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POLITICAL UNCERTAINTY AND STOCK MARKET VOLATILITY: NEW EVIDENCE FROM THE 2014 SCOTTISH INDEPENDENCE REFERENDUM

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Political uncertainty and stock market volatility: new evidence from the 2014 Scottish Independence Referendum

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Abstract

This paper investigates the extent to which companies headquartered in Scotland were exposed to heightened political uncertainty in the run-up to, and after, the 2014 independence referendum. Using a specially constructed capitalisation weighted stock price index for Scottish companies listed on the London stock exchange, evidence is presented to show that in the early part of the sample period, from April 2010 to late 2013, the conditional volatilities of the Scottish stock returns and of returns in the FTSE all share index can be characterised by the same GARCH parameters, but this is no longer the case once the estimation period is extended closer to the referendum date. Further investigation indicates that the relative volatility of Scottish companies' stock returns peaked in early September 2014, when the polls suggested the referendum result was too close to call, fell back after the referendum result was known, but built up again in the run up to the publication of the Smith Commission's report on further devolution in November 2014. These key findings are found to be robust to the inclusion/exclusion of the Royal Bank of Scotland, the whole of the Scottish financial sector, and companies operating in the oil and gas sector from the Scottish stock price index.

Keywords: Scottish independence referendum; stock market volatility; political uncertainty.

Subject classification codes: C32; G10; G14.

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1. Introduction

An interesting feature of referendums is that they are often motivated by the desire to resolve big debates, or to settle issues characterised by strong and divergent views, once and for all. Unlike countries such as Switzerland where referendums have been commonplace, in the UK they had been much less frequent. But two big referendum campaigns – the Scottish independence referendum in 2014 and the EU referendum in 2016 – have had highly significant implications for the UK economy.

One consequence of referendums can be a rise in uncertainty. This is especially likely when the economic and political stakes are high, as was the case during both the Scottish independence and EU referendums. The effects are also likely to be strongest when the outcome is uncertain, as again was the case in the run up to the Scottish independence and EU referendums (in both cases, opinion polls shortly before the vote put both sides within sight of victory). In a world of 24 hour news coverage, it is also much more likely that every scrap of information, both credible and more speculative, is shared across a wider number of people. This too can lead to heightened uncertainty.

This paper examines information from financial markets in the run up to, and immediately after, the 2014 Scottish independence referendum. To the best of our knowledge it is the first study to focus on stock market volatility around the time of the Scottish independence referendum. More specifically, we construct a capitalisation weighted daily stock price index for Scottish companies listed on the London stock exchange, and model stock returns for this index as compared to returns for the FTSE all share index. We are able to show that for the early part of our sample period, from April 2010 to late 2013, the conditional volatilities of the Scottish stock returns and of returns in the FTSE all share index can be characterised by the same GARCH parameters, but that this is no longer the case once estimation extends beyond mid December 2013. Upon further investigation we show that that the relative stock market volatility of Scottish companies' stock returns peaked in early September 2014, at a time when the polls suggested the referendum result was too close to call, fell back after the referendum result was known, but built up again in the run up to the publication of the Smith Commission's report on further devolution in November 2014. We demonstrate that these findings are robust to the inclusion/exclusion of the Royal Bank of Scotland; to the exclusion of the whole of the Scottish financial sector; and to the exclusion of Scottish listed companies operating in the oil and gas sector.

Note that this analysis does not constitute an attempt to assess whether or not Scottish independence would be good or bad for the economy. Instead it is designed to investigate the impact of the referendum itself on financial market volatility, to see whether or not the referendum added significantly and differentially to the volatility of stock returns of Scottish companies as compared to the FTSE as a whole; and to determine whether any differential impact diminished rapidly once the referendum result was revealed.

Stock market volatility matters in part because it is likely to discourage new share issues and initial public offerings. The performance of companies' shares also impacts on lenders' risk assessments, meaning that higher volatility can result in an increase in the companies' costs of borrowing. Recent research, see for example Bloom, Baker and Davis (2013), has suggested that the kind of political uncertainty associated with elections and referendums can increase unemployment and reduce investment, but this will matter less if any period of heightened volatility is short lived.

It is interesting to note that since the 2014 referendum, the Scottish economy has grown much more slowly than the UK as a whole. Over the two years to the end of 2016 for example, the UK economy grew by 3.6% while the Scottish economy grew by just 1.2%. A number of prominent business leaders and politicians have expressed fears that the uncertainties caused by 2014 referendum – and a possible future re-run – could, in part, be a reason for this much weaker performance.

The remainder of the paper proceeds as follows: section 2 briefly discusses some key findings in related literature, which help to motivate our work; section 3 sets out a timeline of key events in the run up to, and in the aftermath of, the 2014 Scottish independence referendum. In section 4 we explain how the publicly listed companies headquartered in Scotland were identified and describe the data used in this study. Section 5 outlines the econometric methodology employed. Section 6 presents the key results. A number of robustness checks are carried out in section 7 and section 8 concludes.

2. Related literature

There are very few empirical studies of the impact of referendums on stock market volatility. Nonetheless a number of studies have examined the behaviour of stock market volatility around the time of elections: these include Goodell and Vähämaa (2013) and Li and Born (2006) who focused on US presidential elections; Smales (2014) who looked at Australian elections; and Bialkowski, Gottschalk and Wisniewski (2008) who looked at evidence for 27 OECD countries around the time of national elections. Each of these studies concluded that elections are accompanied by a significant hike in stock market volatility, and demonstrated that this heightened volatility is more pronounced in closely contested races when polling suggests that no candidate has a dominant lead. They also point to a number of cases in which the excessive volatility could not be resolved quickly, for example when the political orientation of the government changes or when the election result was inconclusive. These empirical results are consistent with the theoretical predictions of Pástor and Veronesi (2012, 2014).

Other aspects of political uncertainty have been studied by Siokis and Kapopoulos (2007) who provided evidence that political regime changes impacted on the conditional variance of the Athens stock market indices. Alongside the multi-country results presented by Bialkowski *et al.* (op. cit.), Vuchelen (2003) emphasised that election results tend to contain much less information about future policies in coalition-based political systems. Whilst election results may have some impact in reducing uncertainties by eliminating some possibilities, more decisive positions only become clear once a new coalition has been announced. Using Belgian data he demonstrated that election outcomes are considered by investors with a time lag while the formation of a new coalition that tends to have the more significant impact on the stock prices at the Brussels Stock Exchange. This kind of timing issue may be relevant after the Scottish referendum result too, particularly given that neither a ‘yes’ or ‘no’ vote was going to result in prolonging the status quo. As is explained in section 3, a commitment had been given prior to the vote by the then leaders of the three main UK parties campaigning against Scottish independence, that further powers would be devolved to the Scottish Parliament should voters opt to remain within the UK.

Arin, Molchanov and Reich (2013) examined the effects of a number of political variables on stock returns and their volatilities using Bayesian methods applied to a panel dataset for 17 parliamentary democracies spanning the post-war period until 1995. They argued against focusing only on election years and found the empirical case for effects of political variables on stock return volatilities was considerably stronger than the case for effects of these variables on stock returns.

Far fewer studies that have explored how political uncertainty influences financial markets outside of the election cycle. An exception, with some similarities to our own, is Beaulieu, Cosset and Essadam (2006). This paper focuses on the Quebec referendum in October 1995 which could have led to the separation of Quebec from the Canadian federation. As in the Scottish case, opinion polls did not agree on a clear winning side, so uncertainty associated with the Quebec referendum could not be resolved prior to the vote. Even after the result, when 50.6% voted No, it was not clear that this had immediately resolved uncertainty with respect to Quebec's future.

The impact of the resolution of uncertainty has been investigated in several papers that look at the behaviour of asset price volatility around the time of scheduled information releases. The clear consensus of these empirical studies is that volatility in financial markets tends to: i) be significantly greater on announcement days than on other days; ii) remain significantly higher for several hours after the information release; and iii) dissipates rapidly as uncertainty is resolved; see for example, Smales (2013), Vähämaa and Äijö (2011), Chen and Clements (2007), Nikkinen and Sahlström (2004), and Donders and Vorst (1996) and Ederington and Lee (1996, 1993).

