

An Alternative way of Predicting the Outcome of the Scottish
Independence Referendum: the Information in the Ether.

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1. Introduction

It was not an easy task to predict the outcome of the Scottish referendum as there were many twists and turns en route to the final poll, which made it difficult for even mainstream pollsters to gauge public opinion. Even with the benefit of hindsight there are still many important questions yet to be answered months after the event. For example, did voters have enough *clear* information on the key issues of the referendum?; was there any ‘Yes’ momentum following the rejection of a currency union?; what roles did emotion and rationality play in the decision process of voters?

It is difficult, if not indeed impossible, to project the final referendum results by traditional means, such as surveys, polling, etc. and the unforeseen events and puzzling polling results of the final month before the referendum complicated the forecasting task considerably. An innovative way of forecasting is needed to make more precise forecasts robust to uncertain situations and one which does not rely on snapshot polls.

For example, the polling results of the last month of the referendum indicated that the ‘Yes’ and ‘No’ votes were close. However, the ‘No’ side won the referendum with a comfortably wide margin. There were claims that the television debate broadcast by the BBC and the interventions of three main Westminster parties, especially in terms of ‘the Vow’, determined the referendum path and contributed to the subsequent ‘No’ victory. However, it is difficult to verify these claims by standard methods.

In this paper we propose a new and innovative way of analysing the Scottish referendum using a large data set from Google and advanced econometric methods. We believe our research, covering the period between August 2013 and September 2014, provides a better understanding of the salient issues in the referendum debate and has much wider applicability, since it could be applied to other referenda and standard election processes.

The paper is organized as follows. We first provide background information on the referendum-related issues between August 2013 and mid-August 2014, and then, in Section 2, conduct an empirical analysis using an innovative information demand approach that projects the voting results based on weekly information available more than one month before the event. It is important to note that although this is an ex post analysis of the Scottish referendum our predictions are truly ex ante in the sense that they are predictions based only on information available at the time.

After listing the main events between mid-August and mid-September 2014 and updating our projection with the new information, Section 3 provides a thorough analysis of daily interrelationships between voting intention and a newly constructed ‘Yes’ indicator, and the effects of key events on the two variables. The paper ends with a summary of the main findings and proposals for further research.

2. Big Data Analysis of the Referendum until August 2014

2.1 The Referendum-Related Issues

This section describes several referendum-related issues which are difficult to tackle by surveys or other traditional approaches. Our proposition is that we believe that many voters in the Scottish referendum did not obtain sufficient information about the referendum through traditional means. Although there was clearly plenty of coverage in the newspapers and on TV, what we suggest is that this did not give potential voters a *clear* information signal due to the noisiness of the data. For example, newspapers and TV channels might cherry-pick and provide conflicting reports on the same events. Even professional pollsters provided polling results with huge variations within a very short time span. Many voters seemed to be lost in a morass of information. Therefore, the first main issue facing referendum voters was whether and where they could get enough clear information for their decision making process.

There is no doubt that the most debated referendum issue until August 2014 was that of currency. The polling results from several companies did show some gains on the ‘Yes’ side after George Osborne rejected the idea of a currency union in February 2014. Some reports claimed that the ‘Yes’ campaign had gained momentum from the currency debates. However, such claims remain to be verified.

For many referendum voters, their decisions to vote ‘Yes’ or ‘No’ might depend on both rational factors - focusing on their well-being and that of generations to come - and emotional factors influenced by on-going events in Scotland and the rest of UK. In a year full of significant events, - e.g., rejection of a potential currency union, the Commonwealth Games and the Bannockburn anniversary - the effects of event-driven emotion should not be ignored since they seemed to play an important role in the referendum timetable set by the then First Minister, Alex Salmond. Meanwhile, it remains an issue to distinguish between emotion and rationality, and their effects on the decisions of voters.

2.2 An Innovative Approach Based on Big Data Set from Google

The traditional referendum-related research on polling results, news reports, etc., are essentially analyses of information supplied to voters. In this section, we propose an innovative approach, based on search volume measured by a Google Trends big data, to analyse the active information demand by referendum voters.

