The Costs of Economic Nationalism: Evidence from the Brexit Experiment*

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Abstract

Economic nationalism is on the rise. What are the costs of cutting back international economic integration and rising policy uncertainty? We use the unexpected outcome of the Brexit vote in June 2016 as a natural macroeconomic experiment to study the costs of economic disintegration and their causes. As a methodological innovation, we propose a novel combination of synthetic control methods to identify the output loss caused by the Brexit vote, conjoined with an expectations-augmented vector autoregression to understand its drivers. Using the synthetic control, we first show that forward looking households and businesses have lowered spending in response to the Brexit vote, causing an output loss of close to 2 percent. Decomposition of the VAR estimates shows that shocks to economic policy uncertainty and growth expectations in the quarter following the Brexit vote explain almost the entire output loss. While higher uncertainty accounts for much of the initial output drop, the economic costs increase over time because of a downward revision of output growth expectations. Overall, both uncertainty and growth expectations account for about one half of the total economic costs of the Brexit vote. Linking quasi-experimental identification to structural time series variance decomposition, our study exposes not only the aggregate costs of the UK's expected economic disintegration from Europe but also specifies the channels through which the Brexit vote affected the macroeconomy.

Keywords: Economic nationalism, Brexit, natural experiment, Synthetic control method, Anticipation effects, Economic policy uncertainty, Expectations-augmented vector autoregression

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> "It is the maxim of every prudent master of a family, never to make at home what will cost him more to make then to buy (...) What is prudence in the conduct of every private family, can scarce be folly in that of a great kingdom." (Adam Smith, 1776)

1 Introduction

The specter of economic nationalism is haunting the global economy. Supporters of the rule-bound liberal world economic order that was constructed after World War II are on the defensive. For economists, the recent rise of protectionism represents a particular challenge. From its beginnings, the benefits of an international division of labor have been a central tenet of the discipline. Foreshadowing a large literature, Adam Smith diagnosed, in disarmingly simple words, that foregoing the gains from trade would harm the wealth of nations.

It seems therefore all but possible that the recent rise of economic nationalism could take a toll on future economic prosperity. And to the extent that market participants act in a forward-looking manner, expectations of economic disintegration and de-globalization could already affect investment and consumption today. In addition, as trade agreements are torn apart, old alliances nullified, and protectionist measures contemplated, policy uncertainty has increased substantially. Increased uncertainty, too, could negatively impact the global economy.

Can we measure its economic costs? In this paper we make an attempt to do so as we exploit a unique natural experiment: the decision of the UK to leave the European Union. Two aspects are key for interpreting the vote for Brexit as a natural experiment. First, the outcome of the referendum on June 23, 2016 came as a major surprise. Both voter polls and betting markets indicated a "Remain" victory by a considerable margin. Second, the voting behavior was largely unrelated to UK's recent macroeconomic performance. Rather, according to many observers, the case for Brexit was predominantly based on the political imperative to "take back control."

The Brexit experiment allows us to measure the costs of economic nationalism because the UK's departure from the Single European Market entails significant economic disintegration. The disintegration shock will extend beyond trade in goods and services. The British labor market will become less open to foreign workers, and capital markets will be affected through disintegration from the common European market for financial services. However, while the direction of the change is clear, the exact extent of disintegration remains uncertain, not least because the details of Brexit are still negotiated. Hence, the Brexit experiment nests both a disintegration shock and a policy uncertainty shock: it is a showcase of economic nationalism.

Methodologically, our paper breaks new ground by combining two different approaches in empirical macroeconomics. Crucially, this combination allows us to both identify the overall costs of the Brexit vote to the UK's macroeconomy, and also to understand the channels driving these causal effects. First, we use the synthetic control method that was recently added to the toolbox of empirical macroeconomics by Abadie and Gardeazabal (2003) and Abadie et al. (2010, 2015). Under fairly mild assumptions we are able to identify the causal effect of the Brexit vote on UK's macroeconomic performance since the referendum. But while the synthetic control approach exposes causal effects at the aggregate level, the underlying channels remain in the dark. In a second step, we therefore map the results of the synthetic control method into a structural time-series framework. Using an expectations-augmented vector autoregression, similar to e.g. Perotti (2014), allows us to quantify the contribution of different channels to the aggregate causal impact of the Brexit vote estimated by the synthetic control method.

Specifically, the synthetic control method makes it possible to measure the causal impact of the Brexit vote on the UK economy by estimating its synthetic "doppelganger". It does so by letting 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 and what weight they are assigned is entirely data-driven. The better the algorithm constructs a doppelganger for the UK economy as a weighted combination of other economies before the referendum, the more precise our results will be. We use the largest available country dataset to obtain the best match possible.

Comparing the evolution of this synthetic doppelganger to actual data for the UK economy directly quantifies the aggregate costs of the Brexit referendum. Identification hinges on the very notion that the Brexit vote is a natural experiment: because the vote was unanticipated and unrelated to macroeconomic performance, the doppelganger continues to evolve in the way the UK economy would have in absence of the referendum. The difference in output between the UK economy and its doppelganger after the referendum is the causal effect of the experiment. Importantly, our approach does not depend on having the right economic model for the British, the European, or the global economy, nor do we need to assume a particular Brexit deal emerging from future negotiations.

We find that the economic costs of the Brexit vote are already visible and quite large: there is a sizable output gap between the doppelganger and actual output in the UK. By year-end 2017, the "doppelganger gap" amounts to approximately 1.8 percent, and the cumulative loss of GDP is close to 25 billion pounds. Following Abadie et al. (2015), we also conduct a number of time- and country-placebo tests, reassuring us of the causal effect of the Brexit vote.

However, while the synthetic control method points to large causal effects of the Brexit vote on the UK economy, the underlying channels remain a black box. In order to open this black box we turn to a structural time-series framework. The starting point is the fact that the estimated aggregate costs have materialized before Brexit itself has actually taken place. Therefore, the impact of the Brexit referendum on UK's macroeconomy must necessarily be caused by changes of expectations in response to the Brexit vote.

Yet, expectations may have changed in two distinct ways. On the one hand, households and firms may have revised downwards their expectations of future prosperity, because they expect economic disintegration to take its toll on "the wealth of the nation". Such a downward revision induces an immediate reduction of consumption and investment spending (e.g., Blanchard et al. 2013). On the other hand, market participants may also have become more uncertain about future income, not least because the details of Brexit are still unclear. Such uncertainty effects are also detrimental to economic activity (Baker et al. 2016; Bloom 2009; Born and Pfeifer 2014; Fernández-Villaverde et al. 2015).

To dissect the doppelganger gap and unscramble anticipation and uncertainty effects we estimate a structural expectations-augmented vector autoregression (EVAR), similar to e.g. Perotti (2014). The EVAR features quarterly data on output and interest rates, but also a measure of economic policy uncertainty, and importantly, forecast revisions ("news") regarding future output growth for various forecasting horizons. Specifically, we use a unique data set which comprises output growth forecasts for the UK up until the year 2050. These forecasts have been substantially downgraded in response to the Brexit vote. In addition, we use the Economic Policy Uncertainty (EPU) index compiled by Baker et al. (2016). And again, this index reached an all-time high in the aftermath of the referendum.

This expectations augmented VAR model is able to directly capture the effect of news on macroeconomic performance which a conventional VAR is ill-equipped to recover because of its backward-looking structure. Moreover, the EVAR allows us to purge the growth news of potential uncertainty effects: under our baseline identification scheme we permit uncertainty shock to impact growth news contemporaneously, but not vice versa, because forecasters are likely to downgrade their outlook if uncertainty is high and likely to hurt growth.

Which factors, and to what extent, are behind the costs of the Brexit vote estimated in the first part of this paper? To answer this question, we first identify uncertainty and growth-news shocks *caused* by the Brexit vote. Second, we then use the estimated EVAR to quantify the impact of these Brexit-related shocks on the time-path of real GDP. Specifically, we continue to rely on the Brexit vote being a natural experiment, which singles out structural shocks occurring in 2016Q3, the period right after the Brexit vote, as those caused by the referendum. Next, we use the estimated EVAR model to construct a counterfactual time-path for real GDP by "switching off" these Brexit-related uncertainty and growth-news shocks.

It turns out that this EVAR-based counterfactual tracks the output path of the doppelganger very closely. Because it is based on an altogether different approach and data set, the VAR analysis provides a valuable cross-check of the results obtained under the synthetic control technique. More importantly still, it allows us to separate anticipation and uncertainty effects. Overall, we find that heightened uncertainty and downgrades of future output growth expectations both account for about half of the total estimated costs of the Brexit vote. While the increase of uncertainty triggered by the Brexit vote accounts for the majority of the economic costs of the Brexit vote in the immediate aftermath of the referendum, its relative impact fades quickly. Yet the estimated costs of the Brexit vote continue to rise over time. This is increasingly driven by anticipation effects reflecting downward revisions of output growth expectations.

Our paper relates to work on the impact of (trade policy) uncertainty on international trade (see e.g. Handley and Limão 2015, 2017; Limão and Maggi 2015; Novy and Taylor 2014). We also share a focus of analysis with studies of macroeconomic experiments at the aggregate level (Alesina and Fuchs-Schündeln 2007; Fuchs-Schündeln and Hassan 2016). Billmeier and Nannicini (2013), in particular, also use the synthetic control approach to study the impact of economic liberalizations. Finally, our paper complements a number of influential studies on the instantaneous macroeconomic impact of anticipated future (policy) changes or, more generally, "news" (see e.g. Barsky and Sims 2011, 2012; Beaudry and Portier 2006; Schmitt-Grohé and Uribe 2012).

In regards to our application, only very few studies have investigated the immediate implications of the Brexit vote.[1] An exception is Ramiah et al. (2016) who show that the response of cumulative abnormal returns in different sectors after the referendum is mostly negative. Breinlich et al. (2017) argue that the inflation increase following the post-referendum pound depreciation amounts to about a 400 pound consumption loss for the average British household. Finally, Berg et al. (2017) use a matching strategy to show that bank lending dropped by 20 percent in the syndicated loan market after the Brexit vote.

