasts, the cumulative costs are expected to grow to almost 65 billion pounds by end-2018. At this point we expect output to be 2.2% below what would have been observed in the absence of the Brexit vote. These figures use Bank of England forecasts for the UK economy, and OECD forecasts for the control economies. In other words, even before Brexit actually happens, the output loss triggered by the decision could be equivalent to about 8 years of the UK’s net contribution to the EU.

What explains these large economic costs? In a first step, we decompose the effects and study the evolution of consumption and investment in the UK economy relative to the performance of the doppelganger economy. The economic costs of the Brexit vote are most visible in consumption and investment spending. By Q3 2017, since the Brexit referendum both consumption and investment grew about half as fast in Britain as they would have otherwise. Somewhat surprisingly, the external sector has not cushioned the effects in a meaningful way despite the sharp depreciation of the nominal and real exchange rate in

the wake of the Brexit referendum.

What are the deeper economic reasons for the output decline? Two potential explanations stand out. On the one hand, the reduction in output caused by the Brexit vote could be due to the increased uncertainty linked to Britain's future economic integration with the continent. Such uncertainty may temporarily depress economic activity, but in the absence of hysteresis effects the economy may bounce back once the uncertainty is resolved. On the other hand, the observed decline could be due to the anticipation of lower future living standards as the reduction in trade with the continent will make Britain permanently poorer.

To throw some light on this question we analyze the differential effect of the Brexit vote on the Economic Policy Uncertainty (EPU) index provided by Baker et al. (2016a). Using the synthetic control method once more, we can measure the increase of economic policy uncertainty in the UK due to the Brexit vote. We find that the increase in uncertainty has indeed been substantial. It is even higher than the increase in policy uncertainty in the Great Recession, but this time the effect is concentrated in the UK. Existing estimates put the output cost of heightened policy uncertainty during the Great Recession at about one percent of GDP (Baker et al. 2016a). However, as policy uncertainty is partly endogenous to the state of the economy, these estimates may be upward biased and should be taken with a grain of salt. This being said, at this point we cannot reject the idea that policy uncertainty was a major driver of the output loss which has materialized in the UK because of the Brexit vote.

Related literature: Our paper is not the first to address the economic consequences of Brexit. Over the past year, different papers have attempted to estimate the economic costs and consequences of the withdrawal of the UK from the EU. As mentioned above, the magnitude of the results and the methods employed in these papers differ substantially. Virtually all studies forecast negative output effects stemming from a reduction in trade, a fall in foreign direct investment (FDI), or both.

HM Treasury (2016) use a gravity model of trade to assess the long-term economic impact of leaving the EU under several scenarios for future trade agreements with the

EU. The core result is that losses could be large, up to 6% of GDP in the long term. Kierzenkowski et al. (2016) also consider different post-Brexit trade arrangements with the EU and diverse channels that may hit the British economy at different horizons. In their central scenarios, long-term losses accumulate to a 5% fall in GDP, while the short-term effects are in the vicinity of a 3% drop of GDP. Finally, PricewaterhouseCoopers (2016), commissioned by the Central Bureau of Investigation (CBI), employs a computable general equilibrium (CGE) model and forecast drops in output of around 3% both in the long and short term.

IMF (2016) assess the long- and short-term economic impact of Brexit on the basis of three scenarios of trading with the EU: bilateral agreement, EEA membership, and WTO rules. The paper also studies the effects of uncertainty and risk aversion generated by the withdrawal from the EU. The authors use a VAR analysis to construct an economic uncertainty index, an episode analysis of the recent financial crisis and of the 1992 devaluation, and a macroeconomic model. They consider a limited uncertainty scenario, that delivers output losses of 1.5% by 2019 for the UK, and an adverse scenario, generating a GDP drop of 5.6%. The effects for the EU are much less severe, with Ireland being the most affected country.

OxfordEconomics (2016) combine scenarios for trading arrangements and future policies. In the best case scenario, they calculate a decrease in GDP of 0.1%. In the worst case scenario, the UK suffers an output decline of 3.9% and a fall in income per head of 1000 pounds by 2030.

Booth et al. (2015) work with a dynamic multi-sector and multi-region CGE model. They also generate different scenarios by combining several potential future trade arrangements with economic deregulations that might be taken by the UK government. In the pessimistic scenario where the UK operates under the WTO rules and there is no deregulation, they forecast a GDP fall of 2.23% by 2030. In a positive scenario with a favorable trade agreement and under an ambitious deregulation program, they predict that output could actually grow by 1.55% in the long run. This meshes with a report by the “Economists for Free Trade” who optimistically claim that Brexit could boost UK

GDP. Specifically, Minford (2016) estimates a welfare gain of 4% of GDP if agricultural and manufacturing prices fall sharply as a consequence of lower tariffs and trade barriers than under current EU rules.

The focus of Ellen et al. (2016) is a scenario where the UK is hit by four shocks: increase in tariffs, reduction in FDI, reduction of exports to EU members and loss of net contributions to the EU budget. They find that exports are the main channel by which the UK economy is hurt. They estimate output costs between 2% and 3% in the long run. Similarly, Ebell and Warren (2016) consider the same channels and use as counterfactual three trading arrangements, namely the current deals of Norway and Switzerland, plus WTO rules. They find that the long-term deterioration of the economy and a shift towards savings generates a decline in real wages and in consumption substantially higher than for GDP, ranging from 2.2% to 6.3% for the former and from 2.4% to 5.4% for the latter. Under the extra assumption that Brexit has a direct effect on productivity the economic costs increase and are close to HM Treasury (2016)'s estimates. Bruno et al. (2016), in a technical appendix, directly assess the impact of the withdrawal from the EU on FDI inflows in the UK with a structural gravity approach, predicting a fall of 22% in FDI inflows.

Drawing on CGE trade models, Mansfield (2013) approximates the costs of Brexit. The long-term effects of Brexit on UK GDP of the UK are estimated to be between -2.6% and 1.1%. In the most probable scenario the impact on GDP is 0.1%. Using a static general equilibrium model, Aichele and Felbermayr (2015) estimate the effects of Brexit on trade, sectoral net value added, and real income for different scenarios. Depending on the post-Brexit trade arrangement, costs range from 0.6% to 3% fall of GDP per capita. Real income of EU members drops by 0.1% to 0.4% on average. Additionally, Aichele and Felbermayr (2015) infer dynamic effects of Brexit on per-capita income from empirical ad-hoc models. Taking dynamic effects to illustrate the impact of economic integration on investment and innovation behavior into account, costs of Brexit increase to 2% to 14% of GDP per capita.

Extending a gravity model of trade to include sector-level input-output linkages in

production, Vandenbussche et al. (2017) simulate different scenarios of Brexit (tariff/non-tariff, hard/soft) and measure the impact on employment and valued-added production. They find that the withdrawal from the EU hurts the UK economy much more than it hurts the EU. In value-added terms, losses range from 1% in the most favorable scenario to 5% in a worst-case scenario. In their central forecasts, EU output drops by 0.3% and 1.5% only. Focusing on welfare effects, Dhingra et al. (2017) use a multi-country quantitative general equilibrium model of trade that includes several sectors with intermediate trade. They simulate a hard and soft post-Brexit trade arrangement scenario and find that higher trade barriers lead to large welfare losses for households in both cases, even taking into account fiscal savings. The losses amount to 1.3% in the optimistic scenario and 2.7% in the pessimistic scenario. Combining gravity estimates of trade with income per capita elasticities to trade, they obtain losses in average income per capita that range from 6.3% to 9.4%. Similarly, Forte and Portes (2017) measure the effect of lower immigration from the EU, concluding that it could reduce GDP per capita by between 0.4% and 3.9% in the long run.