The Beaulieu et al. (op. cit.) paper on the impact of the Quebec referendum provides a particularly helpful starting point for our own work. In particular, they sought to contrast the impact of the uncertainty surrounding the referendum outcome on the stock returns of 71 Quebec firms as compared to a sample of Canadian (apart from

Quebec) and U.S. firms. Their choice of Quebec firms was based upon those headquartered in the province of Quebec and listed on the Montreal Stock Exchange and/or on the Toronto Stock Exchange at the time of the referendum. They found that the uncertainty surrounding the referendum outcome had a significant, but ultimately short-term impact on the stock returns of Quebec firms. Furthermore, the reaction of financial markets to the referendum outcome was indicative of a resolution of uncertainty, which they found to be particularly important for domestic Quebec firms.

3. The Scottish Independence Referendum Timeline

The Scottish independence referendum took place on 18th September 2014. The process toward that referendum began in earnest following the Scottish Nationalist Party's victory in the Scottish Parliament election of 5th May 2011 which effectively gave the First Minister, Alex Salmond, the mandate to push forward with the party's plans for the independence referendum. He quickly confirmed his intention to hold the referendum in the second half of the five year electoral term. Intentions were further firmed up on 10th January 2012, when the First Minister announced that the referendum would be held in the autumn of 2014. There followed a protracted period of negotiations between the UK and Scottish governments over the necessary constitutional arrangements. These negotiations culminated in the Edinburgh Agreement, signed on 15th October 2012[1]. The final wording of the referendum question was agreed on 30th January 2013 and the date of the referendum was announced on 21st March 2013.

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[1] The full text of the Edinburgh Agreement: Agreement between the United Kingdom Government and the Scottish Government on a referendum on independence for Scotland, 15 October 2012, is available here: http://www.gov.scot/Resource/0040/00404789.pdf.

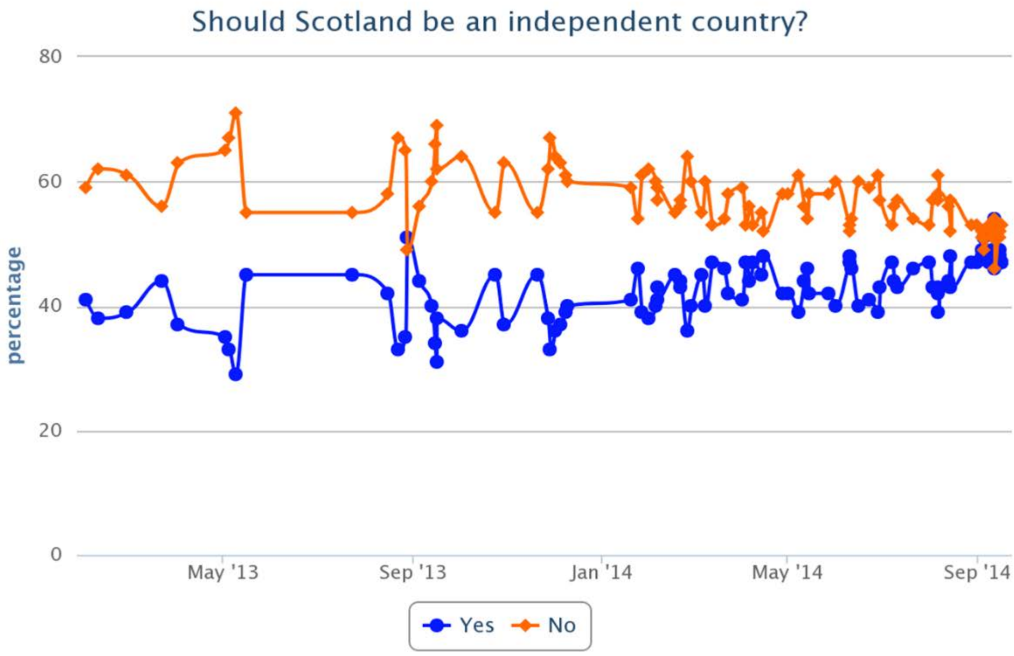
In November 2013 the Scottish Government published ‘Scotland’s Future’ – their ‘blueprint for independence’[2]. During February and March of 2014 the debate was dominated by the ‘currency question’. On 16th June 2014, the Scottish Government published their white paper "Scottish Independence Bill: A consultation on an interim constitution for Scotland"[3]. Both campaigns were well underway when televised debates took place on the 5th and 25th of August.

Initially information on voting intentions was captured relatively infrequently. There were just four opinion polls conducted by British Polling Council members published between May 2011 and the end of that year. Results of a further eight polls were published during 2012, of which half took place around the time of the Edinburgh Agreement. Unsurprisingly, polling intensity increased during 2013 with results of 23 polls published in that year, and a total of 69 poll results published between 3rd January and 17th September 2014. Of these, 20 were conducted in the final month before the vote. During this final pre-referendum period, the gap between the proportions of those intending to vote Yes and No narrowed, as is evident in Figure 1.

Of particular note was a YouGov poll conducted for the Sunday Times, published on 7th September 2014, which found that 51 per cent of voters in Scotland would back independence, compared with 49 per cent opposed (when undecided voters were excluded). This result marked a four point increase in support for a Yes vote in less than a week. This was followed by a TNS poll made public on the night of 8th September which put the two campaigns neck and neck.

[2] Scottish Government (2013) Scotland’s Future: Your Guide to an Independent Scotland, 29th November, is available here: http://www.gov.scot/Resource/0043/00439021.pdf.
[3] Scottish Government (2014) Scottish Independence Bill: A consultation on an interim constitution for Scotland, June 16, 2014, is available here: http://www.gov.scot/Publications/2014/06/8135.

Figure 1. Poll results in the run up to the Scottish independence referendum



Source: ScotCen Social Research, "What Scotland Thinks" http://whatscotlandthinks.org/questions/should-scotland-be-an-independent-country#line

Writing on 9th September 2014, Professor John Curtice – one of the UK's most respected psephologists – expressed a common view:

> *"As a result of today's poll, our poll of polls… has been updated. On that measure Yes support has edged up again and now stands at 48%, with No on 52%. The referendum race is now clearly too close to call."*
>
> http://blog.whatscotlandthinks.org/2014/09/tns-now-say-it-is-a-dead-heat/

These polls resulted in a flurry of activity: George Osborne, the then Chancellor of the Exchequer, announced on the morning of 7th September that a cross-party agreement on new powers for the Scottish Government in relation to taxation and welfare would be confirmed “within days”. This led to the ‘Vow’ being published, two days before the vote, where the then leaders of the three main UK parties campaigning against Scottish independence committed to “extensive new powers” for the Scottish Parliament should voters opt to remain within the UK, "delivered by the process and to the timetable agreed" by the three parties[4].

Ultimately, the vote took place on the 18th September 2014 and the final result was declared on the 19th September 2014. The Prime Minister, David Cameron, established the Smith Commission on the same day with the aim of delivering the ‘Vow’. The Commission reported on 27th November 2014[5], making a number of recommendations in relation to further devolution of powers to the Scottish Parliament. Legislation based on these recommendations was implemented in the Scotland Act 2016, which received Royal Assent on 23rd March 2016[6].

During the referendum campaign, many Scottish companies were initially reluctant to make explicit statements either in favour or against Scottish independence for fear of alienating their shareholders, customers or workforce. However, as the vote approached, there was an increasing flurry of media stories around the consequences of independence. In addition, the UK Government’s campaign put economic uncertainty at

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[4] The vow, a letter signed by the three main UK party leaders, appeared on the front page of the Daily Record on 16th September 2014, see http://www.dailyrecord.co.uk/news/politics/david-cameron-ed-miliband-nick-4265992.

[5] The Report of the Smith Commission for further devolution of powers to the Scottish Parliament is available here: http://webarchive.nationalarchives.gov.uk/20151202171017/http://www.smith-commission.scot/wp-content/uploads/2014/11/The_Smith_Commission_Report-1.pdf.

[6] For further details see http://services.parliament.uk/bills/2015-16/scotland/documents.html .

the heart of much of its argument for Scotland remaining in the UK (UK Government, 2014).