The remainder of this paper is organized as follows. In the following section, we provide more details to support the argument that the Brexit vote can be understood as a natural experiment. Section 3 then describes how we apply the synthetic control method to measure the output effect of the Brexit vote. Section 4 zooms in on the transmission mechanism and quantifies the roles of economic uncertainty and shifts in expectations. A final section concludes.

[1] Instead, a number of authors have investigated actual Brexit scenarios on the basis of model simulations, see, for instance, Dhingra et al. (2017) and the studies surveyed by Sampson (2017).

2 The Brexit vote as a natural experiment

The Brexit vote offers a rare opportunity to measure the costs of economic nationalism. As argued above, economic nationalism reduces international economic integration and raises policy uncertainty. In general—because of confounding factors—it is challenging to quantify the impact of these developments on economic activity. One strategy is to employ fully structural equilibrium models. For instance, following the seminal contributions of Eaton and Kortum (2002) and Melitz (2003), studies have attempted to measure how impediments to trade impact aggregate income. Similarly, Fernández-Villaverde et al. (2015) and Born and Pfeifer (2014) employ dynamic general equilibrium models in order to determine the extent to which policy uncertainty causes economic contractions. Overall, these studies have delivered valuable insights, but the results depend on restrictive assumptions and hence remain controversial.

A second strategy is to pursue a more data-driven approach. As far as economic integration is concerned, a long-standing literature has investigated the correlation between trade openness and growth. Here, the evidence often points towards a positive correlation between openness and growth, but while informative, identifying a causal effect remains a major challenge because trade policies are generally not determined randomly (Goldberg and Pavcnik 2016).[2] Similarly, there is evidence that economic policy uncertainty causes output to contract in the short run, but identification assumptions remain challenging (Baker et al. 2016).

Natural experiments, in contrast, "are situations in which we can argue that the change in policy is large relative to potential confounding factors that cannot be controlled for" (Nakamura and Steinsson 2018). This holds true for the Brexit vote. However, also in this case the underlying identification assumptions have to be made explicit. Fuchs-Schündeln and Hassan (2016, p. 925) define "natural experiments as historical episodes that provide observable, quasi-random variation in treatment subject to a plausible identifying assumption."[3]

That the UK has been subjected to the Brexit vote is indeed random as far as the macroeconomy is concerned, because macroeconomic developments were largely irrelevant for a) the decision to hold a referendum and b) its outcome. According to most observers political factors were the key in both instances. Then Prime minister David Cameron promised in 2013 to hold a referendum as a concession to the euro-sceptic wing of his party. This sceptism—

[2] The historical record is mixed too as some of the greatest success stories in economic history, the rise of the US and German economies in the 19th, and Japan in the 20th century, partly occurred behind high tariff walls.

[3] "The "natural" in natural experiments indicates a researcher did not consciously design the episode to be analyzed, but can nevertheless use it to learn about causal relationships" (Fuchs-Schündeln and Hassan 2016). In this regard natural experiments differ from controlled experiments, "the holy grail of empirical science" (Nakamura and Steinsson 2018).

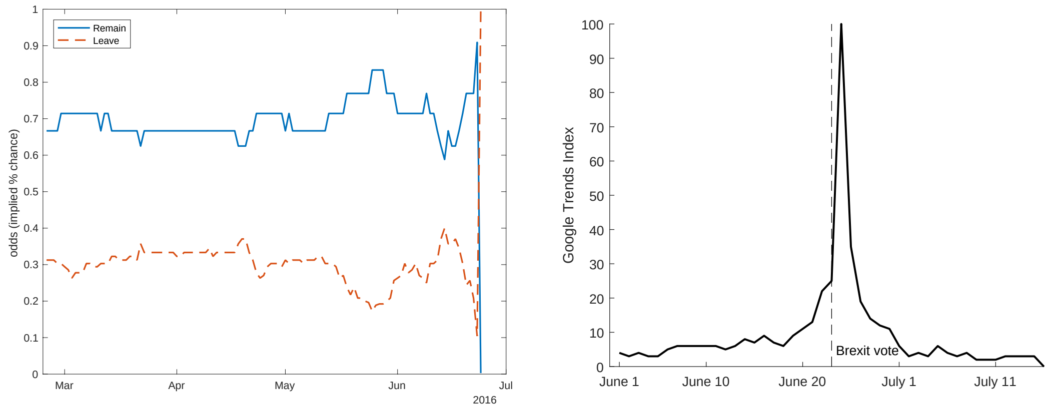


Figure 1: Left: odds for referendum outcome implied by online bets placed on Betfair exchange (source: BETdata). Right: Google search for "Brexit Leave" (source: Google trends).

which eventually prevailed in the referendum—is largely fueled by philosophical considerations, rather than by concerns about economic growth or the business cycle. A key imperative is to "take back control", in turn due to concerns about Britain's sovereignty, notably with regards to immigration and the rulings of the European court of justice (Sampson 2017).[4]

Moreover, we are able to date the "treatment" precisely, because the outcome of the referendum was largely unexpected. This is illustrated by Figure 1. The left panel shows the odds for the referendum outcome implied by bets offered on the Betfair exchange. Throughout our sample period odds were clearly stacked against "Leave". Similarly, for the longest time prior to the referendum most polls suggested a victory for "Remain".[5] The right panel of Figure 1 shows the frequency of Google search incidents for "Brexit Leave". Clearly, interest in the issue arose only after the referendum suggesting once more that the outcome of the Brexit vote took most people by surprise.

Finally, we note that the Brexit vote is a *unique* natural experiment because it involves changes at the *aggregate* level. Other experiments that are studied in macroeconomics do not directly allow to measure the macro impact of policies because treatment takes place at the household or individual level. For instance, an influential study of the US economic stimulus payments in 2008 by Parker et al. (2013), exploits the randomized timing of disbursements of payments to households. As a result it is possible to measure the effect of transfers

[4]Several studies have documented that voting behavior in the referendum varied systematically across regions in terms of educational attainment, demography and industry structure (e.g., Becker et al. 2017). Hence, generally speaking, one may not rule out that economic factors also played a role for the outcome of the referendum. It is unlikely, however, that these economic factors impact economic performance systematically at the *macroeconomic* level.

[5]An exception was a brief period in early June when "Leave" was ahead in the poll of polls, see `https://whatukthinks.org/eu/opinion-polls/poll-of-polls/`.

on household consumption. This effect, however, is not directly informative about the macroeconomic effects of variations in aggregate transfers. Instead, an additional, model-based analysis is required (Fuchs-Schündeln and Hassan 2016).[6] The Brexit experiment, on the other hand, exposes an entire country to a "treatment" such that we are able to measure its macroeconomic effect directly.

3 The output effect of the Brexit vote

In order to evaluate the causal impact of the Brexit vote on the UK macroeconomy we need to define an appropriate comparison economy, a counterfactual benchmark. Since our focus is on the dynamic effects of the Brexit vote on UK output, we require the comparison economy to track the actual UK economy as closely as possible prior to the referendum. At the same time, it must be left unaffected by the Brexit vote.

We follow Abadie and Gardeazabal (2003) and Abadie et al. (2010, 2015) and use synthetic control methods to construct precisely such a doppelganger to the UK economy. Our identifying assumption is that the UK economy would have developed as the doppelganger, had it not been for the Brexit vote. This assumption is plausible to the extent that, given economic fundamentals, the UK economy and its doppelganger were equally likely to obtain the "treatment" of the Brexit vote.

We can then directly quantify the costs of the Brexit vote as the "doppelganger gap": the difference between UK's actual output performance and that of the doppelganger economy. Lastly, we run a number of tests showing that our estimated effects indeed reflect a causal impact of the referendum shock.

3.1 Constructing the doppelganger

We construct the doppelganger as a synthetic control unit. For this purpose we consider a "donor pool" of 30 OECD countries and quarterly observations for real GDP during the period from 1995Q1–2016Q2.[7] Our procedure thus assumes that a possible treatment effect materializes after 2016Q2. Moreover, we assume that the countries in the donor pool are not affected by the treatment. We relax both assumptions in our analysis below.

The doppelganger is a weighted average of the countries in the donor pool. The weights are determined by minimizing the distance between GDP of the UK and of the doppelganger prior to the treatment. Formally, we let X_1 denote the (86×1) vector of observations for real

[6] See also the approach and the discussion in Nakamura and Steinsson (2014).

[7] Specifically, we normalize real GDP to unity in 1995 in each country. See Appendix A.1 for further details on the dataset.

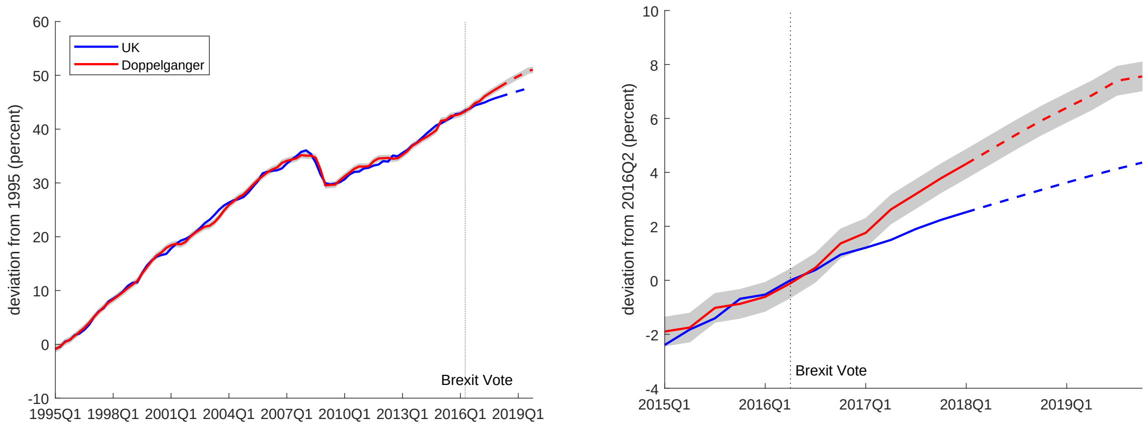


Figure 2: Real GDP of the UK. Actual data (blue line) vs doppelganger (red line). *Note:* shaded area is one standard deviation of difference prior to Brexit vote. Dashed lines are forecasts. Data sources for UK before 2016Q1: OECD Economic Outlook, 2016Q1 – 2017Q3: ONS, 2017Q4–2018Q4: forecasts by BoE, doppelganger: OECD Economic Outlook.