Gudgin et al. (2016) develop a new simulation model for the UK economy that tracks the long-term trends to quantify the consequences of Brexit. They construct different scenarios and use the assumptions from the gravity model of the Treasury. They argue that the output losses could be somewhat lower, reaching from 1% in the milder scenario to 4% of GDP in the worst scenario. To measure the impact of the withdrawal of the UK from the EU on FDI, McGrattan and Waddle (2017) use a multi-country neoclassical growth model with multinational investment firms. By considering different restrictions on FDI, either from the EU or the UK or both, they analyze negative output effects and subsequent changes in employment and welfare.

As pointed out in Sampson (2017), these models do not consider the agglomeration effects of the Brexit on the finance industry as a key sector in the UK economy. Djankov (2017) finds substantial negative effects on the City of London if the UK trades under the WTO rules with Europe, with finance revenues dropping by up to 18% and employment losses that range between 7% and 8%.

Ramiah et al. (2016) use stock market movements to quantify the impact of the Brexit on different sectors. They calculate abnormal and cumulative abnormal returns (CARs) for different sectors after the referendum. They associate positive CARs with expected favorable effects for that sector and negative CARs with expected negative effects of the Brexit on the sector. They find mainly negative abnormal returns. In other words, financial markets are predicting negative effects of the Brexit, especially in the banking sector.

A different approach – and the one most closely related to ours in this study – is followed by Campos et al. (2014). They also use the synthetic control method to quantify the economic benefits from EU membership and find large gains. Ironically, in their analysis, carried out long before Brexit, the gains from membership are particularly large for the United Kingdom.

2 Methods and Data

The comparison unit that serves as counterfactual or control group is of crucial importance to determine the effects of a policy intervention or event. Ideally, the control group has identical characteristics to the unit affected by the intervention so that the only difference is that one group received treatment, the other did not. Put differently, both units are comparable along all dimensions except for the treatment. In practice, this ideal comparison unit is rarely available in observed data and identification of causal effects is extremely challenging when the treated unit is a country.

However, most policy interventions take place at the aggregate level. One option is to pursue comparative case studies. In such case studies, the researcher compares the path of the aggregate outcome variable for the unit affected by the intervention with the evolution of the same outcome variable for the control group. The problem here is that aggregate units such as countries differ widely in their characteristics, making the selection of the control group highly problematic. Also the absence of a systematic method to select suitable comparison units can lead to biased results.

2.1 Synthetic control method

In order to address these methodological challenges, Abadie and Gardeazabal (2003) have proposed a novel data-driven method, formalized in Abadie et al. (2010), called the synthetic control method. The basic idea of this approach is that the best possible control is a weighted combination of all available comparison units. This method provides a transparent, data-driven, systematic procedure to construct comparison units that overcome the main difficulties of comparative case studies.

Following Abadie et al. (2010) suppose that we observe $J + 1$ countries over $T > 1$ periods, where only the first country has been affected by an intervention at a period $T_0 < T$. The remaining J countries, potential comparison units, have not been affected at all by the treatment and compose the “donor pool”. The choice of such a donor pool is not innocuous. Potential comparison entities should be carefully selected, by choosing those countries that best approximate the characteristics and outcome variable of the treated country, in order to avoid interpolation bias.

Let Y_{jt}^N denote the value of the variable of interest that we would observe if country j is not affected by the intervention at period t , and Y_{jt}^A if it is affected. Assume that there are no anticipation effects such that $Y_{jt}^N = Y_{jt}^A$ for all $j = 1, \dots, J + 1$ and all $t < T_0$. Hence, the causal effect of the intervention at period $t = T_0, \dots, T$ is given by $\alpha_t = Y_{1t}^A - Y_{1t}^N = Y_{1t} - Y_{1t}^N$. Thus, the causal effect of the policy intervention or event on the outcome variable of interest could be identified if we observed the outcome variable in absence of treatment Y_{1t}^N . In consequence, all that is missing is a counterfactual unit that accurately approximates Y_{1t}^N . This is achieved by the construction of a proper synthetic control.

Let X_1 denote a $(k \times 1)$ vector of pre-treatment values of the outcome variable and possibly also predictors of this outcome variable in the affected country. Let X_0 denote a $(k \times J)$ vector of the same variables for the different J countries in the donor pool. The aim is to weigh the elements of X_0 such that the resulting values closely resemble X_1 . Let W denote a $(J \times 1)$ vector of weights w_j , $j = 2, \dots, J + 1$. Each possible realization of W will lead to a different synthetic control. The weights are restricted to be nonnegative and

add up to one, forcing the synthetic control group to lie in the convex hull of the donor pool and hence avoiding extrapolation without data support.

The more alike the treated country is to the donor pool, the better the match of its characteristics with the synthetic control group will be. The selection of appropriate potential control units is highly relevant. The optimal weights W^* are chosen such that they minimize a weighted mean square error $(X_1 - X_0W)'V(X_1 - X_0W)$, subject to $w_j \geq 0$ for $j = 2, \dots, J + 1$ and $\sum_{j=2}^{J+1} w_j = 1$, where V is a $(k \times k)$ symmetric and positive semidefinite matrix. The choice of V is not trivial since it affects the weighted mean square error of the estimator and represents the different relevance assigned to the characteristics in X_1 and X_0 . Abadie and Gardeazabal (2003) choose V to be a nonnegative diagonal matrix with higher weights allocated to units with large predictive power on the outcome variable of interest. We follow Abadie et al. (2010) and choose the elements of V using a data-driven cross-validation approach.

Once the weights W^* have been optimally chosen to minimize the distance between the preintervention characteristics of the affected unit and the donor pool, the synthetic control is given by $Y_{1t}^* = \sum w_j Y_{jt}$. The causal effect can then be estimated by $\hat{\alpha}_t = Y_{1t} - Y_{1t}^*$ for $t = T_0, \dots, T$.

Several features of the method have been introduced in the description of the procedure that are important to emphasize. First, explicitly computing the weights assigned to each potential comparison unit makes the method transparent since it shows the individual contribution of each unit of the donor sample and allows to measure how close the treated and the control group are. Second, restricting the weights to be nonnegative and sum to one prevents the synthetic control from lying outside the support of the data. Third, even though extrapolation is avoided, interpolation bias might arise if the potential control units have not been selected appropriately and present characteristics that are far from the treated unit.

Additionally, one should be aware of the explicit assumptions made above. First, we assume that only one country is affected by the treatment and there are no spillover effects on the donor sample. Furthermore, since weights are constructed from pre-intervention

characteristics, the assumption is that there are no differentiated shocks in the post treatment period (Cavallo et al. 2013). Finally, the intervention is assumed to affect the treated unit from the moment of the treatment. If there is reason to expect anticipation effects, one would have to redefine the date of intervention to earlier periods. As the Brexit vote was as a major surprise and not expected, a plausible assumption is that in our case the treatment really begins with the outcome of the referendum on June 23rd 2016.

2.2 Inference

Traditional statistical inference in comparative case studies is difficult (e.g. due to small samples and the absence of randomization). Abadie et al. (2015) propose to overcome this limitation by considering a range of falsification exercises, so called placebo studies.

The basic idea of placebo studies is very intuitive. We can be confident that the synthetic control estimator captures the causal effect of an intervention as long as similar magnitudes are not estimated in cases where the intervention did not take place. Given that we are investigating the causal effect of an intervention at a particular point in time and in a particular country, there are two sets of placebo studies that naturally present themselves.

First, the treatment date can be artificially assigned to a different point in time $t < T_0$ (so called time placebo studies). Second, we can compute the causal effect of the treatment for untreated countries, taken from the donor pool (so called country placebo studies). Both types of exercises are conducted in Section 3.