2.2.1 Google-Related Research

Google Trends is a service, provided by Google, to allow researchers access to the real-time relative online search volume for any keyword within any region of the world. The Google Trends data are presented in a [0, 100] interval, in either a daily or weekly index (Choi and Varian, 2012). The index of a particular term presents the percentage of search volume relative to the total search volume over time. The larger

the index is, the higher the information demanded and searches are for this term. As of October 2014, Google enjoyed a 88.7% share of web search volume worldwide (Statista Inc., January 7, 2015). Given its dominance in the web search market, economic researchers in various fields have started to analyse information demand with the Google Trends data.

For example, Da, et al. (2011) measure investor attention using the Google Trends data and find a positive correlation between Google Trends and other sentiment measures in a vector autoregression (VAR) framework. The Google Trends data are also strongly linked with the sentiment of less sophisticated retail investors, and an increase in Google search volume is correlated with a short-term momentum and long-term reversal in stock prices, which supports the attention theory of Barber and Odean (2008).

Vlastakis and Markellos (2012) use the Google Trends data of the 30 largest stocks traded on the NYSE and NASDAQ as a proxy for information demand. They find that the Google Trends has significant effects on price volatility and trading volume, both at the individual stock level and at the overall market level. The effects become especially significant during the periods when the stock returns are high. Similar results found in the French and Japanese stock markets (Aouadi et al., 2013; Takeda and Wakao, 2014) indicate that the Google Trends data, a measure of information demand, can play an important role in predicting stock returns and price volatilities.

Kita and Wang (2012) adopt the Google Trends data to measure investor information demand in the foreign exchange market. They find strong causal effects of information demand on exchange rate volatility and a positive correlation between the information demands and carry trade returns.

Recently, Vozlyublennaiia (2014) examined the Google Trends in the index markets. She finds that a significant short-run change in index returns is attributable to an increase in Google search queries.

While most Google-related economic studies focus on financial markets, Fondeur and Karamé (2013) test whether the Google Trends can predict the claimant counts in France. Their results indicate that the model with Google search volume data predicts unemployment much better than the one without.

In summary, recent studies have demonstrated that the Google trends data can help explain the dynamics of financial markets and make more accurate economic predictions. However, there is no research using Google Trends to gauge political information demand and make projections on voting results, which is the novelty of the present paper.

2.2.2 Testing Criteria and Referendum Projection

In order to measure the information demand of potential ‘Yes’ voters in the Scottish referendum, we propose using the Google search volume for the key words ‘Alex Salmond’ that occurred within Scotland. We choose ‘Alex Salmond’ for two reasons: Firstly, as the First Minister of Scotland at the time of the referendum and leader of Scottish National Party, the key words ‘Alex Salmond’ was the most popular choice when voters wanted to find information from Google on Scottish independence. Secondly, the search volume of ‘Alex Salmond’ was highly correlated with the polling and voting results of previous voting results of Scottish Parliament elections. For example, we find that the correlation of the search volume and polling result was 0.6 between January and May 2011.

With the available information demand data, we first set testing criteria and forecasting procedures before conducting our main empirical analysis. We adopt search volume of the key word ‘SNP’ within Scotland as the control variable in our models as a robustness check.

(1) Testing Criteria of Clear Information

We assume that, if referendum voters with an inclination to vote ‘Yes’ found enough clear information from Google, the search volume of ‘Alex Salmond’ within Scotland should have significant and positive effects on the polling results of ‘Yes’ votes.

(2) Testing Criteria on Information-Related ‘Yes’ Momentum

To find whether debates relating to the currency issue created ‘Yes’ momentum, we first test whether there was a regime change with respect to the polling results after February 2014 and whether the potential ‘Yes’ votes grew faster in the later regime.

(3) Testing Criteria on Emotion and Rationality

To measure the effects of emotion and rationality distinctively, we assume that emotion might dominate voters’ decision-making process for a while, but the effects are not long lasting or persistent: as in the majority of economic models over a longer time span, rationality is assumed to prevail. To be more specific, we set significant and positive effects lasting less than one week to be mainly ‘emotional’ and more than one week to be ‘rational’.

(4) Referendum Projection with Big Data

Based on available information until mid-August 2014, we provide our version of projections on the voting outcome of the Scottish referendum on 18 September 2014 using the weekly search volume variable.