GDP in the UK and let X_0 denote a (86×30) matrix with observations for real GDP in the countries included in the donor pool. Finally, we let W denote a (30×1) vector of weights w_j, $j = 2, \ldots, 31$. Then, the doppelganger is defined by W^* which minimizes the following mean squared error:

$$(X_1 - X_0 W)' V (X_1 - X_0 W) \ , \tag{3.1}$$

subject to $w_j >= 0$ for $j = 2, \ldots, 31$ and $\sum_{j=2}^{31} w_j = 1$. In this expression, V is a (30×30) symmetric and positive semidefinite matrix.[8]

Turning to the results, the left panel of Figure 2 displays the time series for real GDP in the UK (blue line) and in the doppelganger economy (red line). The dashed lines indicate periods for which only 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 parameters (country weights) in order to match more than 80 observations. This being said, prior to the referendum both series display a very high degree of co-movement—both at low and high frequencies. We are thus confident that the doppelganger provides a meaningful counterfactual which allows us to quantify the effect of the referendum shock 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

[8]The choice of V is not trivial since it affects the weighted mean squared 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.

Table 1: Composition of the doppelganger: country weights

Australia	<0.01	Austria	<0.01	Belgium	<0.01	Canada	0.16
Chile	<0.01	Czech Republic	<0.01	Estonia	<0.01	Finland	<0.01
France	<0.01	Germany	<0.01	Greece	<0.01	Hungary	0.21
Iceland	<0.01	Ireland	0.05	Israel	<0.01	Italy	0.04
Japan	0.23	Korea	<0.01	Luxembourg	<0.01	Mexico	<0.01
Netherlands	<0.01	New Zealand	<0.01	Norway	0.07	Portugal	<0.01
Slovak Republic	<0.01	Slovenia	<0.01	Spain	<0.01	Sweden	<0.01
Switzerland	<0.01	United States	0.24				

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 Norway.

3.2 Measuring the immediate output effect of the Brexit vote

We are now in a position to quantify the output effect of the referendum shock. In order to do this we contrast the output performance in the UK and in the doppelganger economy in the quarters following the referendum shock. For this purpose the right panel of Figure 2 zooms in on the post-referendum period. As before, the shaded area corresponds to one standard deviation of the pre-treatment difference between output of the UK and the doppelganger. We loosely interpret a post-treatment path of GDP that leaves the shaded area as evidence of a significant output effect of the referendum shock and will conduct more sophisticated inference below. To facilitate the quantitative assessment we express output deviations vis-à-vis the UK level in 2016Q2.

A number of observations stand out. While throughout the second half of 2016 there is hardly any effect of the referendum shock, a significant effect begins to materialize since 2017Q1. In fact, the UK seems to embark on a different growth trajectory relative to the doppelganger. By the end of the fourth quarter of 2017, output in the UK falls short of the doppelganger level by about 1.8 percent of GDP. The cumulative loss in terms of 2016 GDP equals approximately 25 billion pounds. Under current forecasts, the trend is going to persist and by the end of 2019 the doppelganger gap will amount to some −3.2 percent.

3.3 Inference

The shaded areas in Figure 2 quantify the standard deviation of the doppelganger gap prior to the Brexit vote. In other words, they are a measure of fit prior to the Brexit vote. The right panel of Figure 2 then highlights that the doppelganger quickly deviates from the realized path of UK GDP that far exceeds these bounds, indicating that such a deviation is non-standard compared to the pre-Brexit vote period.

While such bounds are indicative of strong effects, they are not a formal test of significance. Recently, Hahn and Shi (2017) have suggested that the Andrews (2003) end-of-sample instability test may be used to conduct inference in the context of the synthetic control method. On an intuitive basis, the instability test quantifies whether the post-referendum doppelganger gap and all the pre-referendum doppelganger gaps of the same length can be considered to come from the same distribution.[9]

We follow Andrews (2003) and apply the end-of-sample instability test to our baseline estimation. The results show that the output effects of the Brexit vote are statistically significant at the 10 percent significance level (p-value of 0.096). Therefore, we conclude that despite the relatively short post-Brexit vote period, our estimated output effects of the Brexit vote are not only large, but also statistically significant.

3.4 Causality

Are these effects causal? To back the notion that the doppelganger gap is indeed caused by the referendum shock, this subsection provides a number of placebo experiments (Abadie et al. 2010, 2015). The basic idea of the placebos 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. In addition, we corroborate the results of the placebo tests with data on GDP forecasts just before the Brexit referendum. If indeed the Brexit vote caused the divergence of the doppelganger from the realized path of UK GDP, and if the referendum outcome was unexpected, then this should have not been forecasted prior to June 2016.

3.4.1 Placebo tests

First, we run twelve time-placebo tests for which we shift the treatment date artificially backward in time: we consider treatment dates in all quarters from 2013Q2 to 2016Q1. In each instance, we construct a new doppelganger using exactly the same approach as in the benchmark specification. These doppelgangers are bound to differ from the baseline doppelganger, because the pre-treatment sample is shorter. Yet if there is indeed a causal effect of the actual treatment, then the placebo doppelgangers should diverge from the actual developments in the UK no earlier than the actual treatment took place.

[9] More details on the test can be found in Appendix A.3.

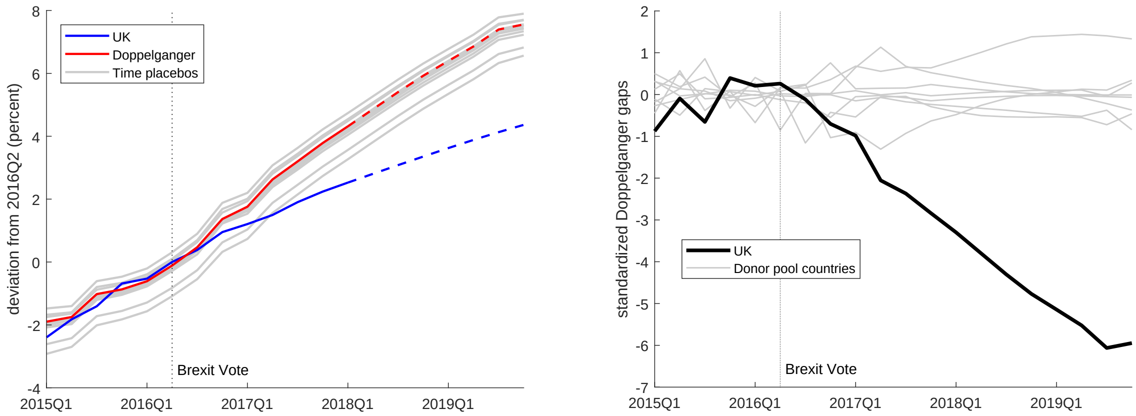


Figure 3: Placebo tests. *Note:* left panel shows real GDP of UK (blue line) and baseline doppelganger (red line), with gray lines representing time placebo doppelganger estimates with fictitious Brexit vote dates ranging from 2013Q2 to 2016Q1. Right panel shows the UK doppelganger *gap* (thick black line), with gray lines representing country placebo doppelganger gaps estimated by considering fictitious Brexit votes in donor pool economies. For comparability, all doppelganger gaps are normalized by their respective pre-Brexit standard deviations and centered around their 2015 means.

The left panel of Figure 3 shows the results together with the series for actual GDP (blue line) and our benchmark doppelganger (red line). Each grey line represents the path of a doppelganger obtained for one placebo treatment. Reassuringly, each time placebo estimate tracks the pattern of the baseline doppelganger 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 treatment at the end of 2016Q2.

In a second set of tests, we estimate synthetic controls for the donor pool countries, while exposing each of them to a placebo treatment at the end of 2016Q2. Once again, if our benchmark estimate for the UK is picking up the causal effect of the referendum shock, its effect should dominate any possible impact of the fictitious Brexit votes in the donor pool countries.

The right panel of Figure 3 shows the UK doppelganger gap together with the doppelganger gaps of the eight countries which account for essentially all the weights in our baseline synthetic control estimate.[10] For comparability, all doppelganger gaps are normalized by their respective pre-Brexit standard deviation and centered around their 2015 means. Relative to the country placebo estimates, the UK doppelganger gap stands out, both in terms of size and the systematic nature of the post-Brexit vote deviation.

An alternative way of quantifying the country placebo results is to compute statistics of rel-

[10]The Appendix shows similar placebo results for all countries in the donor pool.