2.3 Data

The group of candidate countries for the synthetic control group contains all OECD countries for which we were able to obtain contiguous real GDP data starting in 1995Q1 (see Table 1 for a list). For the pre-Brexit-vote period, we use real GDP from the OECD Economic Outlook database, both for the UK and for the doppelganger. For the doppelganger, we also use this dataset for the post-Brexit-vote period, where data

from 2017Q2 onwards are forecasts. For the UK from 2016Q2 to 2017Q3, we splice the OECD data in 2016Q1 with realized growth rates from the Office of National Statistics (ONS). From 2017Q4 till 2018Q4, we use real GDP growth rate forecasts from the Bank of England. The data for the decomposition exercise is build similarly. Consumption and investment for the control group have been obtained from the OECD Quarterly National Accounts and from the Office of National Statistics (ONS) for the UK. Real private consumption is the sum of real final consumption expenditure of both households and non-profit institutions serving households, real investment is total gross fixed capital formation, and net exports is the external balance of goods and services. The inflation series, computed as the change in the Consumer Price Index (CPI), including all items, with respect to the previous quarter, are obtained from OECD Economic Outlook, both for the donor country group and for the UK. The quarterly long-term and short-term nominal interest rates also come from the OECD Finance database for the control group and the UK, and are calculated as quarterly averages of monthly values. Finally, the Bank of International Settlements (BIS) provides the data series for the nominal exchange rates; namely effective exchange rates constructed by the BIS by weighting a broad basket of currencies.

For the uncertainty analysis, we use the Baker et al. (2016a) Economic Policy Uncertainty index available at www.policyuncertainty.com. The index is based on a count of newspaper articles containing the terms uncertain or uncertainty, economic or economy, and one or more policy-relevant terms. We will be working with monthly observations form January 1998 to September 2017.

3 Results

In this section we present the core results of the analysis. First, we construct the doppelganger based on data for the pre-Brexit vote period. This doppelganger serves as the counterfactual UK economy that has not received the “treatment” of the Brexit vote. Contrasting the output growth path of the UK and of the counterfactual, we derive

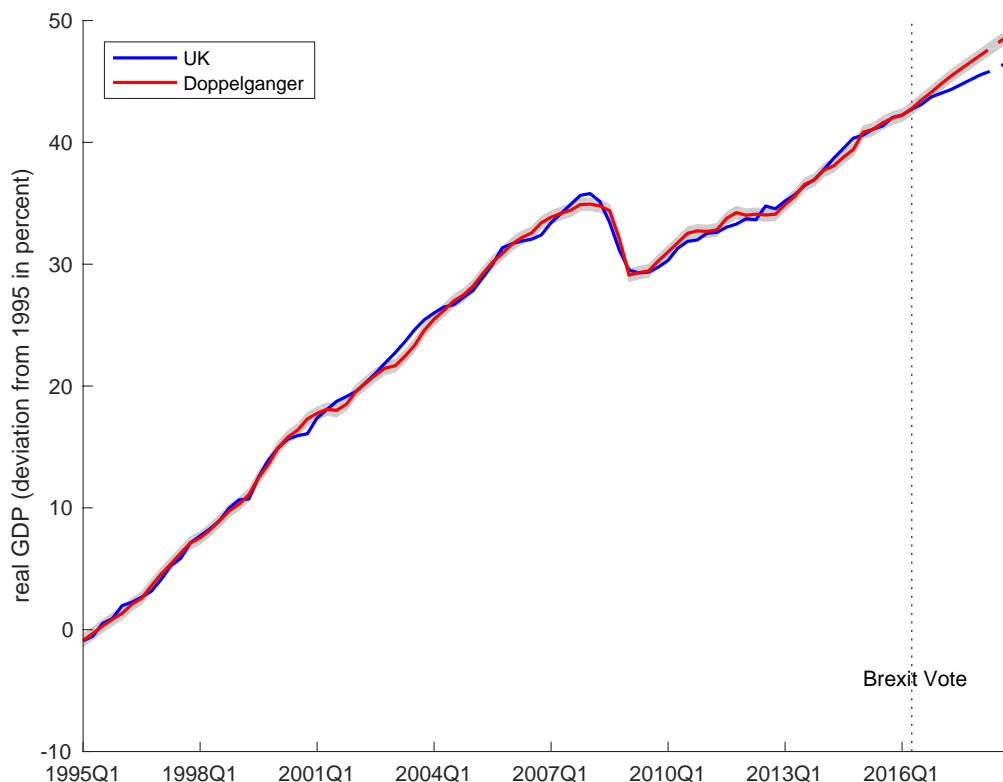


Figure 1: Real GDP of UK (blue line) and doppelganger (red line). *Note:* Shaded area corresponds to one standard deviation of difference between UK and Doppelganger prior to Brexit vote. Dashed lines are forecasts. Data sources for UK before 2016Q1 from OECD Economic Outlook; 2016Q1 – 2017Q3 from ONS 2017Q4–2018Q4 based on forecasts by BoE. Data for doppelganger from OECD Economic Outlook.

the output costs of Brexit. Third, we run a number of placebo test which show that the effects captured in our baseline specification are indeed attributable to the Brexit vote. Lastly, we describe how the Brexit vote transmitted through the economy.

3.1 Introducing the doppelganger

The doppelganger that serves as the counterfactual is a synthetic economy: a weighted average of 30 OECD economies. The weights are determined by a matching algorithm. We match the evolution of real GDP of the UK and the doppelganger prior to the Brexit vote as accurately as possible. For this purpose, we normalize the index of real GDP to unity in 1995 in each country and then obtain the combination of countries that best matches the evolution of UK quarterly GDP from 1995 until the second quarter of 2016.

Figure 1 displays the time series for real GDP in the UK (blue lines) and in the doppelganger economy (red line). The dashed lines indicates periods for which only

Table 1: Composition of synthetic control: country weights

Australia	<0.01	Austria	<0.01	Belgium	<0.01	Canada	0.15
Chile	<0.01	Czech Republic	<0.01	Estonia	<0.01	Finland	<0.01
France	<0.01	Germany	<0.01	Greece	<0.01	Hungary	0.24
Iceland	<0.01	Ireland	0.04	Israel	<0.01	Italy	0.03
Japan	0.25	Korea	<0.01	Luxembourg	0.04	Mexico	<0.01
Netherlands	<0.01	New Zealand	0.04	Norway	0.03	Portugal	<0.01
Slovak Republic	<0.01	Slovenia	<0.01	Spain	<0.01	Sweden	<0.01
Switzerland	<0.01	United States	0.19				

forecasts are available. The shaded area represents one standard deviation of the pre-treatment difference between the UK and its doppelganger. Note that the match is imperfect as our procedure determines 30 free parameters (country weights) in order to match more than 80 observations.

This being said, prior to the Brexit vote both series display a very high degree of co-movement—both at low and high frequencies. Not only do both economies experience smaller recessions almost identically, the path during the Great Recession is also very similar. We are thus confident that the doppelganger provides a meaningful counterfactual which allows us to quantify the effect of the Brexit vote on economic activity in the UK.

Table 1 displays the country weights (rounded to the second digit) which define the doppelganger economy. The United States and Canada, but also Japan and Hungary are assigned the largest weights. Together they account for more than 80 percent of the doppelganger dynamics. This is plausible, given the position of the UK in the world economy and the fact that it operates within the EU, but outside the Euro area (like Hungary). There are also smaller contributions from Ireland, Italy, and Luxembourg.