2.3 Empirical Findings

Our empirical analysis covers the time period between 25 August 2013 and 16 August 2014, when the polls from most mainstream pollsters were available. Our data

analysis involves two main variables and one control variable. The main variable, ‘Potential Yes Votes’, is constructed by the average opinion polling results on ‘Yes’ votes from the six polling companies, i.e., ICM, Dipso Mori, Panel base, Survation, TNS BMRB and You Gov. Another main variable, Google Trends, is from the Google Trends data within Scotland based on the keyword ‘Alex Salmond’. For the purposes of a robustness check, the Google Trends data of the key word ‘SNP’, closely related to the second main variable, is adopted as the control variable.

2.3.2 Rational Regime shifts, Less Clear Information and No ‘Yes’ Momentum

We first use a Markov Switching (MS) model to test whether the dynamics of Potential Yes Votes structurally changed between August 2013 and August 2014. If the mean values of the Potential Yes Votes switch over periods, this behaviour can be treated as a ‘regime switch’, which can be modelled by a Markov regime switching model proposed by Hamilton (1989, 1990).

We first assume that a regime switch of the ‘Potential Yes Votes’ is caused by some unobserved variable, S_t , which measures the states of the world and follows a Markov process. Then we can test whether the Potential Yes Votes can be split into 2 regimes, i.e., the Potential Yes Votes at time t is in regime 0 if $S_t = 0$ and in regime 1 if $S_t = 1$. If the regime switch is preceded by some specific events, e.g., the rejection of a potential currency union in February 2014, we can conclude that the dynamics of the Potential Yes Votes have structurally changed since this event.

Our MS(2) estimation model can be expressed as:

$$Y_t = \mu_{S_t} + \phi X_{S_t,t} + \varepsilon_{S_t,t}, \quad (1)$$

where Y_t represents Potential Yes Votes, μ is the constant term, and is regime dependent. X_t measures the Google Trends, and the error term $\varepsilon_t \propto N(0, \sigma^2)$.

In our model, the constant, Google Trends, and error term switch between regime 0 and regime 1. Here, $P(0|0)$ is defined as the probability of the ‘Potential Yes Votes’ remaining in regime 0 in week $t+1$ if it was in regime 0 in week t . The main findings are presented in Table 1 and Figure 1.

Based on our analysis, we are able to separate the behaviour of the ‘Potential Yes Votes’ into two regimes: Regime 0 spanned from 25th August 2013 to 8th March 2014; and Regime 1 was from 16th March 2014 to 16th August 2014.

The markov model estimates indicate that there was about a 96.5% possibility that the Potential Yes Votes would stay in regime 0 with a constant of 31.9%. However, some specific events might have triggered a potentially unlikely regime change. The regime switch happened during the week of 9th -15th March 2014, about four weeks after the

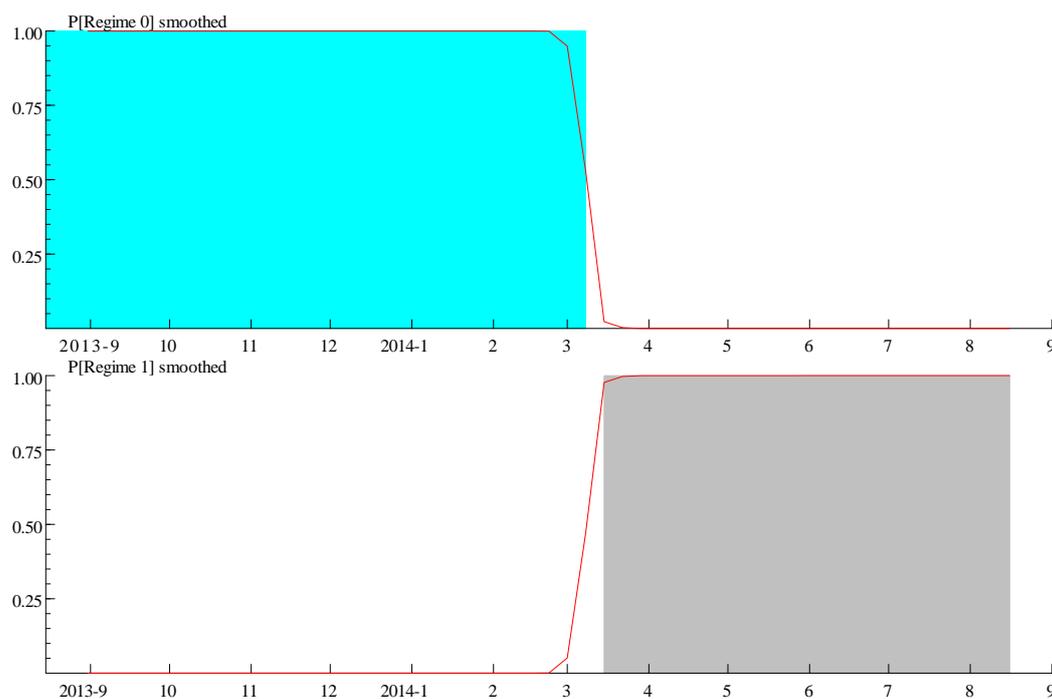
rejection of the continuation of the sterling zone post-independence by George Osborne in February 2014. There was a 4.3% increase, from 31.9% to 36.2%, in the constant of Potential Yes Votes from Regime 0 to Regime 1.