A number of firms were required by corporate governance rules to inform their investors of their contingency plans in the event of a ‘Yes’ vote – including two of the country’s largest financial services companies Standard Life and Royal Bank of Scotland (see, for example, the discussion in the Financial Times, “Standard Life warns on Scots ‘Yes’ vote” published on 27th February 2014).

The timeline of events set out above has informed the choice of sample period in this study. In order to capture key events in the run-up to the referendum date, the estimation period starts in April 2010. In order to examine whether any financial market impacts of uncertainty surrounding the referendum result were resolved after the results were announced, the post referendum sample extends to June 2015. We avoid extending the sample beyond this, e.g. to include the run up to the Brexit referendum, since we want to focus on the period in which Scotland could reasonably be seen to be experiencing uncertainty in a way that is distinctive to that facing the UK as a whole.

4. Data

The first step toward constructing a Scottish stock price index is to identify companies listed on the LSE that can be classified as ‘Scottish’ during the period under study. The key criteria applied are that selected companies had their headquarters in Scotland and/or that their major operations were located within Scotland, during part or all of the sample period investigated. A similar strategy is discussed in Marsh and Evans (2014) although they included Investment Trusts in their index, while we choose to exclude them[7]. From our perspective these types of firms have unique characteristics given their status as investment vehicles. In particular, they are typically run by a very small management team and have limited 'footprint' within the local economy. Our decision to omit them reflects our desire to look at a purer measure of the impact of political uncertainty on Scottish companies.

An alternative approach could be to look at all UK based listed companies' exposure to the potential outcomes of the referendum, differentiating by whether they have any operations in Scotland or not, and by what proportion of their revenues are attributable to sales in Scotland, or perhaps what proportion of their total UK employees are located in Scotland. However this kind of information is simply not available. In any case, in our view it is important to note that uncertainty around independence wasn't just about how well Scotland would perform economically, it was also about fundamental legal and constitutional structures, economic rules and regulations, membership of the EU and applicability of global treaties etc. Many of these factors would have a distinctive impact on companies headquartered in Scotland, not just how exposed they were to our market share. So, for example, two financial services companies with equal market share in Scotland faced a completely different set of risks if one was registered in London and the other in Edinburgh.

Several sources of relevant information were consulted to inform this approach.

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[7] Marsh and Evans (op cit.) reported that 10 of the top 20 Scottish listed companies by market capitalisation at the start of 2014 were Investment Trusts. Investment Trusts were also the second largest sector represented in stock listings, by market capitalisation, "with an astonishing 26% weighting" while this sector has "…just a 3% weighting within the UK as a whole" p4. Based on the reference point of the August 2013 historical files from the London Stock Exchange, we disregarded prices of 39 shares that Marsh and Evans would have included: for 31 'Equity or Non-Equity Investment Instruments', 2 'Real Estate Holding and Development' companies, 3 'Specialty Finance' companies and 3 'Debenture and Loan' companies. Other differences in the number of listed shares reflect exclusions we made following scrutiny of the annual reports held at Companies House, as discussed in the main text.

Up until August 2013, the London Stock Exchange's historical files provide a 'region' indicator for each company. Also, each issue of Business Insider Magazine provides a list of 'Scotland's quoted companies', along with some accompanying commentary on the biggest movers. Lists compiled from these sources were cross-checked against information from Companies House, including each candidate listed company's Annual Reports. This allowed us to investigate any conflicts; to clarify where corporate headquarters are located; and to check that each company does indeed have major operations located in Scotland. Annual reports were also helpful in providing dates of relevant relocations, mergers, closures or de-listings.

A total of 64 Scottish companies listed on the London stock exchange were identified for inclusion in the constructed Scottish stock market index for at least some part of our chosen sample period which extends from 6th April 2010 – 4th June 2015, i.e. one month before the UK General Election in 2010 until one month after the UK General Election in 2015. Table 1 summarises information on the numbers of Scottish listed companies as well as the numbers of entrants and exits during each year of the sample. Within any one year of the sample there were at most 56 Scottish companies in the index.

Table 1. Numbers of Scottish companies listed on the London Stock Exchange

End Year	2010	2011	2012	2013	2014	2014	2016
Number of companies	56	56	51	48	48	45	40
Entrants during the year	4	3	2	0	1	0	0
Exits during the year	1	3	7	3	1	3	5

Source: authors' calculations.

From the above table it is clear that the number of Scottish listed companies has fallen over the last six years, and that no Scottish companies were newly listed on the LSE over the period since the referendum (the last being Exova Group, a leading provider of laboratory based testing and related advisory services, founded in 2008 and headquartered in Edinburgh, who were first listed on the LSE in April 2014). There are no obvious common features among the eleven companies that are dropped from the list of Scottish listed companies between the date of the Scottish election in May 2011 and the Independence referendum in September 2014. Nor are there any obvious common features among the eight companies that have delisted from the LSE since the independence referendum[8]. None of these companies made any mention of the referendum featuring in their decision making with respect to mergers, listing or delisting in the relevant years' annual report.

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[8] Companies that were initially included in the construction of our Scottish stock price index but are dropped at some point after the Scottish election in May 2011 and prior to the referendum are: Forth Ports, acquired by London based Arcus Infrastructure Partners in June 2011; Croma Group, formerly a Dumfries based aerospace and defence company and Pinnacle Telecom Group plc both dropped after reverse takeovers saw them moving key operations and their HQs to locations outside of Scotland in March 2012 and by March 2014 respectively; Wolfson Microelectronics, de-listed in April 2014 following acquisition by US based Cirrus logic; Lee Foods, delisted on the LSE in 2012 after a management buyout; Robert Wiseman Dairies plc, delisted after a takeover by Mueller in February 2012; 3D Diagnostic Imaging ltd, dropped in October 2012 when the company was re-named and re-focused as an investment company; former oil and gas companies, Deo Petroleum, Dana Petroleum and Melrose Resources, delisted in August 2012 September 2012 and October 2012 respectively, after becoming a subsidiary of Parkmeed Group, a takeover, and merging with Dublin based Petroceltic International plc; Quayle Munro who moved their HQ to London in July 2012 and delisted from the LSE a year later before re-registering as a private investment company; Dundee based media company I-Design Group plc, delisted in May 2013 and re-registered as a private company; and finally Angel Biotechnology Holdings who went into administration February 2013 and were delisted in April 2013. Those that have been delisted since the referendum are: Optos, a leading medical technology company based in Fife, focusing on design, manufacture and marketing of ultra-widefield retinal imaging devices, acquired by Nikon in February 2015; Rangers International FC, whose shares were suspended from trading in March 2015; John Swan and Sons, an Edinburgh based livestock auctioneer acquired by Carlisle based H&H Group in October 2015; Interbulk Group PLC, a Glasgow based provider of intermodal logistics solutions to the chemical and mineral industries, now part of Netherlands based Den Hartogh Holding B.V.; Aberdeen based SeaEnergy PLC, delisted after entering administration in July 2016; Energy Assets Group, a fast growing independent supplier of metering services, analytics and utility network services, after acquistion by BidCo Limited in July 2016; Greenock based British Polythene Industries, acquired by Nothamptonshire based RPC Group in June 2016, and Stirling based Superglass Holdings, previously the UK's biggest independent manufacturer of glass mineral and wool insulation, delisted in September 2016 after agreeing to be acquired by a Cyprus based investment company.

Scottish companies are included in the Scottish stock price index from the start of the sample or, where relevant, from the date of listing, up until any date of relocation, merger – with parent company located outside of Scotland, or date of delisting from the London Stock Exchange. This approach contrasts with that used in Beaulieu et al. (op cit.) where Quebec based companies were included in their sample if they were identified as having been listed and headquartered in Quebec at the date of the referendum. In practice this would, for example, miss out any companies that made a strategic move to relocate their HQ prior to the referendum date, any companies making a new listing, or existing listed companies transferring their HQ to Quebec after the referendum. Given the changes observed in the number of Scottish listed companies over our sample period, we believe it is particularly important to avoid any potential bias that could arise from focusing only on companies that were headquartered in Scotland on the date of the Independence referendum.