3.2 The output effect of the Brexit vote

We are now in a position to quantify the effect of the June 2016 vote on real GDP in the UK. In order to do this we contrast the output development of the UK and that of its doppelganger from Q3 2016 onwards. For this purpose Figure 2 reproduces Figure 1, but zooms in on the post-Brexit-vote period. As before, the shaded area corresponds to one standard deviation of the pre-treatment difference between UK and doppelganger and the

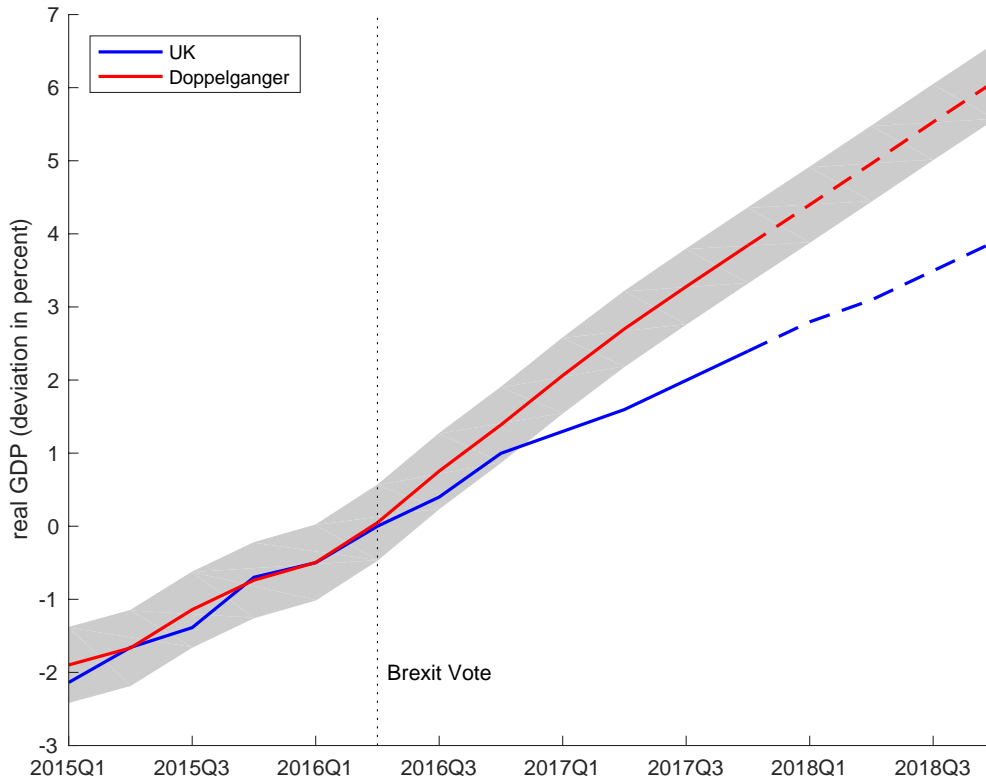


Figure 2: Real GDP of UK (blue line) and doppelgänger (red line). *Note:* Shaded area corresponds to one standard deviation of difference between UK and doppelgänger prior to Brexit vote. Dashed lines are forecasts. Data sources for UK before 2016Q1 from OECD Economic Outlook; 2016Q1 – 2017Q3 from ONS 2017Q4–2018Q4 based on forecasts by BoE. Data for doppelgänger from OECD Economic Outlook.

dashed lines refer to periods for which only forecasts are available.

A number of observations stand out. Throughout most of 2016 there is hardly any effect of the output vote on UK’s output. Yet starting in 2017, the effects begin to materialize as the UK embarks on an different growth trajectory. The effect is also statistically significant as it leaves the statistical boundaries as what can be accounted for as a normal, given the pre-treatment variation in output paths between the UK and its doppelgänger. Under current forecasts, the trend is persisting until the end of 2018 and the output gap between the doppelgänger and the UK that we causally attribute to the Brexit vote will increase.

We provide specific numbers in Table 2. The middle column reports the output loss in percentage points of real GDP. In the second quarter of 2016, there is virtually no output gap between the UK and the doppelgänger. The gap emerges slowly and gradually, reaching only 40 basis points at the end of 2016. However, by the end of the third quarter

Period	GDP loss (in p.p.)	Cum. GDP loss (in bn. pounds)
2016Q2	0.05	0.24
2016Q3	0.35	1.97
2016Q4	0.39	3.87
2017Q1	0.77	7.61
2017Q2	1.10	12.99
2017Q3	1.28	19.26
2017Q4	1.45	26.32
2018Q1	1.60	34.14
2018Q2	1.87	43.25
2018Q3	2.04	53.18
2018Q4	2.19	63.90

Table 2: Brexit costs. *Note:* second column reports percentage point loss in real GDP computed as the difference in post-referendum paths in Figure 2; third column: cumulated losses in billion of pounds computed as column 2 multiplied with non-annualized nominal GDP in 2016Q2 and cumulated. UK before 2016Q1 based on OECD EO data, 2016Q1–2017Q3 based on ONS realizations, 2017Q4–2018Q4 based on BoE forecasts. Data for doppelganger from OECD Economic Outlook (forecasts for 2017Q2–2018Q4).

of 2017, the last quarter for which data are available, the output loss due to the Brexit vote has reached roughly 1.3 percentage points. On current forecasts it will exceed 2 percentage points by mid-2018. The right column of Table 2 reports the cumulative output loss in terms of billions of pounds (in prices of Q2 2016). By now, that is, after the third quarter of 2017, the output loss due to the Brexit votes amounts to approximately 20 billion.

3.3 Placebo experiments

Are these effects causal in the sense that we can attribute them to the Brexit vote? We run two types of experiments to gauge whether our benchmark results are indeed picking up the causal effect of the Brexit vote on UK GDP (see also Section 2). First, we run twelve “time-placebo tests” for which we shift the treatment date artificially backward in time. In other words, we assume treatment dates prior to the 2016Q2, and allow for such placebo treatments in all quarters from 2013Q2 up until 2016Q1. We then re-estimate our synthetic control for UK GDP for each of these placebo treatment dates using exactly the same methodology as in the benchmark specification. If our baseline estimate is truly

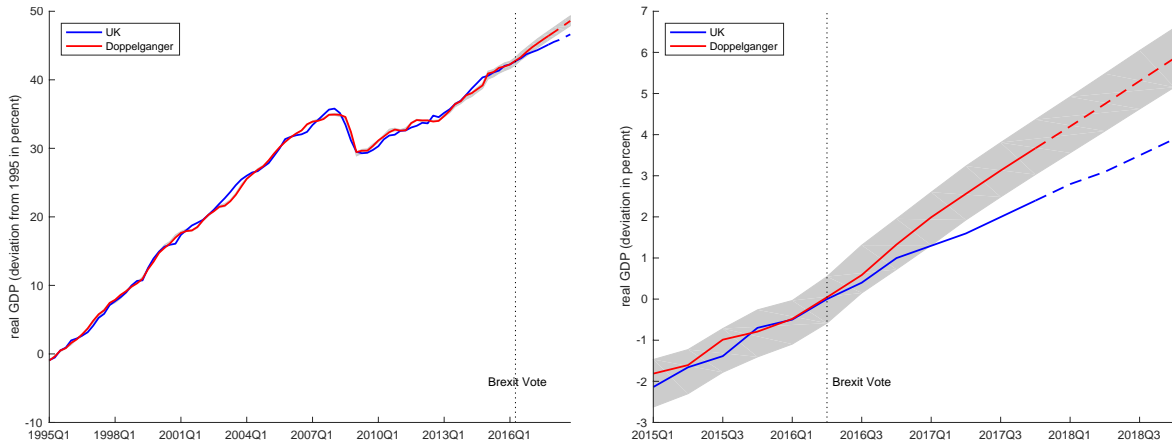


Figure 3: Real GDP of UK (blue line) and doppelganger (red line): alternative treatment dates. *Note:* left panel shows full sample, right panel zooms in on Brexit episode and recenters y-axis. Red line represents result of baseline specification, blue line actual data for UK; dashed lines indicate forecasts; shaded area represents range of maximum and minimum value of the synthetic controls generated by placebo studies with treatment date ranging from 2013Q2 to 2016Q1.

picking up a causal effect of the intervention, then the synthetic controls estimated in each of the time placebo studies should track the baseline estimate and diverge from the UK GDP data only after the actual Brexit vote in 2016Q2.¹

Figure 3 shows the results together with the series for actual GDP (blue line) and our benchmark doppelganger (red line). The shaded areas represent point-wise the range between the maximum and minimum value of the synthetic controls across the twelve time-placebo experiments. Reassuringly, the band is rather narrow and tracks the evolution of the doppelganger established earlier closely. Importantly, despite that the time-placebo studies work with earlier “fictitious” Brexit-vote dates, the resulting synthetic controls diverge from the UK data *only after the actual Brexit vote* in 2016Q2.