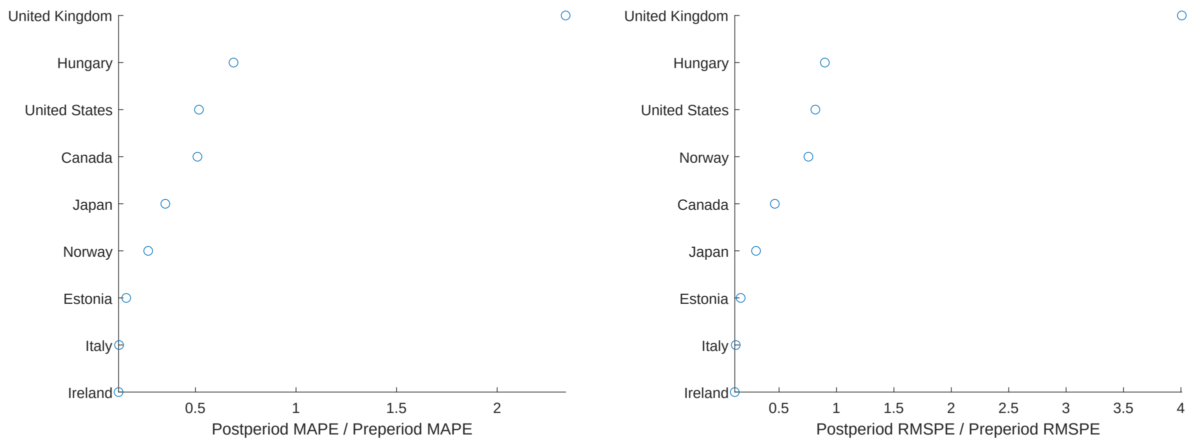


Figure 4: Relative measures of the pre- and post-treatment doppelganger gaps. *Note:* left panel shows the relative maximum absolute prediction error ρ_2, the right panel shows the relative root means squared prediction error ρ_1.

ative pre- and post-treatment fit in the UK and the donor countries.[11] Two such statistics are the relative root mean squared prediction error (RMSPE) and the maximum absolute prediction error (MAPE) defined as $\rho_1 = RMSPE_{post}/RMSPE_{pre}$ and $\rho_2 = MAPE_{post}/MAPE_{pre}$. Letting T denote the sample size and T_0 denote the period of treatment, i.e. the Brexit vote, the pre- and post-treatment measures of fit are defined as[12]

$$RMSPE_{pre} = \sqrt{\frac{1}{T_0 - 1}\sum_{t=1}^{T_0-1}\left(X_{1,t} - X_{0,t}W\right)^2}\ , \tag{3.2}$$

$$MAPE_{pre} = \max\left|X_{1,t} - X_{0,t}W\right|, \quad t \in [1, T_0 - 1], \tag{3.3}$$

$$RMSPE_{post} = \sqrt{\frac{1}{T - T_0 - 1}\sum_{t=T0}^{T}\left(X_{1,t} - X_{0,t}W - X_{1,T_0} + X_{0,T_0}W\right)^2}\ , \tag{3.4}$$

$$MAPE_{post} = \max\left|X_{1,t} - X_{0,t}W - X_{1,T_0} + X_{0,T_0}W\right|, \quad t \in [T_0, T]\ . \tag{3.5}$$

Figure 4 depicts these two relative measures showing that the UK stands out with a particularly large post-treatment doppelganger gap.

[11] Relative measures take into account heterogeneity in terms of pre-treatment fit of donor pool country synthetic controls.

[12] We normalize the post-treatment prediction error to zero at the treatment date to account for the possibility that the post-treatment time-path of the prediction error may be a continuation of previous trends rather than the result of the treatment.

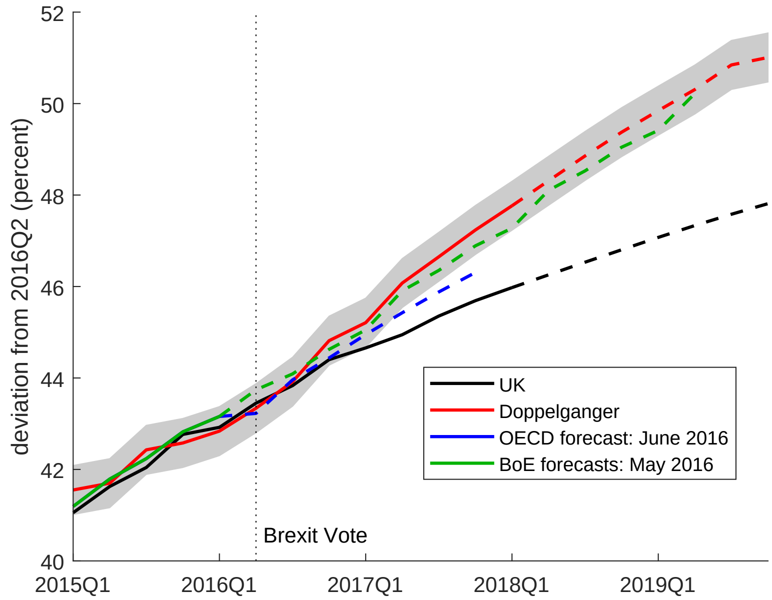


Figure 5: UK output: actual, doppelganger and two forecasts prior to the Brexit vote. *Note:* baseline doppleganger and actual real GDP together with real GDP predicted by the OECD (June 2016 Economic Outlook) and the Bank of England (May 2016 Inflation report). Both forecasts use the 2016 Economic Outlook data prior to 2016.

3.4.2 The doppelganger and GDP forecasts prior to the Brexit vote

To further corroborate the causal effect of the Brexit vote on the development of UK GDP, one can look at GDP forecasts just *before* the referendum. Given the unexpected nature of the Brexit vote outcome, and to the extent that this event had a causal effect on the subsequent evolution of GDP, one would expect that forecasts just prior to the referendum would not predict a slowdown in output growth but would rather be closer to our estimated doppelganger.

We verify this argument by using GDP forecasts from the June 2016 vintage of the OECD Economic Outlook and from the May 2016 Inflation Report of the Bank of England. Figure 5 then shows our baseline doppelganger, actual GDP and the GDP evolution based on the above two forecasts. Clearly, both forecasts are very close to our estimated doppelganger providing further support of the causal nature of the Brexit vote on the development of UK GDP.

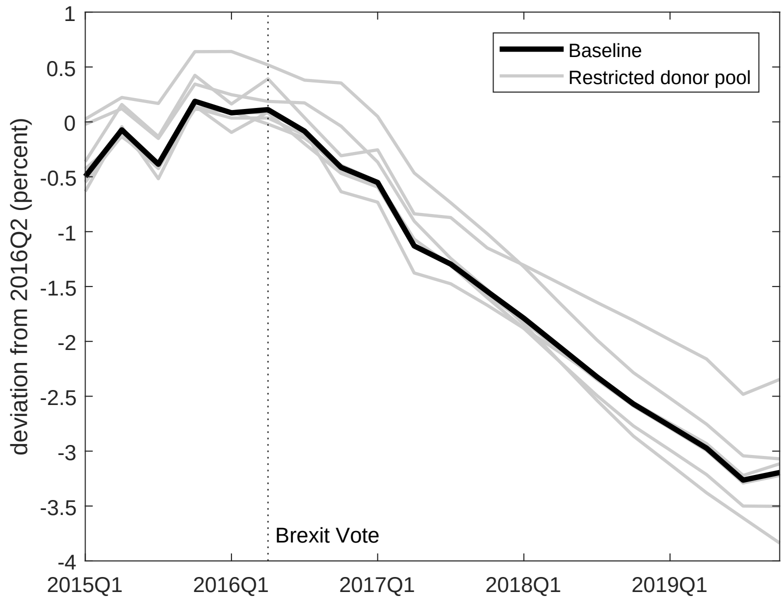


Figure 6: Baseline Doppelganger gap and restricted donor pool Doppelganger gaps. *Note:* baseline Doppelganger gap with alternatives estimated by sequentially dropping each donor pool country which received a positive weight in the baseline estimates.

3.5 Sensitivity

Before moving on to understanding what drives the doppelganger gap, we gauge the sensitivity of our results along two dimensions. First, we investigate whether our results are disproportionately driven by a single donor pool country. Second, we analyze the sensitivity of our results to data revisions.

3.5.1 Effect of individual countries in the donor pool

Let us now check to what extent each of the donor pool countries with non-zero weights in the baseline UK doppelganger contribute to its evolution. Towards this end, we iteratively re-estimate our baseline model while omitting in each iteration one of the countries which received a positive weight in the baseline estimation. This robustness check investigates whether one particular donor pool country is the main driver of our results.

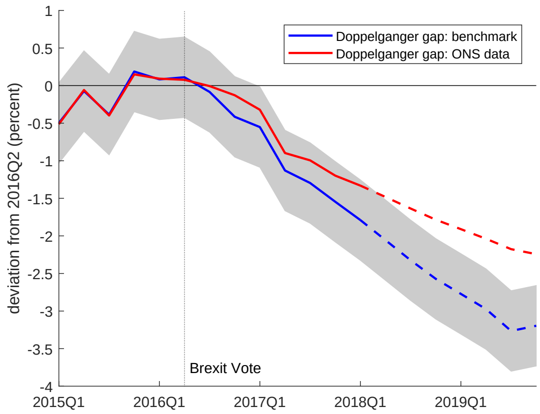
Figure 6 shows the baseline doppelganger gap together with that estimated with the restricted pool of countries, each omitting one of the countries which received a positive weight in our baseline specification. While there is some variation in the estimates, the overall conclusion remains unchanged indicating that the Brexit vote resulted in substantial output losses.

The lowest estimated effect obtains in the case when Hungary is excluded from the donor pool. Even then, however, the output loss amounts to almost 2 percent of GDP at the end of 2018. Moreover, by excluding countries from the donor pool, we sacrifice goodness of fit. In case Hungary is excluded, the mean squared prediction error worsens by 25 percent. Still, the one-standard-deviation bands around the doppelganger gap in the baseline and the case when Hungary is excluded overlap. This suggests that one cannot easily distinguish the two estimates quantitatively. Finally, Table 2 shows the estimated weights in the baseline and in the restricted donor pool cases.

Table 2: Doppelganger weights: baseline and restricted donor pools

	baseline	I	II	III	IV	V	VI	VII
Australia	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Austria	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Belgium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Canada	0.16	NA	0.24	< 0.01	0.10	< 0.01	0.16	0.28
Chile	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Czech Rep.	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Estonia	< 0.01	0.01	0.04	< 0.01	0.01	< 0.01	0.01	0.01
Finland	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
France	< 0.01	0.06	< 0.01	< 0.01	0.08	< 0.01	< 0.01	< 0.01
Germany	< 0.01	0.05	< 0.01	< 0.01	< 0.01	0.17	< 0.01	< 0.01
Greece	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Hungary	0.21	0.23	NA	0.24	0.21	0.26	0.19	0.20
Iceland	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ireland	0.05	0.04	0.07	NA	0.06	0.02	0.06	0.07
Israel	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Italy	0.04	0.04	0.20	0.01	NA	0.05	0.04	< 0.01
Japan	0.23	0.18	0.18	0.18	0.24	NA	0.25	0.28
Korea	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Luxembourg	< 0.01	0.04	< 0.01	0.08	< 0.01	< 0.01	< 0.01	< 0.01
Netherlands	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
New Zealand	< 0.01	< 0.01	0.15	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Norway	0.07	0.05	< 0.01	0.06	0.06	0.15	NA	0.1
Portugal	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.04
Slovak Rep.	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Slovenia	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Spain	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sweden	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Switzerland	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
U.S.	0.24	0.36	0.12	0.46	0.25	0.34	0.29	NA

Note: doppelganger weights on donor pool countries in the baseline specification and nine restricted donor pools. In each of the seven cases (I to VII) we omit one of the donor countries that received a positive weight in our baseline specification.