Beaulieu et al. constructed a matched sample of Quebec and US/Canadian companies using capitalisation and other data as close to the date of the referendum as possible. We were keen to avoid the short-cut of fixing capitalisation weights throughout the sample period. Even a look at the variation in the market capitalisation of the top 10 Scottish listed companies at some key dates suggests this would be unwise, see Table 2 below. We therefore collected daily data on both market capitalisation and stock prices for each Scottish listed company from Datastream, and chose to construct a capitalisation weighted stock price index in which the capitalisation weights are updated each period, mimicking the construction of the FTSE indices as closely as possible.

Table 2. Top 10 Scottish Listed Companies by Market Capitalisation

31st December 2009		18th September 2014		20th October 2016	
RBS	31.8	RBS	30.0	RBS	33.2
SSE	20.7	SSE	19.7	SSE	24.6
Standard Life	9.4	Standard Life	13.2	Standard Life	10.0
Cairn Energy	9.0	Aberdeen Asset Man't	7.6	Aberdeen Asset Man't	6.4
Aggreko	4.9	Weir Group	7.5	Weir Group	5.8
First Group	4.0	Aggreko	5.5	Wood Group	4.6
Wood Group	3.2	Wood Group	3.7	Aggreko	3.3
Weir Group	2.9	Stagecoach Group	2.8	First Group	1.9
Aberdeen Asset Man't	2.6	First Group	1.9	Cairn Energy	1.9
Stagecoach Group	2.4	Cairn Energy	1.4	Stagecoach Group	1.7
% of market cap	**90.8**		**93.2**		**93.4**

Source: Datastream and authors' calculations.

The presence of the Royal Bank of Scotland (RBS) in our sample raises some 'interesting' issues. As is well known, RBS received a substantial bail-out during the depths of the financial crisis. Throughout our sample period the UK Government held 81% of the company's shares. Given the peculiarities of this special case, our core sample excludes RBS shares from the construction of the Scottish share price index, nonetheless, at various points we also show results that do include RBS in the index.

More generally the finance sector makes up a large, and growing, part of the Scottish stock price index than the FTSE over the sample period considered here. Another sector that has historically had strong representation among Scotland's listed companies is the oil and gas sector. This sector has also been subjected to particular challenges over the period we investigate – with the oil price falling from around $100 per barrel in 2014 to half that by the end of 2015. These considerations have motivated us to construct of a number of additional indicies which are used in several robustness checks discussed in Section 6. For now we simply summarise market capitalisation by sector over each full calendar year from 2010 to 2015 in Table 3.

Table 3. Top 10 Scottish Listed Companies by Sector

End year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Financial Services	44.5	35.6	48.6	50.4	53.6	60.8
Electricity	16.9	22.4	20.7	18.8	21.2	20.0
Engineering +Technology	10.7	13.1	10.7	10.6	8.7	6.0
Business support services	6.9	11.3	8.7	8.4	7.0	5.1
Oil & Gas producers	12.1	8.7	4.0	3.6	2.1	1.6
Travel & Leisure	5.4	6.3	4.8	5.5	4.9	4.1
Food & Beverages	1.6	2.0	1.7	1.6	1.6	1.4
Media	1.4	0.5	0.5	0.5	0.6	0.4
Other	0.5	0.0	0.4	0.5	0.3	0.4

Source: Datastream and authors' calculations.

Daily data were also collected for the FTSE all share index, which is used as a benchmark series to compare and contrast with the volatility of the Scottish indices. Focusing on comparing the volatility of stock returns based on alternative capitalisation weighted stock price indices with that of the FTSE all share index avoids us having to match each individual Scottish listed company with a 'similar' company located elsewhere in the UK. In our view, attempting this kind of matching would be both non-trivial and, in many cases, controversial. The FTSE all share index is chosen over the

FTSE100 or FTSE250 since there are relatively few of the Scottish companies represented in these alternative indices. We discuss the suitability our choice of the FTSE all share index as the benchmark index further in Section 6.

Summary statistics for the key series investigated over the full sample, i.e. all trading days from 6th April 2010 to 4th June 2015, are provided in Table 4.

Table 4. Summary Statistics for Daily Percentage Change in Stock Price Indicies

N=1304	**FTSE all share index**	**Scottish index**	**Scottish exc. RBS**	**Scottish exc. finance sector**
Mean	0.023	0.023	0.040	0.029
Std. deviation	0.957	1.322	1.034	1.012
Skewness	-0.132	-0.033	-0.236	-0.260
Kurtosis	5.490	5.666	4.992	5.379
Maximum	5.154	8.440	4.506	4.293
Minimum	-4.490	-6.995	-5.488	-5.767
Shapiro–Francia test (H_0: normality)	7.697 [.00]	7.142 [.00]	6.816 [.00]	7.155 [.00]
Skewness t-test	-1.948 [.05]	-0.481 [.63]	-3.437 [.00]	-3.842 [.00]
Ex.Kurtosis t-test	18.35 [.00]	19.65 [.00]	17.54 [.00]	17.54 [.00]
ARCH 1 $\chi^2(1)$	39.98 [.00]	48.58 [.00]	35.31 [.00]	40.39 [.00]
ARCH 5 $\chi^2(5)$	148 [.00]	131 [.00]	126 [.00]	131 [.00]
ARCH 10 $\chi2(10)$	171 [.00]	167 [.00]	170 [.00]	197 [.00]

Probability values for the various tests are shown in [.].

On the basis of the Shapiro-Francia test, the null hypothesis that the respective stock returns series are normally distributed is rejected conclusively in each case, this is not unexpected. Skewness that is significantly different from 0 and kurtosis different from

3 signifies non-normality. The appropriate t-tests of H0 : skewness = 0 and H0 : no excess kurtosis are reported and the results are consistent with excess kurtosis in every case, with significant skewness in most, but not all, cases. Furthermore, normal quantile plots of all three series are suggestive of symmetric distributions with fat tails; i.e. extreme positive and negative values of returns occur more frequently in the data than would be consistent with the normal distribution. The final three tests reported in Table 4 provide evidence of significant autoregressive conditional heteroscedasticity in each series, which is supportive of the need for the GARCH modelling strategy adopted in this paper.

5. Econometric Methodology

Our key objective is to examine the extent to which listed companies headquartered in Scotland were exposed to heightened political uncertainty in the run-up to, and after, the 2014 independence referendum. To achieve this objective, having constructed the stock price indicies described in the previous section, and after calculating daily returns, i.e. the percentage change in each stock price index, a set of bivariate and univariate GARCH models are estimated to both capture and compare the conditional volatility of stock returns as represented by the Scottish stock price index on the one hand and the FTSE all share index on the other.

Specifically, having demonstrated that the stock returns series exhibit significant volatility clustering on the basis of the ARCH effects identified in Table 4 above, we estimate a bivariate GARCH model which provides time-varying estimates of the conditional covariance matrix for Scottish and FTSE all share stock returns. A number of multivariate GARCH specifications are available, all of which allow the conditional variances and covariance of the stock returns to depend on their own past history. Following Bollerslev, Engle and Wooldridge (1988), we choose to use the relatively parsimonious diagonal VECH representation which assumes that the conditional covariance matrix is diagonal, implying that each variance and covariance depends only on its own past history. In the bivariate DVECH GARCH(1,1) model the conditional variances and covariances are specified as follows:

$$h_{11t} = \sigma_{1,t}^2 \quad = \varpi_{11} + \alpha_{11}\varepsilon_{1,t-1}^2 + \beta_{11}\sigma_{1,t-1}^2$$

$$h_{12t} = \sigma_{1,t}\sigma_{2,t} = \varpi_{12} + \alpha_{12}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{12}\sigma_{1,t-1}\sigma_{2,t-1}$$

$$h_{22t} = \sigma_{2,t}^2 \quad = \varpi_{22} + \alpha_{22}\varepsilon_{2,t-1}^2 + \beta_{22}\sigma_{2,t-1}^2$$

The model also incorporates mean equations for the two stock return series. We shall investigate whether lags of each of the returns series play any significant role in the two mean equations, either individually or jointly. Our expectation is that they will not, in line with the common finding that stock returns are unpredictable, while we expect to be able to capture systematic elements of conditional volatility in the equations set out above.