Next, we estimate synthetic controls for each of the countries in the donor pool while exposing them to a treatment in 2016Q2. Once again, if our benchmark estimate is picking up the causal effect of the intervention, then the divergence of country-specific synthetic controls from the respective GDP data following the treatment date should be considerably smaller than in case of the UK.

Figure 4 shows the results of the country-placebo experiments. It quantifies how

¹Note that the placebo study estimates will not be identical to the benchmark since they are based on a shorter pre-treatment sample due to the earlier treatment dates.

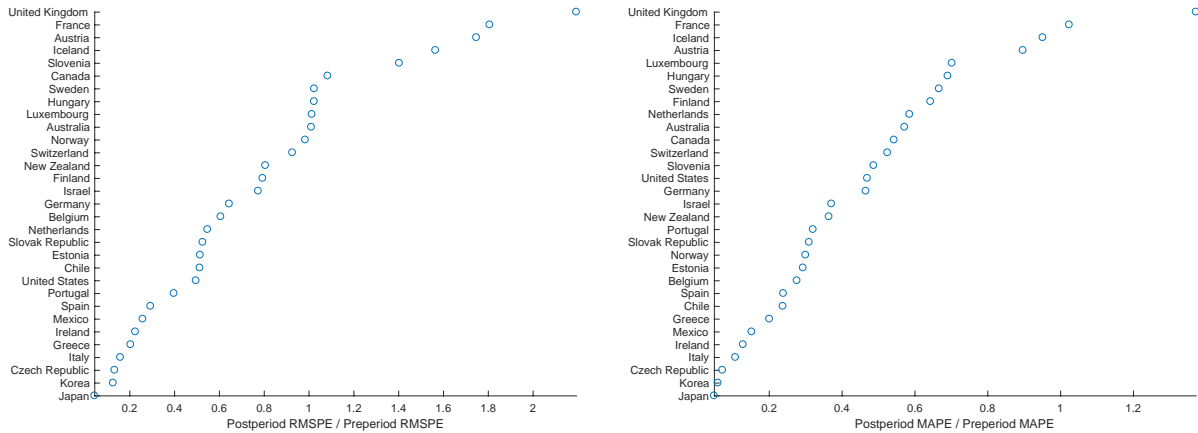


Figure 4: Result of country-placebo experiments. *Note:* ratio of post-to-pre treatment fit; left: mean squared prediction error (RMSPE), right: maximum absolute prediction error (MAPE). Each country of the donor pool is exposed to Brexit-vote treatment in 2016Q2.

closely the country-specific synthetic controls follow the data post-treatment relative to the pre-treatment fit. The left panel reports the post-and-pre-treatment ratio of the root mean squared prediction error (RMSPE). The right panel reports the ratio based on the maximum absolute prediction error (MAPE). We provide more details in the appendix. Using such relative measures controls for the fact that the estimated country-specific synthetic controls are characterized by different degrees of accuracy across countries. Intuitively, the larger the value of these relative measures, the stronger is the deviation of the synthetic control from the data after the intervention (compared to its average pre-intervention fit).

As is apparent from Figure 4, the UK stands out from the donor pool for both measures, RMSPE and MAPE. Still, the figure shows that several other countries are also characterized by post-treatment deviations which are larger than the average pre-treatment fit (that is, relative measures greater than 1).² This could be indicating certain spill-over effects of the Brexit vote onto these countries. Such spill-over effects would violate the assumption that the donor pool countries are unaffected by the treatment. We therefore consider restricting the donor pool of countries as a robustness check in the appendix, but the results are very similar to those which we obtain for our baseline specification.

²Note that while the method is fitting pre-treatment data and therefore the post-treatment fit is likely to be worse, the post-treatment period is relatively short (10 quarters). Therefore, it is not a priori clear whether the two measures of relative fit, RMSPE and MAPE, will indeed be larger than one since chance may have it that the post-treatment doppelganger remains to fit the data well.

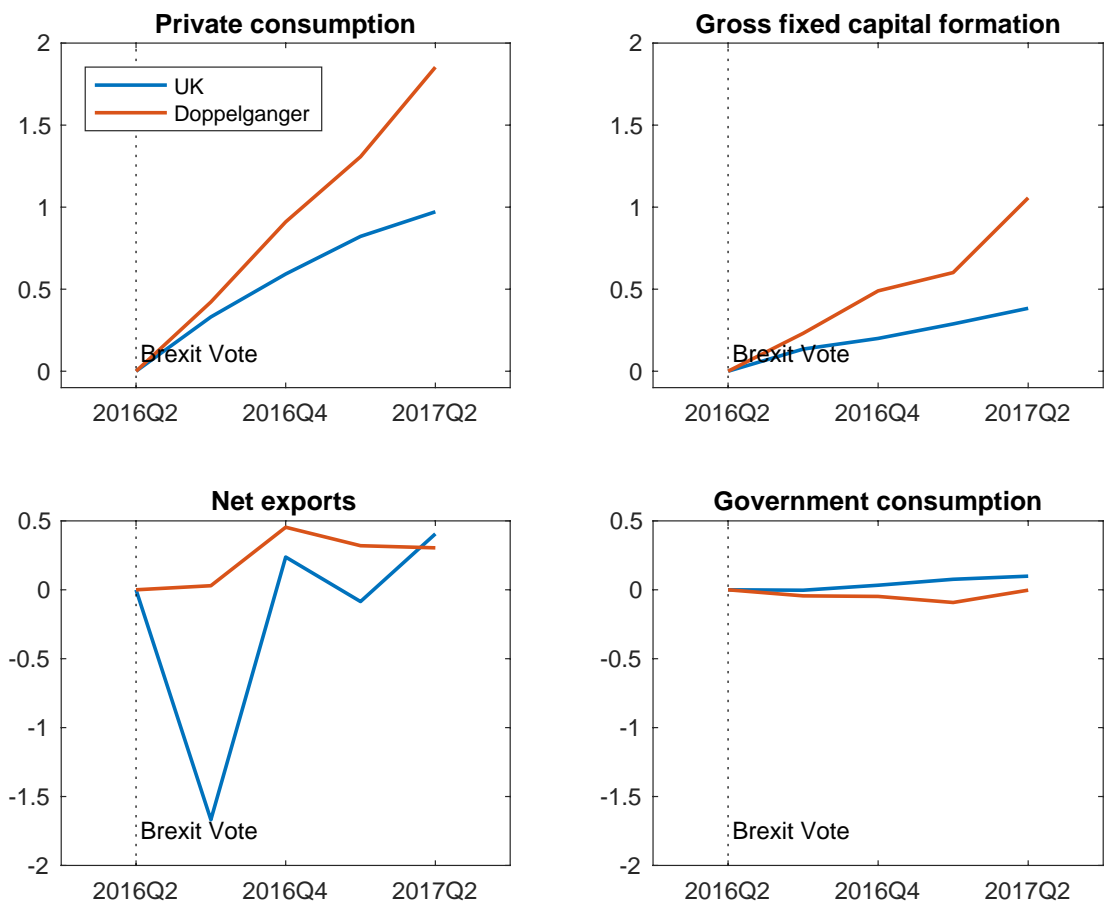


Figure 5: Evolution of macroeconomic aggregates in UK (blue) and doppelganger (red) economy: post referendum. *Note:* doppelganger as in Figure 1; vertical axis measures deviations from 2016Q2 in percent of GDP (i.e., percent deviations of the macroeconomic aggregates are scaled by their share of GDP in 2016Q2 in the UK).