Table 1: Effects of Google Trends on Potential Yes Votes in a MS(2) Model

Potential Yes Votes	Coefficient	Std Error	t-value	t-prob
Constant(0)	31.9161	0.4010	79.6000	0.0000
Constant(1)	36.1931	0.2266	160.0000	0.0000
Google Trends (0)	0.0821	0.0253	3.2500	0.0020
Google Trends (1)	0.0109	0.0076	1.4400	0.1580
$\sigma(0)$	1.0121	0.1380	7.3400	0.0000
$\sigma(1)$	0.6352	0.0964	6.5900	0.0000
P(0 0)	0.9649	0.0345	28.0000	0.0000

Note: The coefficients are significant if their values are bold.

Figure 1: Regime Changes of Potential Yes Votes



Based on the estimation results and the testing criteria on rationality, we can conclude as follows: the currency-related debates in February and March caused a regime change and a 4.3% increase in ‘Potential Yes Votes’. In other words, we predict that 4.3% swing voters, after some consideration, seem to have moved to a ‘Yes’ vote in the referendum because of the currency related debates.

However, the effects of Google Trends on ‘Potential Yes Votes’ became insignificant (P-value 0.16) after 15th March 2014. Based on the testing criteria on clear

information, voters in the Scottish referendum encountered difficulties in finding enough clear information to justify a decision to vote ‘Yes’.

Furthermore, according to related criteria, there was no ‘Yes’ momentum based on information search results after 16th March 2014. There were significant and positive effects of Google Trends on Potential Yes Votes (0.0821) before 15th March 2014. After that time the positive effects became much smaller (0.0109) and insignificant.

2.3.3 Emotion-Driven Yes Votes after the Rejection of Currency Union

The main purpose of this section is to find whether emotion or rationality mattered in the decision-making process of voters during the referendum process. To do this we adopt a Vector Auto-Regressive (VAR) model to analyse the effects of emotion and rationality on ‘Potential Yes Votes’ between 16th March and 16th August of 2014.

A Vector autoregressive model (VAR) is a multivariate regression model with more than one dependent variable. The model is flexible and able to incorporate more information than traditional univariate regression models. This paper adopts a VAR model setup similar to Brooks and Tsolacos (1999) and Vozlyublennaia (2014).

In our case, we analyse the main variables, i.e., the Potential Yes Votes, and Google Trends in a bivariate VAR, where we denote them Y_t and X_t respectively. The current values of the two variables depend on the values of both variables during the previous 4 weeks, and error terms, can be expressed as follows:

$$Y_t = \mu_Y + \alpha_{11} Y_{t-1} + \dots + \alpha_{14} Y_{t-4} + \beta_{11} X_{t-1} + \dots + \beta_{14} X_{t-4} + \varepsilon_{Y,t}, \quad (2)$$

$$X_t = \mu_X + \alpha_{21} Y_{t-1} + \dots + \alpha_{24} Y_{t-4} + \beta_{21} X_{t-1} + \dots + \beta_{24} X_{t-4} + \varepsilon_{X,t}, \quad (3)$$

where $\varepsilon_{Y,t}$ and $\varepsilon_{X,t}$ are white noise disturbance terms with mean equal to zero. The estimation results of equation (2), most related to Potential Yes Votes, are listed in Table 2.