Under the assumption of conditional normality the system of equations that characterise the DVECH GARCH(1,1) model can be estimated by maximum likelihood. The standard GARCH coefficients, $\{\alpha_{11}\ \beta_{11}\ \alpha_{22}\ \beta_{22}\}$ capture how lagged shocks and conditional volatilities impact on the current conditional volatilities. The coefficient α_{12}, attached to the past product term $\varepsilon_{1,t-1}\varepsilon_{2,t-1}$, captures co-movements across markets, while the coefficient β_{12} on the term $\sigma_{1,t-1}\sigma_{2,t-1}$ captures the persistence of covariance. Likelihood ratio tests will be applied to test the null hypothesis of a constant conditional covariance matrix i.e. to check whether it is data admissible for the parameters $\{\alpha_{11}\ \beta_{11}\ \alpha_{12}\ \beta_{12}\ \alpha_{22}\ \beta_{22}\}$ to be jointly restricted to 0.

Within this bivariate set-up, we are also able to test the null hypothesis that the conditional volatilities of the two series can characterised by the same GARCH process, that is $\alpha_{11} = \alpha_{22}$ and $\beta_{11} = \beta_{22}$. If this null hypothesis is data admissible, at least over some part of the sample period that we examine, this provides some justification for using the FTSE all share index as a reasonable benchmark against which to compare volatilities Scottish companies' stock returns. In the results presented in Section 6 we first look at the full sample period and find that the null hypothesis is rejected, but then find that if estimation is ended in October 2012, at the point that the Edinburgh Agreement was signed, this null hypothesis of equality of the GARCH parameters cannot be rejected. Then by successively rolling forward the end date of the sample used in estimation we are able to investigate at what point in time there is sufficient evidence to conclude that the parameterisation of the volatility of Scottish stock returns differs from that of returns on the FTSE all share index. Nonetheless, results from this kind of sequential testing should be seen as relatively informal, and indicative, since tests of this kind are not statistically independent, with the consequence that the true size of the tests is likely to be distorted.

One disadvantage of bivariate GARCH modelling is the imposition of symmetry in the effects of positive and negative shocks. We therefore move on to separate univariate modelling of the conditional volatility of the two stock returns series, exploiting the greater flexibility this allows. Both exponential (EGARCH) and threshold (TGARCH) models, proposed by Nelson (1991) and Glosten, Jagannathan and Runkle

(1993) respectively, are shown to be more appropriate than the simple GARCH model for our data. Again this is not unexpected. Both these specifications allow for asymmetric effects of shocks on volatility, in the sense that 'bad news' in the form of a drop in the share price index tends to be followed by higher volatility than 'good news' i.e. a rise in the index of the same magnitude. The precise specifications of the conditional volatility equations in each of these cases is are shown below:

$$\text{GARCH}(1,1): \qquad h_t = \sigma_t^2 = \varpi + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$$

$$\text{EGARCH}(1,1): \qquad \ln h_t = \varpi + \beta \ln \sigma_{t-1}^2 + \gamma\frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \alpha\frac{|\varepsilon_{t-1}|}{\sigma_{t-1}}$$

$$\text{TGARCH}(1,1): \qquad h_t = \sigma_t^2 = \varpi + \alpha\varepsilon_{t-1}^2 + \gamma d_{t-1}^{+}\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$$

$$\text{where } d_{t-1}^{+} = 1 \text{ if } \varepsilon_{t-1} > 0, \text{ and } = 0 \text{ otherwise.}$$

Another issue to be confronted in the univariate modelling is the choice of distribution assumed in estimation. This choice is fundamental to obtaining efficient parameter estimates and to admitting the extreme errors that financial markets sometimes produce. The initial examination of our data, as summarised in Table 4, indicated that the returns series are far from normally distributed: each of the key stock returns display significant skewness and excess kurtosis. Weiss (1986) and Bollerslev and Wooldridge (1992) have demonstrated that even when normality is inappropriately assumed, maximising the Gaussian log-likelihood results in quasi maximum likelihood estimation that is both consistent and asymptotically normally distributed but inefficient, provided that the conditional mean and variance of the model are correctly specified. Whilst the calculation of Woolridge's robust standard errors is feasible, if the standardised residuals follow a skewed distribution then Engle and Gonzalez-Rivera (1991) and Bollerslev and Wooldridge (op cit.) have shown that quasi maximum likelihood estimation can be problematic. To properly model the fat tails and asymmetry implied by excess kurtosis and skewness, it is likely to be necessary to fit the models under the assumption of an appropriate non-normal distribution. Two alternative distributional assumptions are available, both of which are likely to work better with fat tailed distributions: Student's t; and the generalised error distribution (GED).

Following estimation under the assumption of the Student's t distribution the estimation of an additional parameter provides information about the thickness of the tails of the distribution. The Student's t distribution approaches normal when this parameter is greater than 30, while a significantly lower parameter indicates thicker tails. Estimation of the models under the assumption that the error variance follows a standardised GED adds estimation of a shape parameter that controls the fatness of the tails. When this shape parameter is 2 the tails are well represented by the normal distribution. A shape parameter that is significantly larger or smaller than 2 is indicative of fatter tails.

After estimating GARCH, EGARCH and TGARCH models under each of the available distributional assumptions, a preferred specification can be chosen in line with standard practice on the basis of: i) the significance of the estimated parameters; ii) the diagnostic tests based upon the properties of the standardised residuals; and iii) minimising the relevant information criterion.

Having chosen the preferred specifications for each of the key returns series, the time series for the estimated conditional variances from the separately estimated univariate models are examined. At this point we can seek evidence of any widening divergence in the conditional volatility of stock returns of the Scottish companies relative to that of the UK benchmark series. By identifying the time periods in which any major divergences occur and checking to see if these periods are associated with the timing of key events associated with the timeline of the independence referendum as set out in section 2, then by checking whether any divergence persists or is resolved as further time passes, we are able to explore the whether there is evidence of clear financial market impact of the political uncertainty generated by the independence referendum.

6. Results

6.1 Bivariate GARCH results

The first set of results, shown in column 1 of Table 5, are the DVECH GARCH estimates that jointly model the mean, variances and covariance of the Scottish stock returns, excluding RBS, and returns in the FTSE all share index over the full sample period. The mean equations in each case involve an intercept term and the first lags of each of the returns series in each equation, so stock returns are modelled using a VAR of order 1. Whilst the lagged terms in the mean equations do not appear to be significant individually they are jointly significant as indicated in the first of the likelihood ratio tests provided in the table; on this basis they are retained (although it is worth pointing out the same inference with respect to the other parameters of the model holds, whether the mean equations contain a lag of each returns series or just an intercept term). The second likelihood ratio test reported in each column indicates that the null hypothesis of constant variances and covariance is strongly rejected in every case, so supports modelling the time varying conditional variances and covariances.