3.4 Transmission mechanism

We have shown that the Brexit decision has already had substantial output costs that are expected to grow to more than 60 billion pounds before the UK even leaves the EU. In this section, we shed light on how the effects of Brexit vote were transmitted to the UK economy. We first look into the reaction of several macroeconomic variables – consumption, investment, government spending, net exports – and compare their post-referendum path to the doppelganger. In a second step, we look deeper into potential economic explanations for the output loss after the Brexit vote, and pay particular attention to heightened policy uncertainty as a key suspect.

3.4.1 Decomposing the output loss

Figure 5 shows the evolution of macroeconomic aggregates after the Brexit vote for the UK and for the doppelganger economy. Here and in what follows, the results for the doppelganger are computed using the weights which we obtained by matching the series for real GDP prior to 2016Q2, as detailed in Section 3.1 above. In each instance, because of limited data availability, we only consider data up to the second quarter of 2017, but we will update the charts as we track the performance of the UK economy over time.

At this point the gap between consumption in the doppelganger economy and in the economy is equivalent to 0.9 percentage point of GDP (upper-left panel). The gap for investment (gross fixed capital formation) is somewhat smaller, but of a similar order of magnitude (upper-right panel). As investment accounts for a considerably smaller fraction of GDP, the percentage decline of investment (relative to the doppelganger) is therefore much more pronounced. We can thus confirm that tepid investment spending is a key reason for the weak performance of the UK economy after the Brexit vote.

We do not find substantial deviations for either government spending or net exports. Government consumption (lower-right panel) is fairly flat, both in the UK and in the doppelganger economy. Perhaps more surprising is that net exports have not made a larger positive contribution to the performance of the UK economy after the substantial devaluation of the pound. Yet except for a large, but temporary drop in the third quarter of 2016 the gap between the doppelganger and the UK is rather small (lower-left panel).

The evolution of the UK exchange rate is shown together with that of the doppelganger in the upper-left panel of Figure 6. While one might suspect that valuation effects are key for the drop of net exports, data on trade volumes suggest that net exports declined because the volume of imports rose sharply in 2016Q3 and to a lesser extent because export volumes contracted (Office for National Statistics 2016).

On balance, net exports did not make a distinctly positive contribution to output growth although a full year has passed since the nominal and the real depreciation of the pound.³

³The decline in net export is matched by a strong increase of inventories (not shown). Hence, even

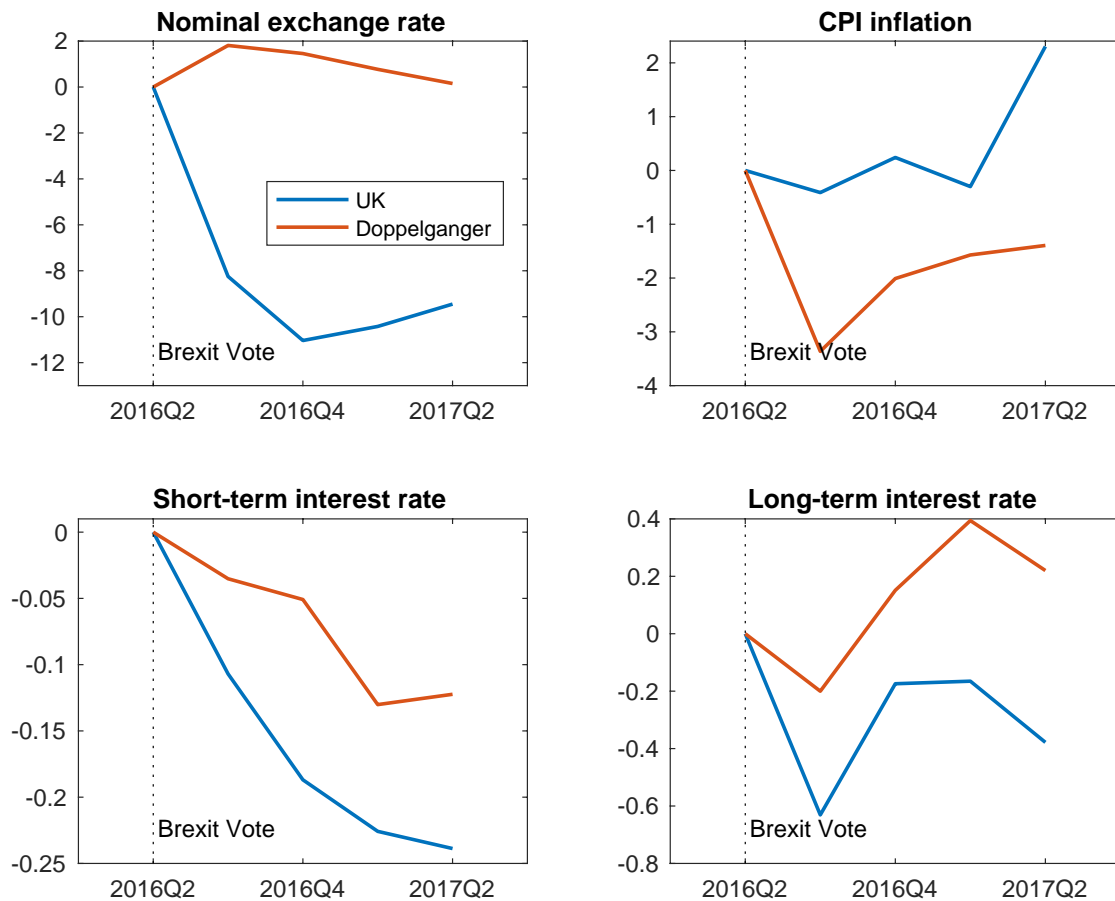


Figure 6: Evolution of macroeconomic indicators in UK (blue) and doppelganger (red) economy: post referendum. *Note:* doppelganger as in Figure 1; deviations from 2016Q2 in percentage points except for the exchange rate (percent).

Figure 6 shows furthermore that post-referendum the UK saw inflation rise and interest rates decline—notably in comparison to the doppelganger economy. The implied monetary stance was particularly loose and may have contributed to stabilize domestic absorption in the first year after the Brexit vote, even though the exchange-rate depreciation did little to boost net exports.

3.4.2 Economic policy uncertainty

A year after the Brexit vote the adverse effects on output have become more and more visible, driven by relative losses in investment and consumption. Yet through which channel did the referendum affect spending in the economy? Two factors could be responsible for the decline. On the one hand, economic activity may be contracting relative to though net exports drop strongly and the other expenditure components shown in Figure 5 are fairly stable, output is also fairly stable.

the doppelganger, because market participants are more pessimistic about the long-run growth prospects of the post-Brexit UK economy. We refer to this conjecture as the “bad news hypothesis”.

On the other hand, the negative effects could be due to heightened economic policy uncertainty. As the future relationship between the UK and Europe has become a subject of intense political debates, uncertainty about economic policies has increased. This, in turn, is likely to be detrimental for economic activity, even if *on average* the long-term growth outlook has not been downgraded (Bloom 2009; Born and Pfeifer 2014; Fernández-Villaverde et al. 2015). We refer to this conjecture as the “uncertainty hypothesis”.