Table 2: Estimation Results: Equation for Potential Yes Votes in a VAR model

Potential Yes Votes at week t	Coefficient	Std Error	t-value	t-prob
Constant	2.6290	2.4880	1.0600	0.3074
Google Trends at t-1	0.0109	0.0027	4.0800	0.0010
Google Trends at t-2	0.0034	0.0070	0.4870	0.6330
Google Trends at t-3	-0.0007	0.0071	-0.0973	0.9238
Google Trends at t-4	0.0082	0.0064	1.2700	0.2241
Potential Yes Votes at t-1	1.3789	0.2388	5.7800	0.0000
Potential Yes Votes at t-2	-0.2933	0.4140	-0.7090	0.4895
Potential Yes Votes at t-3	-0.5640	0.4100	-1.3800	0.1891
Potential Yes Votes at t-4	0.3954	0.2367	1.6700	0.1154

Note: The significant coefficients are denoted in bold.

Using the VAR based approach we find that the effects of Google Trends on Potential ‘Yes’ Votes were significant only within one week. From the testing criteria on emotion or rationality, our results suggest that, after the rejection of the potential currency union in February 2014, the information-related Yes votes were driven by short-term emotion rather than long-term rationality, which also supports our findings in the last section that the effects of the Google Trends variable in the second regime were not significant. Our results are robust to the inclusion of the Google search volume of the key term ‘SNP’.

2.3.4 Projection of Referendum Results

Following the empirical tests and analysis in the previous sections, we project the final voting results of the approaching Scottish Referendum in this section. It is not an easy task to predict the results of the Scottish Referendum. Even the main polling companies were highly divergent on the opinions of the Scottish electorate. Based on our calculation of opinion polling results between 25th January and 16th August 2014, the average potential ‘Yes’ supporting rate from results of ICM, Panel base and Survation were 4.9% higher than from TNS BMRB, You Gov and Dipso Mori. Therefore, it is worth projecting the voting results from a different approach.

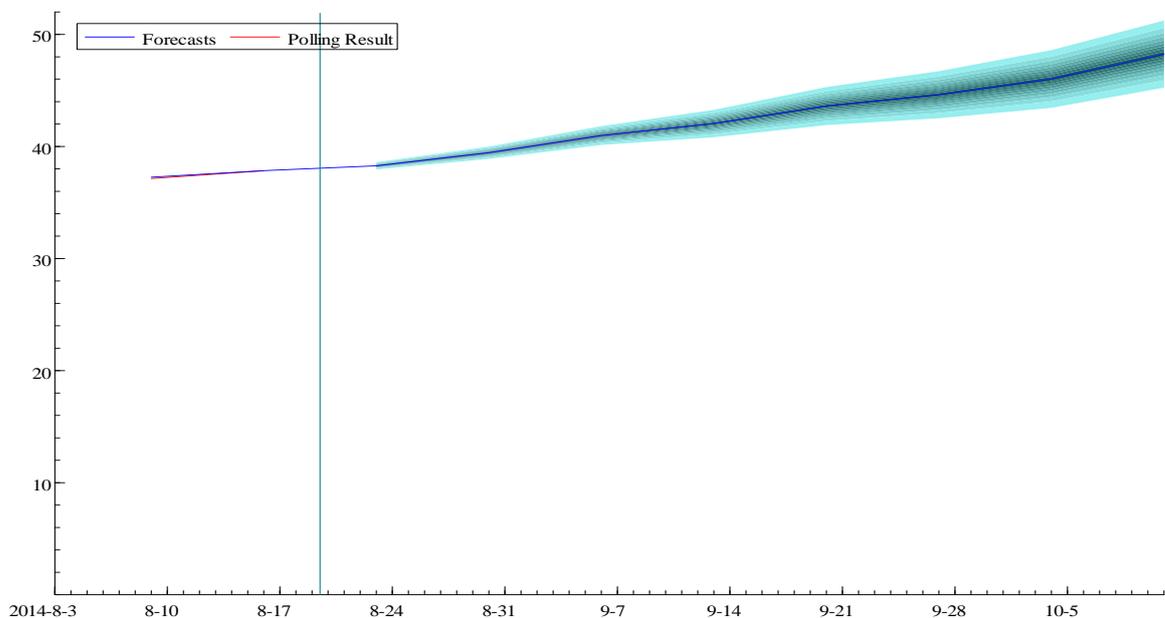
Our projection is based on the VAR model in section 2.3.2 and the procedures of Doornik and Hendry (2013). We first perform dynamic forecasts for the next 8 weeks with error variance only. We project that, based on available information until 16 August 2014, the ‘Yes’ side would get 42.8% of the total vote. And there was 90% chance that the ‘Yes’ campaign would get 41.9%-43.7% of the votes. The projection is illustrated in Figure 2.