Table 5. Bivariate DVECH GARCH estimates

	Full Sample: 6/4/10-4/6/15		Sub-Sample: 6/4/10-15/10/12	
	(1)	(2)	(3)	(4)
Mean equations				
μ_1	0.061 (0.025) [.01]	0.064 (0.025) [.01]	0.084 (0.041) [.04]	0.084 (0.040) [.04]
μ_2	0.042 (0.022) [.06]	0.045 (0.022) [.04]	0.033 (0.039) [.41]	0.034 (0.039) [.39]
μ_{11}	-0.025 (0.053) [.64]	-0.022 (0.053) [.68]	-0.039 (0.088) [.66]	-0.039 (0.088) [.66]
μ_{12}	0.053 (0.058) [.36]	0.053 (0.058) [.36]	0.079 (0.090) [.38]	0.083 (0.090) [.36]
μ_{21}	0.043 (0.047) [.36]	0.046 (0.046) [.32]	0.098 (0.083) [.24]	0.097 (0.084) [.25]
μ_{22}	-0.049 (0.053) [.35]	-0.050 (0.053) [.35]	-0.095 (0.087) [.27]	-0.089 (0.087) [.30]
Variance and Covariance equations				
ϖ_{11}	0.059 (0.015) [.00]	0.054 (0.019) [.01]	0.050 (0.019) [.01]	0.045 (0.018) [.01]
ϖ_{12}	0.031 (0.008) [.00]	0.039 (0.014) [.01]	0.033 (0.012) [.01]	0.037 (0.015) [.01]
ϖ_{22}	0.026 (0.008) [.00]	0.042 (0.015) [.01]	0.031 (0.013) [.02]	0.042 (0.017) [.01]
α_{11}	0.066 (0.012) [.00]	**0.074 (0.016) [.00]**	0.050 (0.011) [.00]	**0.052 (0.012) [.00]**
α_{12}	0.056 (0.011) [.00]	0.069 (0.015) [.00]	0.046 (0.010) [.00]	0.049 (0.011) [.00]
α_{22}	0.056 (0.012) [.00]	**0.074 (0.016) [.00]**	0.050 (0.012) [.00]	**0.052 (0.012) [.00]**
β_{11}	0.871 (0.025) [.00]	**0.868 (0.034) [.00]**	0.908 (0.022) [.00]	**0.909 (0.022) [.00]**
β_{12}	0.899 (0.019) [.00]	0.874 (0.032) [.00]	0.921 (0.017) [.00]	0.913 (0.021) [.00]
β_{22}	0.908 (0.020) [.00]	**0.868 (0.034) [.00]**	0.922 (0.019) [.00]	**0.909 (0.022) [.00]**

LR test - dropping lagged terms in the mean equations - H_0: $\mu_{11} = \mu_{12} = \mu_{21} = \mu_{22} = 0$

$\chi^2(4)$=12.00 [.02] $\chi^2(4)$=18.08 [.00]

LR test - constant variances and covariances - H_0: $\alpha_{11} = \alpha_{12} = \alpha_{22} = \beta_{11} = \beta_{12} = \beta_{22} = 0$

$\chi^2(6)$=250 [.00] $\chi^2(6)$=94.16 [.00]

LR test - same parameters in GARCH processes - H_0: $\alpha_{11} = \alpha_{22}$ and $\beta_{11} = \beta_{22}$.

$\chi^2(2)$= 8.29 [.02] $\chi^2(2)$=2.86 [.24]

Notes:

1. Estimation is by maximum likelihood and was conducted using Stata 14.
2. Series 1 is the Scottish index, excluding RBS; series 2 is the FTSE all share index.
3. Standard errors are given in (.) and probability values are provided in [.].
4. Restricted parameters are shown in bold in columns (2) and (4).

Columns (1) and (2) report the unrestricted and restricted estimates of the model using the full sample period, where the restricted model constrains the ARCH and GARCH parameters to be the same for both series. The null hypothesis that the two returns series are characterised by the same ARCH and GARCH parameters is strongly rejected over the full sample, 6th April 2011 – 4th June 2015, as indicated in the likelihood ratio test at the foot of column (2) of Table 5, and its respective p-value of 0.02. However, this result is overturned if estimation is ended in October 2012, at the point that the Edinburgh Agreement, which agreed the legislation necessary for the independence referendum, was signed. Columns (3) and (4) of Table 5 show the unrestricted and restricted estimates of the model when the sample ends on 15th October 2012. We are unable to reject the null hypothesis that the two returns series are characterised by the same GARCH process using this shorter estimation period, as indicated in the second likelihood ratio test shown at the foot of column (4). We appeal to this finding to justify our use of the FTSE all share index as a benchmark against which to compare the volatility of Scottish stock returns.

Our next step is to repeat the estimation of the unrestricted and restricted DVECH GARCH models and construct the equivalent likelihood ratio tests for a number of different sample periods. The objective is to investigate at what point in time there is sufficient evidence to conclude that the parameterisation of the volatility of Scottish stock returns begins to differ significantly from that of returns on the FTSE all share index. As explained in Section 5, the results obtained from this investigation should be seen only as indicative, since sequential tests of this kind are not statistically independent.

Table 6. LR tests of the null hypothesis that the conditional volatilities of the two series are characterised by the same GARCH parameters – the effect of rolling forward the sample end date

Sample end date	Event	LR test [p-value]
15th October 2012	Edinburgh Agreement	2.86 [.239]
30th January 2013	Referendum Question set	2.52 [.283]
21st March 2013	Date of Referendum announced	3.50 [.174]
26th November 2013	'Blueprint for Independence'	5.74 [.057]
1st July 2014	Scottish Independence Bill	9.16 [.010]
18th September 2014	Referendum	9.34 [.009]

Sample end date	Number of months prior to the referendum	LR-test [p-value]
18th March 2013	18	3.32 [0.190]
18th April 2013	17	3.92 [0.141]
17th May 2013	16	4.60 [0.100]
18th June 2013	15	5.61 [0.061]
18th July 2013	14	6.61 [0.037]
16th August 2013	13	5.29 [0.071]
18th September 2013	12	5.63 [0.060]
18th October 2013	11	5.94 [0.051]
18th November 2013	10	5.71 [0.058]
18th December 2013	9	6.34 [0.042]
17th January 2014	8	6.85 [0.033]
18th February 2014	7	5.74 [0.057]
18th March 2014	6	5.36 [0.069]
17th April 2014	5	7.67 [0.022]
16th May 2014	4	8.73 [0.013]
18th June 2014	3	8.79 [0.012]
18th July 2014	2	8.23 [0.016]
18th August 2014	1	8.90 [0.012]

The results presented in the top panel of Table 6 indicate that by the time of the publication of the 'Blueprint for Independence' in November 2014, the volatility of Scottish stock returns had already begun to deviate from that of the volatility of the FTSE all share index, the LR test indicates that the null hypothesis of equality of the GARCH parameters is rejected at the 10% level of significance. The rejection of the null is stronger, at the 1% level of significance when estimation extends through to the publication of the Scottish Independence Bill in July 2014. The lower panel of Table 6 repeats the same testing but this time stopping the estimation period to 18 months before the referendum date, then extending the end date at monthly intervals through to 1 month before the vote (the end date is chosen to be the 18th of each month, or the last trading day prior to this date). While inference cannot be entirely precise, it is notable that the null hypothesis that the same GARCH parameters can adequately describe the volatility of returns on the FTSE all share index and the volatility of Scottish returns is rejected at the 10% level of significance, or less, for estimation periods that end on 18th June 2013 onwards, that is 15 months prior to the date of the referendum, onwards; and the relevant probability values are strictly decreasing over the last 5 months prior to the referendum.

6.2 Univariate GARCH, EGARCH and TGARCH models

As explained in Section 5, there are some disadvantages of multivariate GARCH models. In practice, univariate models can be more flexible and are likely to be better able to capture some aspects of the data. Tables 7a, 7b and 7c report the results of estimating GARCH, EGARCH and TGARCH models under different distributional assumptions for FTSE all share index stock returns; the Scottish stock returns index; and the Scottish index that excludes RBS. In every case the full sample period, 6th April 2011 – 4th June 2015 is used.