In a first step, we try to quantify what role the increase in uncertainty has played for the output decline. We start by establishing the increase in economic policy uncertainty due to the Brexit vote. For this purpose we apply once more the synthetic control method, this time we match to the Economic Policy Uncertainty (EPU) index provided by Baker et al. (2016a). This index measures the volume of news articles discussing economic policy uncertainty (normalized to average 100).

Results are shown in Figure 7. The blue line represents the policy index for the UK, the red line shows the EPU in the doppelganger economy. As before, shaded area denotes one standard deviation of the pre-treatment difference between UK and doppelganger. Note that in this case the doppelganger economy is not identical to the output doppelganger discussed above because of data availability.

Figure 7 shows that the increase in uncertainty in the UK due to the Brexit vote has been truly remarkable. It dwarfs even the increase in policy uncertainty during the Great Recession. Still, as Baker et al. (2016b) point out, the increase in EPU has been concentrated in the UK, a fact which is also borne out by Figure 7. This is remarkable because global policy uncertainty has been rather high due to, among other things, the US presidential elections. Yet we find that the increase of EPU in the UK exceeds the increase in the EPU-doppelganger by about 250 points in the year after the Brexit vote.

As Baker et al. (2016b) argue, the uncertainty effect of the Brexit vote is concentrated

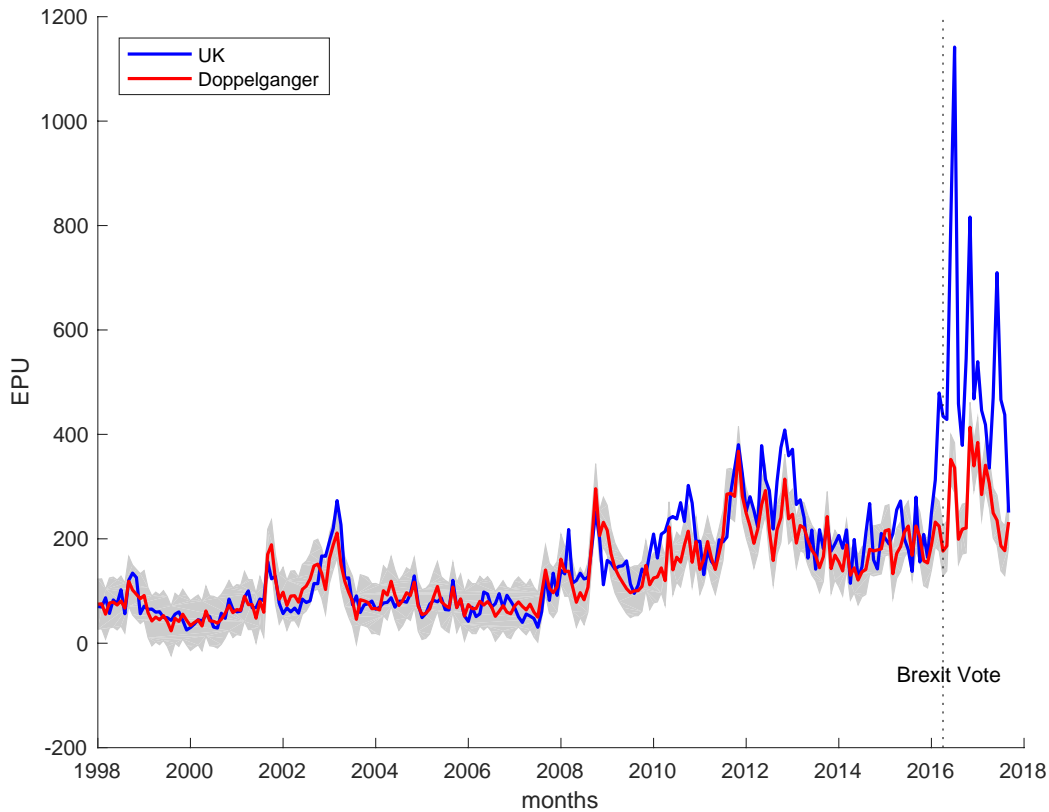


Figure 7: Economic policy uncertainty in the UK (blue line) and in a (new) doppelganger economy (red line). *Note:* economic policy uncertainty index based on Baker et al. (2016a). Shaded area denotes one standard deviation of the pre-treatment difference between UK and doppelganger. EPU: scaled and standardized measure of the number of news articles discussing economic policy uncertainty (normalized to average 100).

in the UK, but its effect may be comparable to the (smaller) increase of uncertainty during the Great Recession that translated into a decline of economic activity by about one percentage point. In any case, at this point we cannot reject the uncertainty hypothesis or, put differently, that the output loss which has materialized so far is due to increased policy uncertainty. Yet as current forecasts suggest that the output loss is going to increase further, the anticipation of the post-Brexit regime, i.e., the bad news channel, could come to play a more prominent role going forward.

4 Conclusion

The Brexit referendum of June 23, 2016 was a momentous political decision taken with very little knowledge of its economic implications. The binary choice question “Should the United Kingdom remain a member of the European Union or leave the European Union?” left important issues open. Did “leave” voters vote to leave the Single Market, adopt an EFTA, or a WTO framework? How many leave voters would have preferred to remain if the alternative is a bare-bones WTO trading arrangement? It is impossible to say how people would have voted had the concrete options been spelled out. Economists are keenly aware that establishing collective preferences is highly complex and can quickly lead to Arrow’s impossibility theorem.

It is little surprising then that until today the debate about the “type” of Brexit continues. This paper presents the first empirical assessment of the realized costs of the Brexit vote and brings potentially important guidance for policy-makers and the general public. While the details of the Brexit process are still unclear, we show that the costs are already being felt and are likely to grow (if current GDP forecasts are correct). Moreover, the effects are substantial in economic terms, accumulating to many years of the UK’s net contribution to the EU. By Q2, the output costs of the Brexit vote are equivalent to about 300 million pounds in lost output per week – a prominent measure in the campaign.

In the 1920s, Keynes critically commented on the plan to bring Britain back to the gold standard by saying that “He who wills the end, wills the means.” On the one hand, Keynes implied that if there is political determination to achieve a goal, the ways to make it happen will be found even it is the wrong choice to begin with. Yet on the other hand, Keynes dictum also alerts us to the fact that political resolve can trump but not substitute economic logic. The means will be found, but the economic costs cannot be avoided.

5 Appendix

5.1 Further details on country placebo studies

This subsection provides further details on the country placebo studies discussed in the main text. Let us first explicitly describe the calculations involved in the results. The main statistics of interest are the relative measures of fit post- and pre-treatment in the donor countries (and the UK). The main text considers two such statistics, the relative root mean squared prediction error (RMSPE) and the maximum absolute prediction error (MAPE). These relative measures are defined as $\rho_1 = RMSPE_{post}/RMSPE_{pre}$ and $\rho_2 = MAPE_{post}/MAPE_{pre}$. The pre-intervention fit is given by

$$RMSPE_{pre} = \sqrt{\frac{1}{T_0 - 1} \sum_{t=1}^{T_0-1} (Y_t^* - Y_t)^2} \quad (5.1)$$

$$MAPE_{pre} = \max |Y_t^* - Y_t|, \quad t \in [1, T_0 - 1] \quad (5.2)$$

The post-treatment measures of fit are defined similarly with the treatment date prediction error normalized to zero

$$RMSPE_{post} = \sqrt{\frac{1}{T - T_0 - 1} \sum_{t=T_0}^T (Y_t^* - Y_t - Y_{T_0}^* + Y_{T_0})^2} \quad (5.3)$$

$$MAPE_{post} = \max |Y_t^* - Y_t - Y_{T_0}^* + Y_{T_0}|, \quad t \in [T_0, T] \quad (5.4)$$