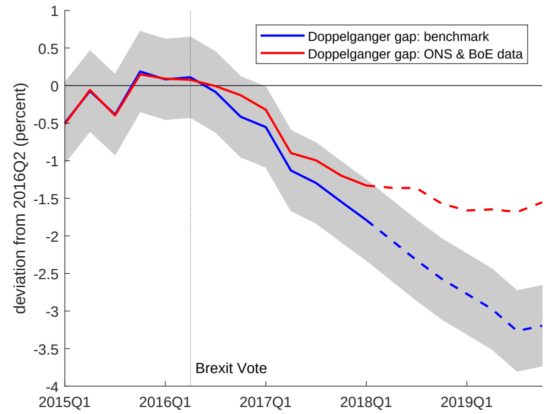


Figure 7: Effects of data revisions. *Note:* left panel shows the baseline Doppelganger with that estimated using GDP data (for 1995Q1 to 2017Q4) from the Office of National Statistics (ONS) and OECD Economic Outlook forecasts (for 2018Q1 to 2019Q4). The right panel shows the same but with EO forecasts replaced by those of the Bank of England (BoE).

3.5.2 Effect of data revisions

Our results are based on data from the OECD Economic Outlook database. The primary advantage is that this database provides a consistent source of information across the UK and all the donor pool countries. This is true not only for past values of real GDP, but also for its forecasts.

Therefore, this subsection re-estimates the baseline model but with different data for the UK economy. In particular, we consider the quarterly national accounts data from the Office of National Statistics (ONS) which include the fourth quarter of 2017. In addition, we consider the more recent real GDP forecasts from the Bank of England (BoE), which may reflect new information not yet available at the time of publication of the Economic Outlook database.

Figure 7 shows how our baseline estimates change when considering the above data updates and revisions. The left panel uses ONS data for the realizations of GDP (including the fourth quarter of 2017), but retains the Economic Outlook forecasts. The right panel then in addition replaces the Economic Outlook forecasts with those of the Bank of England.

In both cases, the two estimates differ mainly in their forecasted effects of the Brexit vote for the years 2018 and 2019. In particular, the Bank of England forecasts are more optimistic resulting in a Doppelganger gap of -1.6 percent at the end of 2019 compared to -3.2 percent in the baseline estimates.

However, the realized losses up until the end of 2017 are very similar across the estimates. Specifically, while our baseline estimate of the Doppelganger gap in the fourth quarter of 2017 is -1.8 percent, it is -1.3 percent when using the ONS data.

Therefore, we conclude that the realized losses from the Brexit vote amount to around −1.5 percent of real GDP at the end of 2017. There is, understandably, more uncertainty about the potential future losses. At the lower end, our estimates suggest that the losses will continue to hover around −1.5 percent. Using gloomier forecasts, these losses may be as high as −3.2 percent of real GDP by the end of 2019.

4 What drives the doppelganger gap?

The doppelganger gap emerged in response to the Brexit vote, before Brexit has actually taken place. It shows that the Brexit vote triggered a change in expectations which—because of forward-looking decisions—impacts the economy prior to actual Brexit. Specifically, household and firm responses may be driven by a downgrade in the average economic outlook but also an increase in uncertainty about the future.

In what follows we first provide evidence that consumption and investment indeed play a crucial role in explaining the doppelganger gap. Second, we document that increased uncertainty can explain at most half of the doppelganger gap. These results therefore attribute the majority of the output costs of the Brexit vote to gloomier average expectations of households and firms about the economic future of the UK.

4.1 The role of consumption and investment

In this part we quantitatively evaluate the contribution of forward-looking households and firms to the doppelganger gap. Specifically, we construct a counterfactual GDP path where we replace, in turn, consumption and investment in the UK with their respective doppelgangers (using expenditure shares of 2016Q2). On the basis of these counterfactuals, we show that consumption and investment (gross fixed capital formation) disproportionately contributed to the doppelganger gap. A negative contribution implies that the variable declined in the UK relative to the doppelganger.

The left panel of Figure 8 shows the results: both variables contribute to the doppelganger gap—the Brexit vote has caused a decline of consumption and investment (relative to the doppelganger)—with the contribution of consumption being somewhat larger than that of investment. The right panel of Figure 8 shows a counterfactual GDP path (dashed line) assuming that both consumption and investment had been unaffected by the Brexit vote. It turns out that in this scenario the doppelganger gap is approximately closed. Taken together the other expenditure components therefore made only a moderate contribution to the doppelganger gap. Their individual contributions have also been limited during our

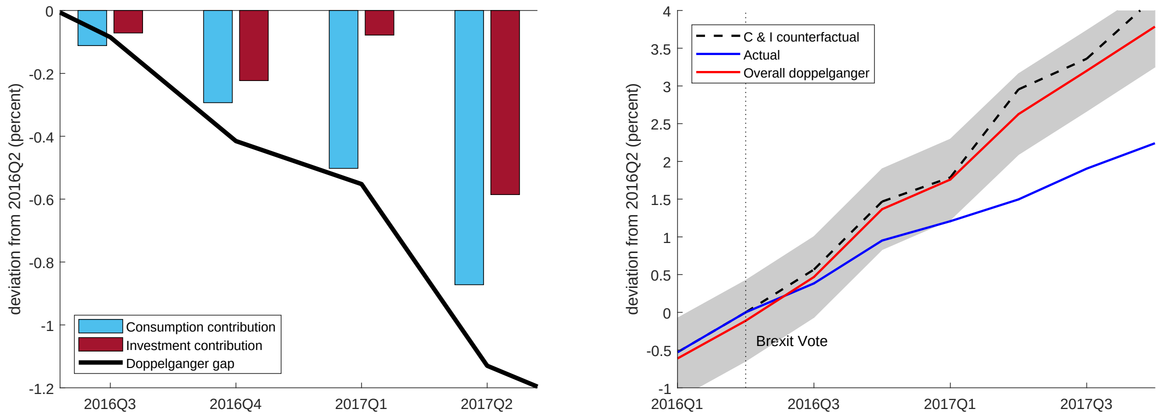


Figure 8: Accounting for the doppelganger gap. *Note:* left panel shows contribution of consumption (blue) and investment (red); right panel shows counterfactual GDP path (dashed line) assuming that both investment and consumption had been unaffected by the Brexit vote.

sample period.[13]

Overall, our findings are consistent with the notion—central to modern macroeconomics—that the private sector responds in a forward-looking manner to an anticipated policy change.[14] In our case, it is clear that Brexit will amount to a bundle of policy measures which will result in economic disintegration between the UK and the European Union. Whether this is because of higher tariffs, non-tariff barriers or both, it is likely to bring about a reduction of living standards which, in turn, may rationalize reduced investment and consumption expenditures: not only in the future, but—because of anticipation effects—already today.

4.2 The role of uncertainty and anticipation effects

Up until now, we have implicitly linked the doppelganger gap to a downgrade in expectations of forward-looking households and firms, that is, to "anticipation effects". However, in addition to a possible downgrade in the average economic outlook, the Brexit vote also increased economic uncertainty considerably—not least because the details of Brexit are still unclear. Higher economic uncertainty is likely to take its toll on investment and consumption expenditures, quite independently of any anticipation effects. In fact, even if the economic outlook were unchanged on average, an increase of uncertainty will hamper economic activity,

[13] An exception is the third quarter of 2016, when there was a large built-up of inventories, offset by a decline of net exports (both in value and volume terms), despite the strong depreciation of the pound (Office for National Statistics 2016).

[14] Our focus is on consumption and investment spending. For evidence on how the Brexit vote impacts firms' financing decisions, see Berg et al. (2017).

as established in a seminal contribution by Bloom (2009).

In what follows, we explicitly quantify the extent to which the doppelganger gap identified above is due to (i) anticipation effects of reduced future prosperity, and (ii) more dispersed expectations, that is, uncertainty effects. Specifically, we estimate an expectations-augmented structural vector autoregression and identify shocks to uncertainty and expectations. Once again using the notion that the Brexit vote is a well-defined natural experiment allows us to single out uncertainty and expectations shocks occurring in 2016Q3 as those *caused* by the referendum. The estimated model, together with these identified "Brexit shocks", enable us to quantify to what extent the doppelganger gap is caused by anticipation or uncertainty effects.

4.2.1 Uncertainty and expectations data

Given that the Brexit vote has primarily uncertain consequences for future policies, we measure uncertainty using the Economic Policy Uncertainty (EPU) index. The index is based on a (standardized) count of newspaper articles containing the terms uncertain or uncertainty, economic or economy, and one or more policy-relevant terms (see Baker et al. 2016). The right panel of Figure 9 shows that the EPU index increased dramatically around the Brexit referendum. For our application, however, it is especially important that it captures *mean-preserving* changes in policy uncertainty. Baker et al. (2016, Table IV) show that controlling for various proxies of future expectations changes little of their results.[15]

To capture anticipation effects we rely on proprietary data of the professional forecasting firm *Oxford Economics* which provides growth forecasts for the UK up until the year 2050.[16] Indeed, there is little doubt that the Brexit vote induced market participants to reduce their long-term income expectations. This is exemplified in the left panel of Figure 9, where we display month-to-month changes of *Oxford Economics'* output growth forecasts throughout our available sample, cumulated over a ten year forecast horizon. The figure shows that the forecast revisions in response to the Brexit vote, i.e. the difference between growth forecasts in July and June 2016, were unprecedented in size *and persistence* even when compared to the Great Recession period.[17] Sampson (2017) surveys the studies which quantify the per

[15]In the appendix, we consider an additional measure of macroeconomic uncertainty proposed by Jurado et al. (2015) and computed for the UK by Redl (2017).