However, we have to consider the uncertain situations in case unplanned events

happened between late August and mid-September 2014. Therefore, we perform dynamic forecasts with consideration of parameter uncertainty. In the latter case, we project that there was a 90% chance that the percentage of votes for independence was 38.0%-47.7%.

In summary, based on weekly information on voting intention and information demand until 16th August 2014, this section offers two types of dynamic projections, considering error variance and parameter uncertainty, respectively. In both cases, the projection for final 'Yes' voting results was less than 50%, which indicate that Scotland would remain in the UK. Nevertheless, the result is subject to further examination considering the information available in the last month before referendum.

Figure 2: Forecasts of 'Yes' Votes



Note: The error fans in the figure are defined with a 90% confidence interval.

3. The Momentous Month before the Referendum: An Examination

This section offers a unique examination of the twists and turns in the last month of the independence referendum using a daily data base, attributable to the availability of more frequent polling publications and daily Google search volume of several 'Yes'-related items. The data-base contains new information to identify the events and their short-term impact within a week, and analyse the daily dynamics of voting intention and information demand, which is not possible with a weekly data set.

Accordingly, this section specifies key events, updates previous projection results, based on new weekly information, and provides an innovative analysis of voting intentions, information demand, and key events with a newly constructed daily Google indicator. To be specific, our analysis based on daily data offers a detailed examination of the effects of key events on the referendum campaign and a thorough explanation why there was a jump in ‘Yes’ support from 37%, the average polling result of main pollsters on 9th August 2014, to 45%.

3.1 Key Events between Mid-August and Mid-September 2014

This section summarizes the key events that happened in the last month before the referendum in Table 3. The effects of the events on voters’ information search behaviour and voting intention are analysed in Section 3.3.

Table 3: Key Events between Mid-August and Mid-September 2014

Time	Events	Dummy
25 Aug. 2014	Broadcast of Scotland Decides: Salmond versus Darling	D0825
5-6 Sep. 2014	You Gov conducted and published the result of a poll indicating that ‘Yes’ lead ‘No’ for the first time in 2014.	D0905
11 Sep. 2014	Broadcast of Scotland Decides: The Big, Big Debate	D0911
15-16 Sep. 2014	BBC's News Night Broadcast of Cameron’s willingness of more devolution powers, and publication of the Vow by the three main unionist parties in the Daily Record	D0915

3.2 Updated Projection Results

This section updates the previous projection on ‘Yes’ votes with the information available until 13 September 2014, 5 days before the referendum. The events related to more devolution powers are not included in the above analysis for the following reasons: Firstly, the events and the referendum happened in the same week, which made the projection based on a weekly data set statistically impossible (using daily data we can, in the next sub-section, analyse actual events in the week before the referendum). Secondly, and more importantly, we would like to establish whether our projection results are robust to the unexpected events that happened in the week of the referendum.

With the available information until 13 September 2014, we project that the ‘Yes’ side would get 45.0% votes. There was a 90% chance that the ‘Yes’ campaign would get 44.8%- 45.2% of the votes. However, if unplanned events happened in the last few days before the referendum, we project that that there was a 90% chance that the percentage of votes for independence was 44.6%-45.4%. In summary, with updated weekly information, we get very precise projections on the final voting results using solely ex ante information (that is information available at the time and not in any way altered ex post)

3.3 Examination of the Referendum with an Innovative Daily Google Indicator

With an innovative indicator measuring daily information search activities of referendum voters, this section examines the interactions between information demand and voting intention in more detail. At the same time, it measures the effects of the events on the two variables between 7 August and 16 September 2014. Furthermore, we answer the question as to why there was a sharp increase in ‘Yes’ support in the last month. The frequent publications of the polling results and availability of recent daily Google Trends data permit us to conduct a more detailed analysis.