Table 7a. Modelling FTSE Stock Returns

FTSE	GARCH			EGARCH			TGARCH		
N=1305	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mean Equation:									
μ	0.048	0.051	0.051	0.003	0.020	0.017	0.010	0.023	0.022
	(0.024)	(0.021)	(0.02)	(0.023)	(0.02)	(0.02)	(0.023)	(0.02)	(0.02)
	[0.05]	[0.01]	[0.01]	[0.91]	[0.33]	[0.41]	[0.67]	[0.27]	[0.29]
Conditional Volatility Equation:									
ϖ	0.030	0.023	0.026	-0.010	-0.013	-0.012	0.031	0.032	0.031
	(0.016)	(0.009)	(0.009)	(0.009)	(0.007)	(0.007)	(0.014)	(0.006)	(0.006)
	[.07]	[.01]	[.01]	[.26]	[.07]	[.07]	[.03]	[.00]	[.00]
α	0.112	0.108	0.107	0.161	0.153	0.158	0.194	0.227	0.208
	(0.042)	(0.022)	(0.023)	(0.045)	(0.033)	(0.036)	(0.079)	(0.039)	(0.036)
	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]
β	0.855	0.870	0.865	0.954	0.957	0.955	0.881	0.870	0.874
	(0.054)	(0.025)	(0.027)	(0.007)	(0.009)	(0.009)	(0.054)	(0.022)	(0.022)
	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]
γ				-0.155	-0.189	-0.168	-0.219	-0.264	-0.237
				(0.039)	(0.023)	(0.020)	(0.076)	(0.039)	(0.034)
				[.00]	[.00]	[.00]	[.00]	[.00]	[.00]
Diagnostic testing:									
Distribution		2.389	0.503		2.606	0.538		2.57	0.532
		(0.385)	(0.055)		(0.448)	(0.056)		(0.449)	(0.056)
		[.00]	[.00]		[.00]	[.00]		[.00]	[.00]
Shapiro –	4.664	4.729	4.696	4.720	6.670	4.848	4.444	4.848	4.562
Francia test	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]
Skewness	-2.988	-3.074	-3.037	-4.103	-5.397	-4.243	-3.821	-4.243	-3.956
t-test	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]
Ex.Kurtosis	5.361	5.567	5.462	6.452	11.20	6.841	5.438	6.841	5.908
t-test	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]	[.00]
ARCH 1	1.286	0.900	1.013	1.906	0.704	1.475	2.575	2.22	2.566
$\chi^2(1)$	[.26]	[.34]	[.31]	[.17]	[.4]	[.22]	[.11]	[.14]	[.11]
ARCH 5	3.185	2.985	3.063	4.656	4.798	4.684	7.54	9.813	8.356
$\chi^2(5)$	[.67]	[.70]	[.69]	[.46]	[.44]	[.46]	[.18]	[.08]	[.14]
ARCH 10	5.216	5.214	5.22	7.791	7.792	7.764	11.46	13.74	12.229
$\chi^2(10)$	[.88]	[.88]	[.88]	[.65]	[.65]	[.65]	[.32]	[.19]	[.27]
AIC	3333.75	3308.53	3299.97	3261.86	3238.40	3240.12	3258.31	3237.72	**3237.45**
SBIC	3354.44	3334.40	3325.83	3287.72	3269.44	3271.16	3284.17	3268.76	**3268.49**

Notes:

1. Estimation is by maximum likelihood and was conducted using Stata 14.
2. Standard errors are given in (.) and probability values are provided in [.].
3. The ‘Distribution’ row in the diagnostic tests presents results relevant to the specific estimates which are discussed in the main text.
4. Minimised information criteria are shown in bold.

Table 7b. Modelling Scottish Stock Returns

SC_ALL	GARCH			EGARCH			TGARCH		
N=1305	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mean Equation:									
μ	0.048 (0.032) [.13]	0.044 (0.03) [.15]	0.047 (0.03) [.12]	0.006 (0.031) [.86]	0.010 (0.03) [.75]	0.011 (0.03) [.71]	0.012 (0.031) [.70]	0.016 (0.031) [.59]	0.018 (0.031) [.56]
Conditional Volatility Equation:									
ϖ	0.028 (0.014) [.04]	0.023 (0.011) [.04]	0.026 (0.012) [.03]	0.006 (0.004) [.15]	0.006 (0.004) [.12]	0.006 (0.004) [.10]	0.022 (0.011) [.05]	0.02 (0.008) [.01]	0.021 (0.008) [.01]
α	0.061 (0.018) [.00]	0.060 (0.013) [.00]	0.061 (0.012) [.00]	0.106 (0.031) [.00]	0.106 (0.022) [.00]	0.106 (0.020) [.00]	0.081 (0.010) [.00]	0.083 (0.014) [.00]	0.082 (0.013) [.00]
β	0.920 (0.022) [.00]	0.925 (0.016) [.00]	0.923 (0.017) [.00]	0.985 (0.006) [.00]	0.987 (0.005) [.00]	0.986 (0.006) [.00]	0.944 (0.010) [.00]	0.944 (0.012) [.00]	0.944 (0.012) [.00]
γ				-0.066 (0.016) [.00]	-0.068 (0.014) [.00]	-0.067 (0.013) [.00]	-0.079 (0.019) [.00]	-0.082 (0.017) [.00]	-0.081 (0.016) [.00]
Diagnostic tests:									
Distribution		1.724 (0.354) [.00]	0.353 (0.061) [.00]		1.949 (0.334) [.00]	0.418 (0.061) [.00]		1.966 (0.362) [.00]	0.423 (0.061) [.00]
Shapiro – Francia test	3.349 [.00]	3.433 [.00]	3.380 [.00]	2.454 [.01]	2.474 [.00]	2.454 [.01]	4.110 [.00]	4.196 [.00]	4.114 [.00]
Skewness t-test	0.001 [.50]	0.512 [.51]	0.012 [.50]	-0.785 [.22]	-0.831 [.20]	-0.813 [.21][	-4.084 [.00]	-4.180 [.00]	-4.125 [.00]
Ex.Kurtosis t-test	4.649 [.00]	4.846 [.00]	4.727 [.00]	4.727 [.00]	3.673 [.00]	3.630 [.00]	4.111 [.00]	4.358 [.00]	4.200 [.00]
ARCH 1 $\chi^2(1)$	0.117 [.73]	0.113 [.74]	0.115 [.73]	0.126 [.72]	0.129 [.72]	0.127 [.72]	1.433 [.23]	1.663 [.20]	1.578 [.21]
ARCH 5 $\chi^2(5)$	1.978 [.85]	1.935 [.86]	1.962 [.85]	3.375 [.64]	3.405 [.64]	3.407 [.64]	3.789 [.58]	4.394 [.49]	4.088 [.54]
ARCH 10 $\chi^2(10)$	5.585 [.85]	5.375 [.86]	5.495 [.86]	9.277 [.51]	9.223 [.51]	9.282 [.51]	12.27 [.27]	12.71 [.24]	12.48 [.25]
AIC	4190.43	4192.03	4177.24	4170.24	4171.64	4178.77	4171.36	4172.54	4201.67
SBIC	4216.30	4217.90	4203.10	4201.28	4202.68	4204.64	4202.40	4203.58	4222.37

Notes: see Table 7a.

Table 7c. Modelling Scottish (exc. RBS) Stock Returns

SC_XRBS	GARCH			EGARCH			TGARCH		
N=1305	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mean Equation:									
μ	0.055 (0.026) [.03]	0.061 (0.025) [.01]	0.058 (0.024) [.02]	0.015 (0.036) [.68]	0.027 (0.025) [.28]	0.025 (0.025) [.31]	0.018 (0.025) [.48]	0.030 (0.025) [.23]	0.028 (0.025) [.26]
Conditional Volatility Equation:									
ϖ	0.032 (0.016) [.04]	0.031 (0.013) [.01]	0.032 (0.013) [.01]	0.000 (0.006) [.99]	-0.002 (0.005) [.72]	-0.002 (0.004) [.72]	0.041 (0.018) [.02]	0.039 (0.01) [.00]	0.041 (0.011) [.00]
α	0.075 (0.023) [.00]	0.077 (0.017) [.00]	0.076 (0.017) [.00]	0.102 (0.021) [.00]	0.108 (0.027) [.00]	0.105 (0.026) [.00]	0.139 (0.04) [.00]	0.148 (0.028) [.00]	0.143 (0.028) [.00]
β	0.893 (0.035) [.00]	0.893 (0.025) [.00]	0.893 (0.025) [.00]	0.970 (0.01) [.00]	0.970 (0.009) [.00]	0.969 (0.009) [.00]	0.901 (0.034) [.00]	0.899 (0.021) [.00]	0.899 (0.022) [.00]
γ				-0.121 (0.026) [.00]	-0.134 (0.02) [.00]	-0.127 (0.020) [.00]	-0.163 (0.045) [.00]	-0.174 (0.032) [.00]	-0.168 (0.031) [.00]
Diagnostic tests:									
Distribution		2.132 (0.388) [.00]	0.452 (0.059) [.00]		2.366 (0.414) [.00]	0.500 (0.059) [.00]		2.57 (0.423) [.00]	0.498 (0.059) [.00]
Shapiro – Francia test	4.051 [.00]	4.054 [.00]	4.054 [.00]	4.049 [.00]	4.057 [.00]	4.112 [.00]	4.110 [.00]	4.196 [.00]	4.114 [.00]
Skewness t-test	-3.209 [.00]	-3.207 [.00]	-3.207 [.00]	-3.210 [.00]	-4.236 [.00]	-4.397 [.00]	-4.084 [.00]	-4.180 [.00]	-4.125 [.00]
Ex.Kurtosis t-test	4.593 [.00]	4.619 [.00]	4.593 [.00]	4.594 [.00]	4.180 [.00]	4.571 [.00]	4.111 [.00]	4.358 [.00]	4.200 [.00]
ARCH 1 $\chi^2(1)$	0.088 [0.77]	0.148 [0.7]	0.108 [0.74]	1.274 [0.26]	1.543 [0.21]	1.430 [0.23]	1.433 [0.23]	1.663 [0.2]	1.578 [0.21]
ARCH 5 $\chi^2(5)$	2.569 [0.77]	2.488 [0.78]	2.535 [0.77]	5.281 [0.38]	6.216 [0.29]	5.706 [0.34]	3.789 [0.58]	4.394 [0.49]	4.088 [0.54]
ARCH 10 $\chi^2(10)$	8.159 [0.61]	8.100 [0.62]	8.133 [0.62]	12.75 [0.24]	13.65 [0.19]	13.18 [0.21]	12.27 [0.27]	12.71 [0.24]	12.48 [0.25]
AIC	3619.86	3604.55	3603.54	3574.25	3563.83	3564.89	3577.81	3567.34	3568.06
SBIC	3640.56	3630.42	3629.41	3600.11	3594.87	3595.93	3603.67	3598.38	3599.10