[16]Ideally, we would use forecasts from a variety of firms. However, *Oxford Economics* stands out in terms of forecasting horizon. Reassuringly, we find that forecasts revisions by *Oxford Economics* for the short run are very similar to the average forecast revision by a large group of professional forecasters published by Her Majesty's Treasury (see `https://www.gov.uk/government/collections/data-forecasts`), see Figure 16 in the Appendix. Interestingly, it also shows that the drop in output growth expectations is mostly due to a decrease in expected consumption and investment.

[17]Growth forecasts are more strongly downgraded in the short run. However, even long-horizon growth

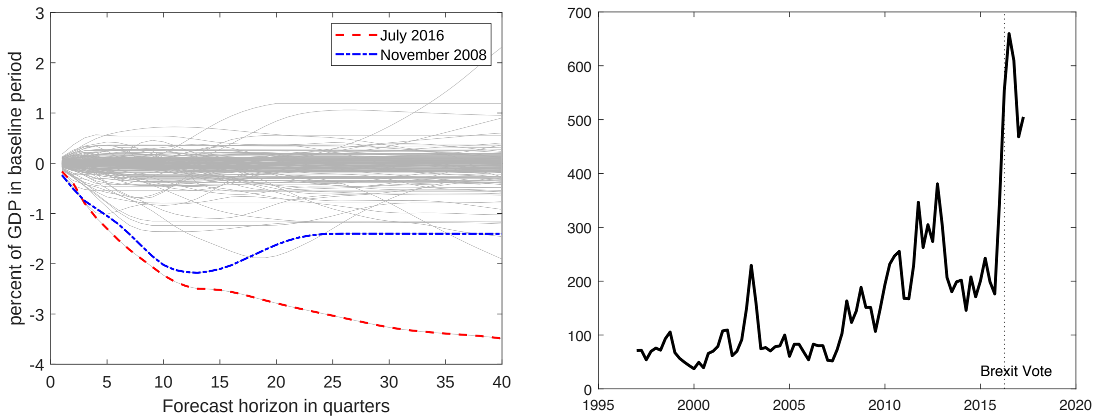


Figure 9: Downgrade of output expectations and uncertainty after the Brexit vote. *Note:* left panel shows cumulated month-to-month changes of output growth forecasts by *Oxford Economics* with the downgrades between July and June 2016 (dashed red line) and November and October 2008 (dash-dotted blue line) highlighted; right panel shows the index of economic policy uncertainty (EPU, source: `www.policyuncertainty.com`).

capita income loss due to Brexit and finds plausible estimates range between -1 and -10 percent for a forecast horizon of 10 or more years after Brexit. The downgrade of output growth by *Oxford Economics* after the referendum is consistent with these estimates.

4.2.2 Estimation

In order to quantify the uncertainty and anticipation effects that are manifest in the doppelganger gap, we estimate a vector autoregression (VAR) on quarterly time series. Importantly, our VAR features news regarding future output growth in addition to conventional variables. Specifically, letting $x_{t+h,t}$ denote the h-quarter ahead output growth forecast in period t, and $x_{t+h,t-1}$ the output growth forecast for the same period made one quarter before, we define $news_{t+h,t} \equiv x_{t+h,t} - x_{t+h,t-1}$. Formally, we use Y_t to denote the vector of endogenous variables

$$Y_t = \begin{bmatrix} EPU_t & news_{t+h_1,t} & news_{t+h_2,t} & news_{t+h_3,t} & r_t & y_t \end{bmatrix}' . \tag{4.1}$$

It includes the log of the EPU, EPU_t, news which relate to three different forecasting horizons, as well as the bank rate of the Bank of England, r_t, and the log of real GDP, y_t. We then estimate the model:

$$Y_t = c + A(L)Y_{t-1} + \nu_t, \tag{4.2}$$

where c is a constant term, $A(L)$ is a lag polynomial, and $\nu_t \sim (0, \Omega)$ is a vector of white noise errors.

forecasts were substantially downgraded resulting in a persistent fall of cumulated output losses.

Model (4.2) is an expectations-augmented VAR, or EVAR (Perotti 2014). We use it in our analysis for two reasons. First, conventional VAR models face difficulties when it comes to recovering anticipation effects (Fernández-Villaverde et al. 2007; Leeper et al. 2013; Lippi and Reichlin 1994).[18] Hence, several contributions, notably in the context of fiscal policy, have included forecast data in VAR models in order to control directly for "foresight" of market participants (e.g., Ramey 2011). Second, the EVAR specification allows us to pursue a semi-structural identification strategy. As we identify the anticipation effects of Brexit, we capture the possibility that news regarding future output growth impact the economy. In doing so, we account for news which relate to a wide range of forecast horizons, but remain agnostic as to its specific causes. For instance, one may think of growth news as ultimately being due to expected changes in total factor productivity (see, for instance, Beaudry and Portier 2006). Alternatively, output expectations may decline because of economic disintegration and reduced gains from trade. We do not take a stand in this regard because a broad perspective seems warranted in light of the multifaceted event that looms on the horizon.

We identify uncertainty and growth news shocks on the basis of a recursive identification scheme (or, equivalently, through a Choleski decomposition of Ω). This identification strategy has been commonly pursued in the literature on uncertainty shocks. As we order EPU_t first in (4.1), we allow uncertainty shocks to play the largest possible role: all variables may respond contemporaneously to an uncertainty shock. Growth news, in turn, are ordered second such that they may respond contemporaneously to uncertainty shocks—a likely scenario, notably for short-term forecasts. Our specification also allows for a contemporaneous effect of growth news shocks on output and interest rates, but rules out an immediate effect on uncertainty. We do not provide a structural interpretation of the other shocks in the model such that the ordering of output and interest rates relative to each other is immaterial.[19]

We estimate model (4.2) on observations for the period 1997Q1–2017Q3.[20] We allow for four lags and set the forecast horizon of news, h_1, h_2 and h_3 to 5, 11, and 17 quarters, respectively. Our closest forecast horizon is 5 quarters because this allows us to capture growth news shocks in response to the Brexit vote that relate to the period just beyond the end of our sample: given $h_1 = 5$, Brexit news that potentially materialize in 2016Q3 pertain to growth in 2017Q4. In addition, we consider news regarding output growth that is expected

[18]The moving average representation of structural models with foresight is often non invertible, or non fundamental given the set of variables that are typically included in VAR models. This provides a rationale for estimating structural models using full-information econometric methods (e.g., Blanchard et al. 2013; Schmitt-Grohé and Uribe 2012).

[19]In the appendix, we perform a number of robustness exercises which include the relaxation of our identification assumptions. There, we also display impulse response functions to an uncertainty shock which we find to be in line with what Baker et al. (2016) find for US data.

[20]Further details on the data can be found in the Appendix A.1.

to take place after another 1.5 and 3 years, respectively.[21]

4.2.3 Quantifying uncertainty and anticipation effects

We are now equipped to quantify to what extent uncertainty and anticipation effects drive the estimated doppelganger gap. Towards this end, we use the estimated model to construct a counterfactual GDP path. Specifically we switch off uncertainty and news shocks in 2016Q3, the quarter immediately after the Brexit vote. Our maintained assumption is that these shocks are caused by the referendum: we once more interpret the Brexit vote as a natural experiment, just like in our analysis in Section 3 above. As, by construction, all six shocks taken together generate time-paths of the endogenous variables which exactly track the data, switching off the Brexit shocks provides us with the counterfactual GDP path which would have been observed in the absence of the Brexit vote.[22]

Figure 10 shows the results together with the actual time path of GDP in the UK. The figure also reproduces the UK doppelganger which was computed independently in Section 3 above. The dashed line represents the implied path for GDP, had there been no uncertainty shock in 2016Q3. The distance between the counterfactual, "no uncertainty" GDP path and actual GDP is non trivial. We find that the increase of uncertainty due to the Brexit vote explains up to one half of the doppelganger gap—although the relative contribution declines towards the end of the sample.

The dashed-dotted line in Figure 10 shows the counterfactual GDP path that obtains when we switch off the news shocks in 2016Q3 in addition to the uncertainty shock (dashed-dotted line). This GDP path would have been observed in the absence of the Brexit vote according to our estimated VAR model. Notice that it aligns rather well with the output path for the doppelganger. Taken together, uncertainty and anticipation effects thus account fully for the doppelganger gap. In fact, they slightly over predict output relative to the doppelganger. Initially, uncertainty and anticipation effects are of equal importance, but the relative importance of the anticipation effect increases towards to end of the sample.

In the appendix, we report results of various robustness checks. Overall, we find that the role of uncertainty in accounting for the doppelganger gap is sizable, but it does not explain more than 50 percent. This is noteworthy, because our identification scheme allows uncer-

[21] Including news for longer horizons gives rise to unstable results. The likely reason is that changes of forecasts for the very long run are fairly volatile.

[22] In the appendix, we also consider an alternative identification approach based on dummy variables. Specifically, we include dummy variables into our baseline reduced-form EVAR which are equal to 1 in 2016Q3 and zero otherwise. In the same way as in our baseline exercise, we interpret the coefficients on these dummy variables as measuring the effect of the Brexit vote on the respective variables. Constructing a counterfactual time path for real GDP by "switching off" the effects of uncertainty and news measured by the dummy variables gives very similar results to our baseline exercise.