The daily Google Indicator is based on the daily Google search volume of the three most ‘Yes’-related items within Scotland, i.e., ‘Alex Salmond’, ‘SNP’ and ‘Scottish Referendum’. The key estimation results are shown in Table 4.

Table 4: Estimation Results of Daily Movements in a VAR model

Effects on Potential Yes Votes at day t				
	Coefficient	Std Error	t-value	t-prob
Potential Yes Votes at t-1	1.6016	0.1124	14.200	0.0000
Potential Yes Votes at t-2	-0.5984	0.1131	-5.2900	0.0000
‘Yes’ Search Indicator at t-4	-0.0023	0.0006	-3.64	0.0013
D0905	0.1157	0.0528	2.19	0.0386
Effects on ‘Yes’ Search Indicator at day t				
Potential Yes Votes at t-1	-17.11	6.3550	-2.6900	0.0127
Potential Yes Votes at t-4	22.0566	6.753	3.2700	0.0033
‘Yes’ Search Indicator at t-1	0.5791	0.1285	4.5100	0.0001
‘Yes’ Search Indicator at t-2	-0.2547	0.1306	-1.9500	0.0629
D0825	21.6201	6.4340	3.3600	0.0026
D0911	13.2757	6.6680	1.9900	0.0580
D0915	26.3178	7.3290	3.5900	0.0015

Note: All the coefficients in the table are significant.

The key findings are listed as follows. With respect to key events, the You Gov polling shock (D0905) did have significant and positive effects on ‘Yes’ votes, but no effects on the information search activities. However, all other events, i.e., the debates and the Vow, had no significant effects on the final voting results, although they matter to the search indicators.

The ‘Yes’ Search Indicator had negative effects on the ‘Yes’ votes, which means that the more information people were searching, the less likely they would vote ‘Yes’.

Noticeably, the Potential Yes Votes had significant short-term effects on the final ‘Yes’

votes. To be specific, the combined effects of a 1% increase in 'Yes' supporters on day t-1 and t-2 is around 1% increase in 'Yes' votes. The finding means that the grassroots 'Yes' supporters managed to persuade many swing votes during the last month, which seems to reflect the 'Yes' side's strength in terms of local mobilisation.

In sum, the results in this section indicate that most key events in the last month before the referendum failed to affect the final voting results and that the key factor shifting the 'Yes' Vote to 45% was existing 'Yes' Campaigners persuading swing voters to vote 'Yes'. However, our results also show that if swing voters had relied purely on referendum-related information on Google, they were unlikely to vote 'Yes'.

4. Summary

It is not a straightforward task to unravel the issues underpinning the Scottish referendum result: the event was intertwined with emotion and rationality, planned and unplanned events, etc. In this paper using the big data of Google Trends and advanced econometric methods, we are able to show a distinctive picture of the Scottish referendum from that provided by traditional approaches.

With a weekly data set between 25 August 2013 and 16 August 2014, we demonstrate that currency was the key issue during the referendum campaign period which changed the whole structure of voters' opinion and attributed a 4.3% increase in 'Yes' votes. However, between 16th March and 16th August 2014, there was not enough *clear* information for potential 'Yes' voters who finally cast their votes driven by short-term emotion. Furthermore, there was no significant information-related 'Yes' momentum and the 'No' side indeed prevailed. The projection of final 'Yes' voting results was just at targeted, about 45%

With a daily data set of polling results and an innovative Google indicator, we also provide a detailed examination on the key events and the 'Yes' support jump in the final month before the referendum. The broadcasts of several debates and the Vow by three main UK party leaders actually had no direct effects on the voting results and indeed swing voters tended to vote 'No' after searching referendum-related information from Google.

Although innovative our information-demand-based big data approach is subject to further improvements and refinement in terms of further tests and examination. However, we believe this is an important first step in building a well-functioning real-time information indicator measuring society's voting intentions.

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