There are two points to note in the above definitions. First, the reason for considering relative measures of fit is that different countries are characterized by different degrees of accuracy with which the synthetic control tracks the data. In our sample, this heterogeneity in the degree of accuracy is enormous. While the root mean squared prediction error between 1995 and 2016 is 0.005 in the UK, it is e.g. 0.13 in Greece or 0.08 in Ireland. The average pre-treatment RMSPE for the donor countries is almost five times as large as that for the UK. Therefore, when comparing the post-treatment deviations across countries, one must take into account much poorer fit of the synthetic controls in the donor pool countries. Second, the reason for normalizing the post-treatment prediction error to zero at the treatment date accounts for the fact that the post-treatment time-path

of the prediction error may be a continuation of previous trends rather than the result of the treatment. Examples of this are given in Figure 8 which plots the log-difference between the synthetic control and the data for the UK and three other countries which exhibit large post-treatment deviations. However, as is apparent from the Figure, these post-treatment deviations are the result of a poor prior fit, rather than of the Brexit vote. Therefore, normalizing the treatment prediction error to zero accounts for the fact that certain countries “inherit” a large deviation around 2016 simply due to the poor fit of the synthetic control.

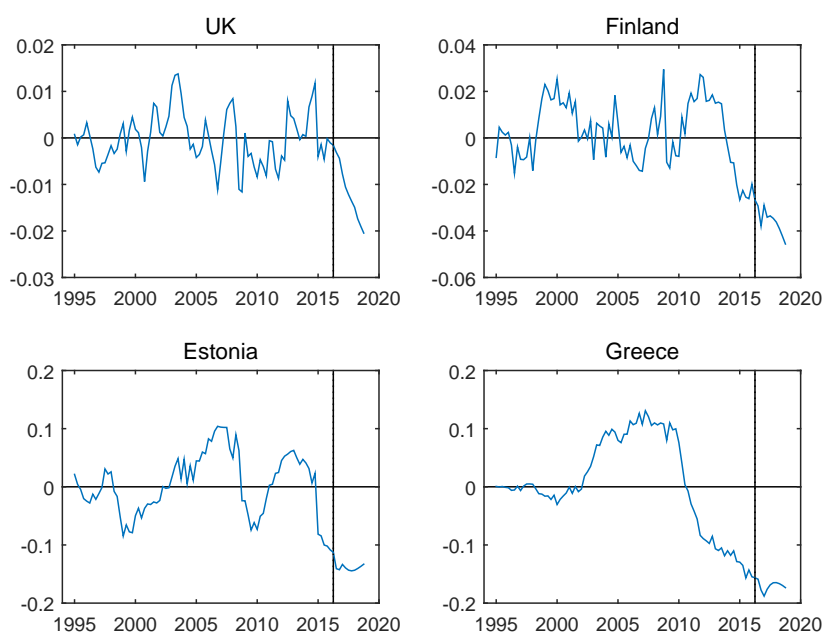


Figure 8: Deviations of synthetic controls from data (in log points)

5.2 Robustness regarding donor pool

The country place studies in the main text reveal that the UK stands out in terms of its post-treatment deviation, relative to the average pre-treatment fit. This suggests that indeed our baseline results are picking up a causal effect of the Brexit vote on UK GDP, since other countries do not display large deviations following their own (fictitious) Brexit referendum. Nevertheless, several countries (Austria, France, Iceland and Slovenia) do display relative post/pre-treatment deviations larger than 1, suggesting that perhaps they were subject to spillover effects from the UK. Such spillover effects, however, would violate

the assumption of no treatment in the donor pool countries.

In this subsection, we investigate whether our benchmark results are robust to the exclusion of the above countries. Specifically, we re-estimate our baseline model, but exclude Austria, France, Iceland and Slovenia from the donor pool of countries. Table 3 displays the country weights in the baseline results and those obtained when using the restricted donor pool. Figure 9 then shows the evolution of UK GDP, the baseline synthetic control and that estimated using the restricted donor pool. As can be seen, the estimated weights using the restricted sample are very similar to those in the baseline estimation. Similarly, the resulting synthetic controls is almost indistinguishable from its baseline counterpart.

Table 3: Composition of synthetic control group: country weights

<i>baseline</i>					
Australia	0.00	Austria	0.00	Belgium	0.00
Canada	0.15	Chile	0.00	Czech Republic	0.00
Estonia	0.00	Finland	0.00	France	0.00
Germany	0.00	Greece	0.00	Hungary	0.24
Iceland	0.00	Ireland	0.04	Israel	0.00
Italy	0.03	Japan	0.25	Korea	0.00
Luxembourg	0.04	Mexico	0.00	Netherlands	0.00
New Zealand	0.04	Norway	0.03	Portugal	0.00
Slovak Republic	0.00	Slovenia	0.00	Spain	0.00
Sweden	0.00	Switzerland	0.00	United States	0.19
<i>restricted donor pool</i>					
Australia	0.00	Austria	NA	Belgium	0.00
Canada	0.15	Chile	0.00	Czech Republic	0.00
Estonia	0.00	Finland	0.00	France	NA
Germany	0.00	Greece	0.00	Hungary	0.23
Iceland	NA	Ireland	0.04	Israel	0.00
Italy	0.04	Japan	0.24	Korea	0.00
Luxembourg	0.04	Mexico	0.00	Netherlands	0.00
New Zealand	0.05	Norway	0.00	Portugal	0.00
Slovak Republic	0.00	Slovenia	NA	Spain	0.00
Sweden	0.00	Switzerland	0.00	United States	0.21

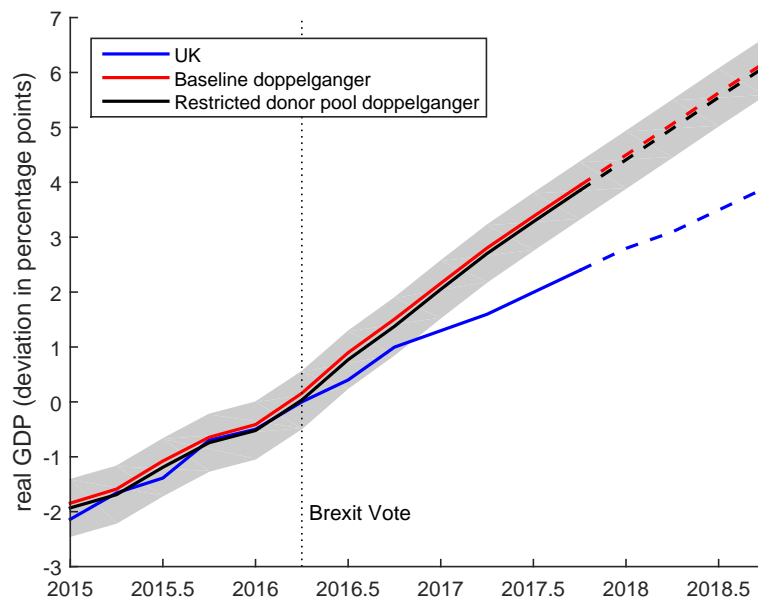


Figure 9: UK (blue line) vs. Baseline doppelganger (red line) vs. Restricted donor pool doppelganger (black line). *Note:* Dashed lines are forecasts. Shaded area denotes one standard deviation of the pre-treatment difference between UK and Baseline doppelganger. UK before 2016Q1 based on OECD EO data, 2016Q1 – 2017Q3 based on ONS realizations, 2017Q4 – 2018Q4 based on BoE forecasts. Synthetic country based on OECD EO data (forecasts for 2017Q2 – 2018Q4).

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