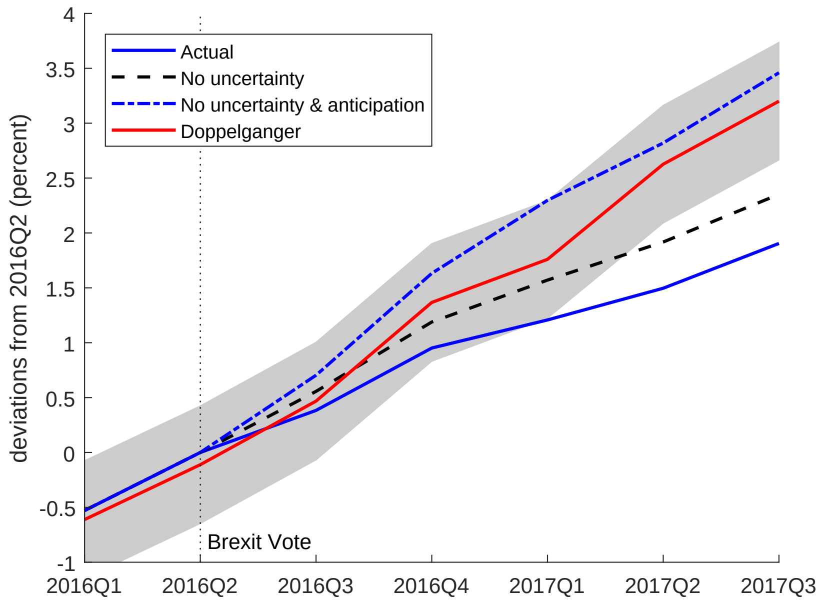


Figure 10: Output path in the UK. *Note:* actual GDP (blue solid line) vs doppelganger (red solid line) vs counterfactual GDP path when uncertainty shock in 2016Q3 is switched off (dashed line) and when both uncertainty and news shocks in 2016Q3 are switched off (dash-dotted line).

tainty shocks the largest possibility to impact economic activity. Despite this—heightened uncertainty explains only a modest share of the overall losses. We find that the remaining gap is fully accounted for by anticipation effects.

5 Conclusion

In this paper, we exploit the natural experiment of the Brexit vote to quantify the costs of economic nationalism. Natural experiments in macroeconomics are rare, but when they occur they offer unique insights into causal mechanisms and the validity of major assumptions underlying macroeconomic models. The unexpected outcome of the Brexit referendum in June 2016 offers such a window on causal relationships. The Brexit vote raises policy uncertainty and reduces international economic integration.

Our first main result is that the Brexit vote has already impacted economic activity well before any policy change has occurred. We show that by the fourth quarter of 2017 the Brexit vote has caused a reduction of GDP by approximately 1.8 percent. On current forecasts the effect is likely to grow over the coming years. Zooming in on the behavior of the private sector, we find that households and businesses have adjusted their behavior in anticipation of Brexit, as macroeconomic theory predicts.

However, while the Brexit referendum shapes Britain's economic present in addition to its future it also raised economic uncertainty. The binary choice question "Should the United Kingdom remain a member of the European Union or leave the European Union?" left important issues open. And while the direction of future economic policies seems clear, the exact extent of Britain's economic disintegration from Europe remains unclear.

Against this background, we show that a wider dispersion of future economic outcomes, that is, heightened economic policy and macroeconomic uncertainty, accounts for close to half of the observed effects. Stripping the overall output loss due to the Brexit vote of the effect of heightened uncertainty—which is arguably temporary—leaves us with anticipation effects of households and firms, which have downgraded their expectations about future incomes. These effects are not only large, but to the extent that they reflect long-run outcomes, they are also there to stay.

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A Appendix

A.1 Data

The donor 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). In the baseline, we use real GDP (gross domestic product, volume, market prices) from the OECD Economic Outlook database (November 2017 edition), where data from 2017Q4 onwards are forecasts. The consumption (private final consumption expenditure, volume) and investment (gross fixed capital formation, total, volume) data for the decomposition exercise, and inflation (change in consumer price index, harmonised, index 2015) and real exchange rate (real effective exchange rate, constant trade weights, index 2010) for the robustness checks, comes from the same source.

For the data revisions robustness check, we splice the OECD data for the UK in 2015Q4 with realized growth rates from the Office of National Statistics (ONS) from 2016Q1 to 2017Q4, and real GDP growth rate forecasts from the Bank of England from 2018Q1 till 2019Q4.

For the uncertainty analysis, we use the Baker et al. (2016) Economic Policy Uncertainty index available at `www.policyuncertainty.com`. The index is based on a (standardized) count of newspaper articles containing the terms uncertain or uncertainty, economic or economy, and one or more policy-relevant terms. The macroeconomic uncertainty index, based on Jurado et al. (2015), has been computed for the UK in Redl (2017) and has been made available to us by Chris Redl. Stock market returns are based on the Datastream total market total returns index for the UK (TOTMKUK). The policy rate is the Bank of England bank rate.

The proprietary real output growth forecasts come from Oxford Economics (`https://www.oxfordeconomics.com`). We aggregate the monthly growth forecasts to quarterly frequency by taking the average over the three months pertaining to a quarter.

A.2 End-of-sample instability test

Andrews' (2003) end-of-sample instability test has recently been suggested in the context of synthetic control approaches by Hahn and Shi (2017) and shown to have good size properties. While the test is technically based on stationary data, Andrews (2003) notes (p. 1681, comment 4), that his test can be shown to be asymptotically valid under stationary errors. To conduct the test, we run the SCM over the *whole* (pre- and post-Brexit vote) sample and then base the test statistic on the sum-of-squares of the post-Brexit vote errors. Following Andrews (2003), the distribution of the test statistic is computed using a subsampling scheme. Specifically, we conduct the matching on the sample $1, \ldots, T_0$, where observations $j, \ldots, j + \lceil m/2 \rceil - 1$ are excluded. Here, m is the number of post-Brexit vote observations, T_0 is the time of the treatment, and we resample for $j = 1, \ldots, T_0 - m + 1$. For each iteration, the resampled test statistic is based on the matching errors from j to $j + m - 1$.

A.3 Additional country placebo tests

The main text conducted placebo tests on the relevant subset of the donor pool, i.e. the countries which received a non-zero weight in the baseline UK doppelganger. This Appendix shows that similar results are obtained for the rest of the donor pool countries.

Figure 11 shows the country placebo time paths and Figure 12 depicts the two statistics of relative pre- and post-treatment fit. Again, the UK economy stands out as the one with the largest post-treatment deviation.

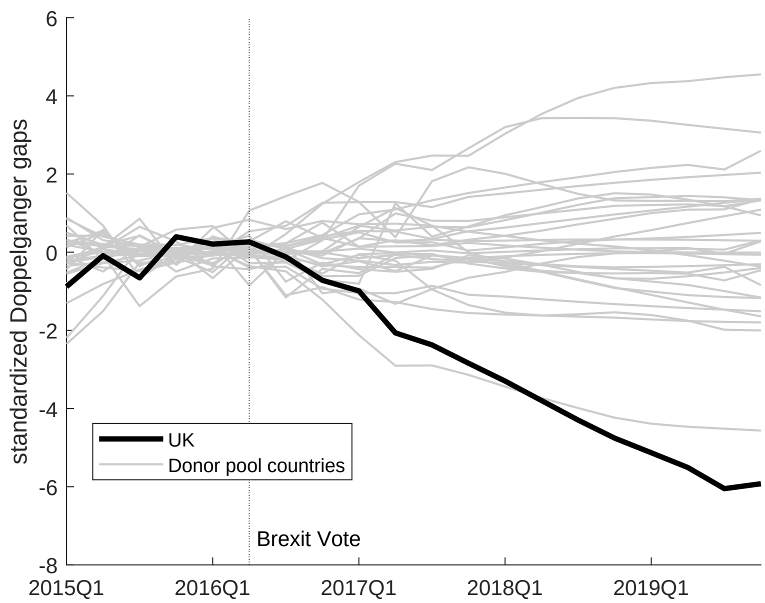

Figure 11: Country placebo tests *Note:* UK doppelganger *gap* (thick black line), with gray lines representing country placebo doppelganger gaps estimated by considering fictitious Brexit votes in all donor pool economies. For comparability, all doppelganger gaps are normalized by their respective pre-Brexit standard deviations and centred around their 2015 means.

There are three countries (Austria, Slovenia and Switzerland) which are also characterized by relatively large post-treatment deviations, though smaller than that of the UK. In principle, large post-treatment changes in the doppelganger gap in other countries may indicate that the Brexit vote outcome affected these economies through spill-over effects. Such interlinkages

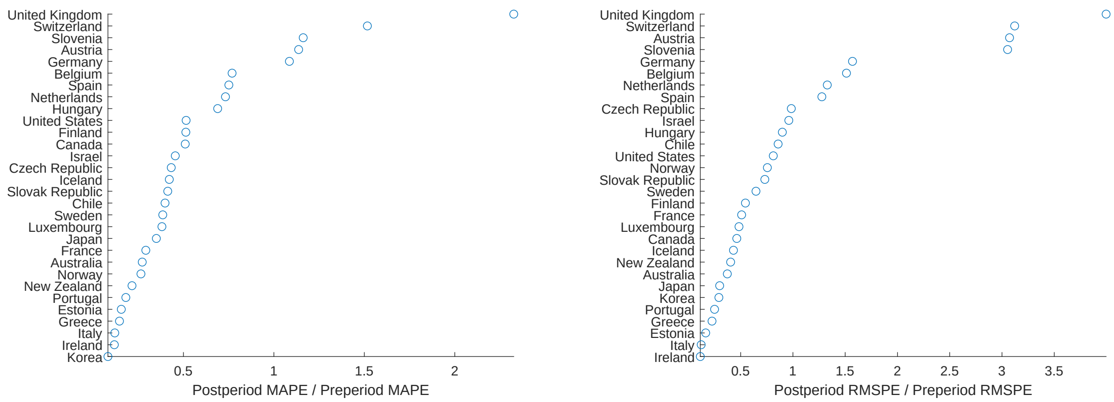

Figure 12: Relative measures of the pre- and post-treatment doppelganger gaps. *Note:* left panel shows the relative maximum absolute prediction error ρ_2, the right panel shows the relative root means squared prediction error ρ_1.

between countries would violate the assumptions about the donor pool countries not being affected by the treatment.

Figure 13 shows the evolution of UK GDP, the baseline synthetic control and the doppelganger based on the restricted donor pool. The synthetic control resulting from the restricted donor pool is essentially indistinguishable from it's baseline counterpart. This is not entirely surprising given that the baseline estimates do not assign large weights on either of the three countries in constructing the doppelganger for the UK economy.

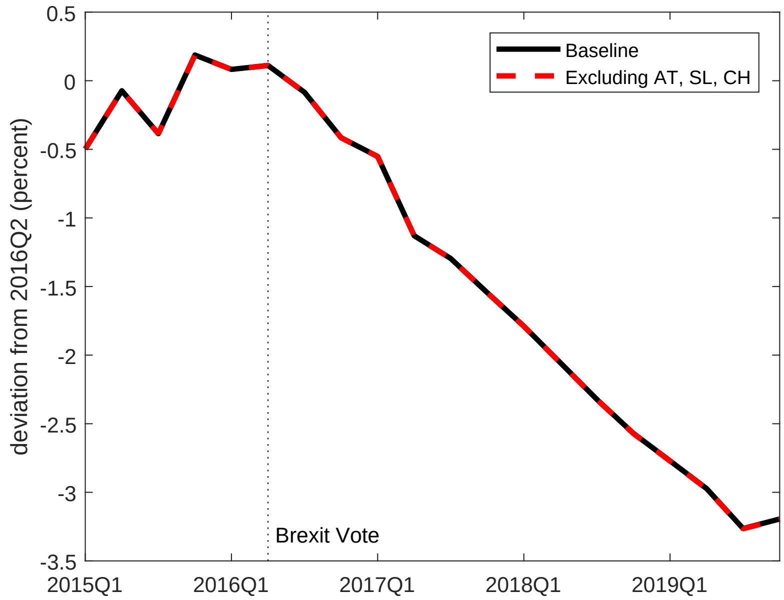

Figure 13: Baseline doppelganger gap and restricted donor pool doppelganger gap. *Note:* baseline doppelganger gap together with that estimated using a donor pool which excludes Austria, Slovenia and Switzerland.

B VAR results

This part of the appendix provides additional results for our VAR analysis in the main text. First, we show that the aggregate dynamics following the identified uncertainty shocks are consistent with findings in the literature. Second, we perform a series of robustness checks on our baseline specification.

B.1 Impulse response functions

Figure 14 shows the impulse response functions of the VAR variables to a one standard deviation uncertainty shock. As has been extensively discussed in the literature, uncertainty increases have contractionary effects.

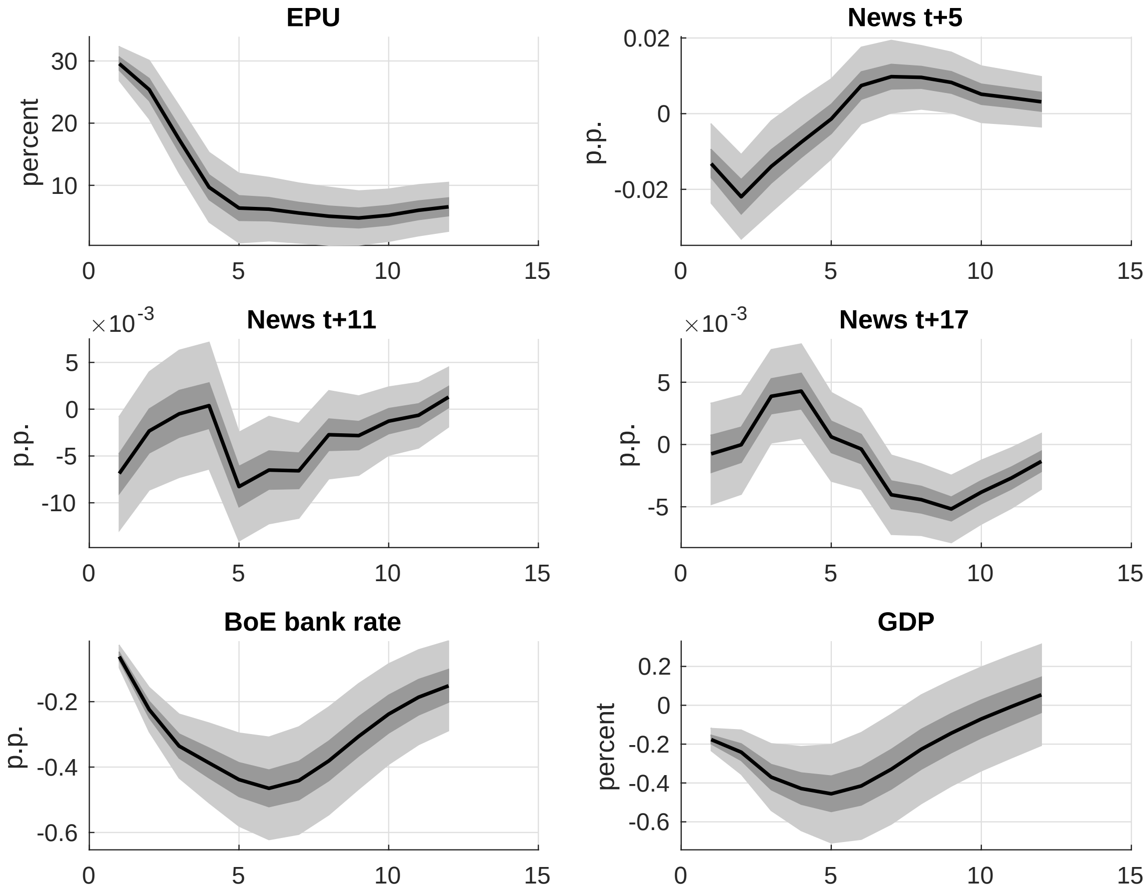

Figure 14: Impulse response functions: economic policy uncertainty. *Note:* impulse response functions to a one standard deviation increase in uncertainty. Light and dark shaded areas indicate one standard deviation and 90 percent bootstrapped confidence bands, respectively.

B.2 Robustness

We now investigate whether the contributions of uncertainty shocks and growth news shocks to the doppelganger gap depend on the specific VAR setup chosen. The left panel of Figure 15 presents the results for the contribution of uncertainty shocks alone, while the right panel shows the joint contribution of uncertainty and expectation changes. We estimate alternative VAR with one of the following items changed: 2 instead of 4 lags, news horizons of 5, 10, and 16 quarters, investment instead of the 11 quarter ahead news variable, and a linear trend in the VAR. One may also be concerned with the ordering of the variables in the VAR, so we change this as well. We also conduct a check where we replace economic policy uncertainty by a Jurado et al. (2015)-style proxy of general macroeconomic uncertainty, computed for the UK by Redl (2017). To account for movement in inflation and the real exchange rate around the Brexit vote, we include them one after the other in the VAR. The last check we conduct is the dummy EVAR specification described in footnote 22.

Overall, as Figure 15 shows, these changes do not fundamentally change our conclusion that uncertainty can explain at most half of the doppelganger gap and that negative expectations about the future are a major driver of the gap.

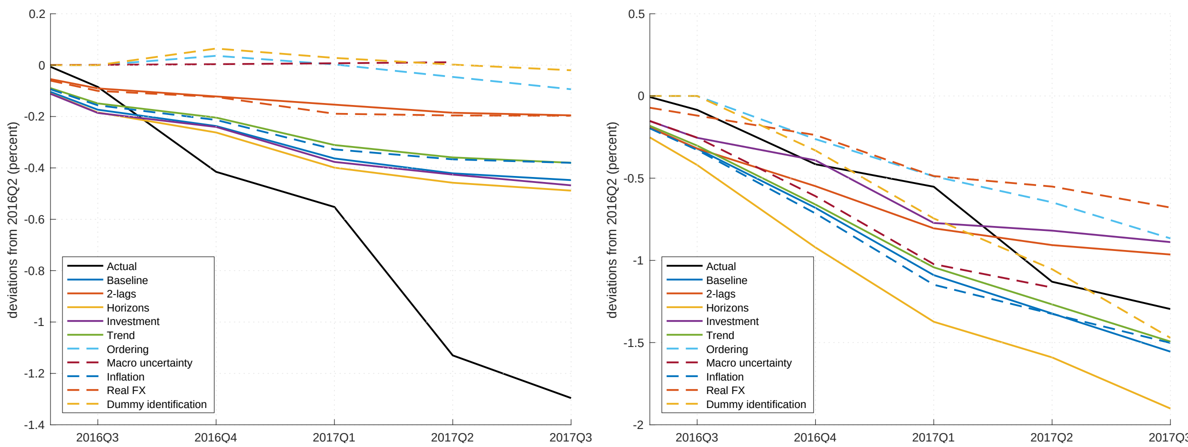

Figure 15: VAR results: robustness. *Note:* doppelganger gaps (difference between doppelganger and data) when uncertainty shock in 2016Q3 is switched off (left panel) and when both uncertainty shock and news shocks in 2016Q3 are switched off (right panel) for alternative specifications.

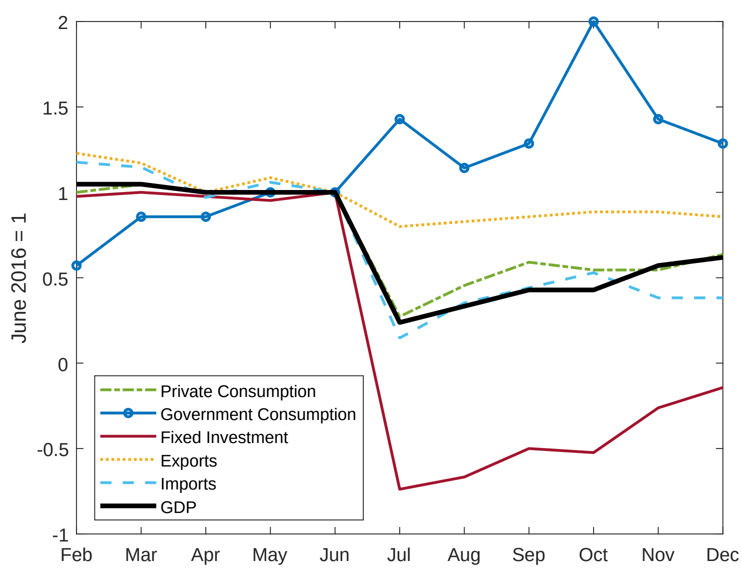

Figure 16: Expectations around the Brexit vote. *Note:* left panel: averages of professional forecasts of 2017 GDP growth and of it's components published during the months of 2016.