Notes: see Table 7a.

Columns (1) to (3) in each table report the results of GARCH estimation under three different distributional assumptions. Estimation in column (1) assumes asymptotic normality. Estimation is by quasi-maximum likelihood, with Wooldridge's robust standard errors. Column (2) provides estimates under the assumption of Student's t-distribution. Column (3) reports the estimation results under the assumption that the error variance follows a GED. Columns (4) to (6) report estimates of the EGARCH model and columns (7) to (9) report the TGARCH estimates, again under each of the three distributional assumptions.

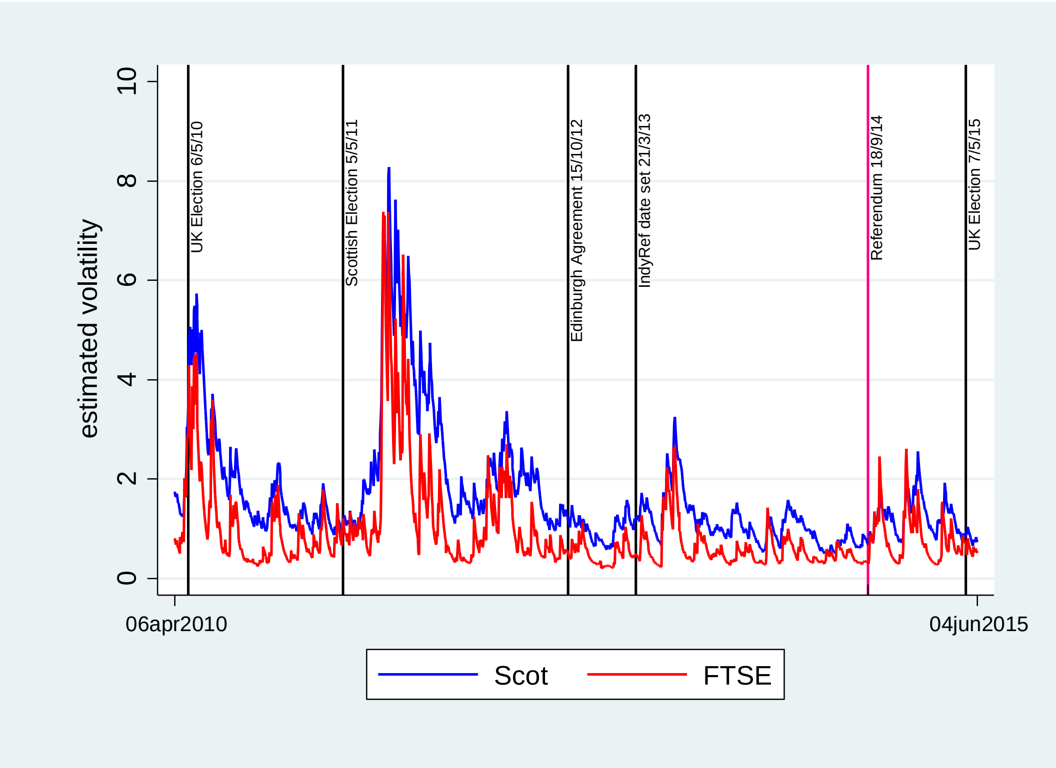
Throughout these univariate results the mean equations consist only of an intercept term. The addition of the first lag of the stock returns was statistically insignificant in every case – this is consistent with the usual result that the level of stock returns is not predictable from its own past history. In columns (2), (5) and (9), the result reported in the 'Distribution' row in the diagnostic tests section of the table and provides information relating to the thickness of the tails of the distribution. The significance of this parameter indicates fatter tails than the normal distribution would predict. In columns (3), (6) and (9) the shape parameter from the GED estimates is reported is recorded in the 'Distribution' row of the diagnostic tests section of the table. The fact that this parameter is always significantly below 2 across all the GED estimates is also indicative of fat tails. Provided that the GARCH models are correctly specified, all three estimators are consistent, but given the presence of fat tails, we expect the estimates that assume the Student's t-distribution or alternatively the GED should work better and be more efficient. In practice, and as expected, the estimates of each of the parameters are very similar for a given GARCH, EGARCH or TGARCH specification, but the standard errors are typically lower for the estimates that assume a Student's t-distribution or the GED than the robust standard errors obtained for the quasi maximum likelihood estimates.

In every case, the key estimated parameters in the conditional volatility equations $\{\alpha, \beta, \gamma\}$ are always significantly different from zero, as indicated in the very low p-values recorded in the tables. This suggests that the systematic behaviour of the conditional volatility of stock returns is captured well by the models; only the intercept term in the conditional volatility equations, ϖ, often fails to reach significance. The diagnostic tests, conducted using the standardised residuals, indicate that the null hypothesis of normally distributed disturbances is always rejected, echoing the message that the robust standard errors and/or the assumption of non-normal error distributions is appropriate. In most cases the standardised residuals exhibit both skewness and excess kurtosis, the only exceptions are the GARCH and EGARCH models of Scottish stock returns (columns (1) to (6) of Table 7b), for which no significance skewness is detected. The report ARCH tests convey a more positive message, indicating that the modelling of conditional volatility is sufficient to fail to reject the null hypothesis of no remaining autoregressive heteroskedasicity of order 1, up to order 5 or up to order 10 in the (squared) standardised residuals.

The significance of the asymmetric terms in the EGARCH and TGARCH models implies that either of these specifications is preferable to the pure GARCH model and the parameter estimates are consistent with the interpretation that negative shocks have a greater impact on conditional volatility than positive shocks of the same magnitude. Further discrimination between the models is feasible through use of the information criteria. The AIC and SBIC are both minimised when the GED estimates of the TGARCH model is chosen, in column (9) of Table 7a for the FTSE returns. This achieves a marginal improvement on the EGARCH estimates that assume the t-distribution shown in column (5); the quasi maximum likelihood estimates of the EGARCH model with robust standard errors achieve minimum AIC and SBIC in the case of the Scottish stock returns series, i.e. column (4) of Table 7b; and in the case of the Scottish series excluding RBS in Table 7c, the EGARCH model estimates that assume the t-distibution in column (5).

Having chosen a set of preferred models, we now go on to examine the estimated conditional volatilities of stock returns for the FTSE all share index and the Scottish indices respectively. Figure 2a plots the estimated conditional volatilities derived from the preferred models reported in Tables 7a and 7b over the full sample period.

Figure 2a: Estimated Conditional Volatilities of Stock Returns
Scottish index and FTSE all share index

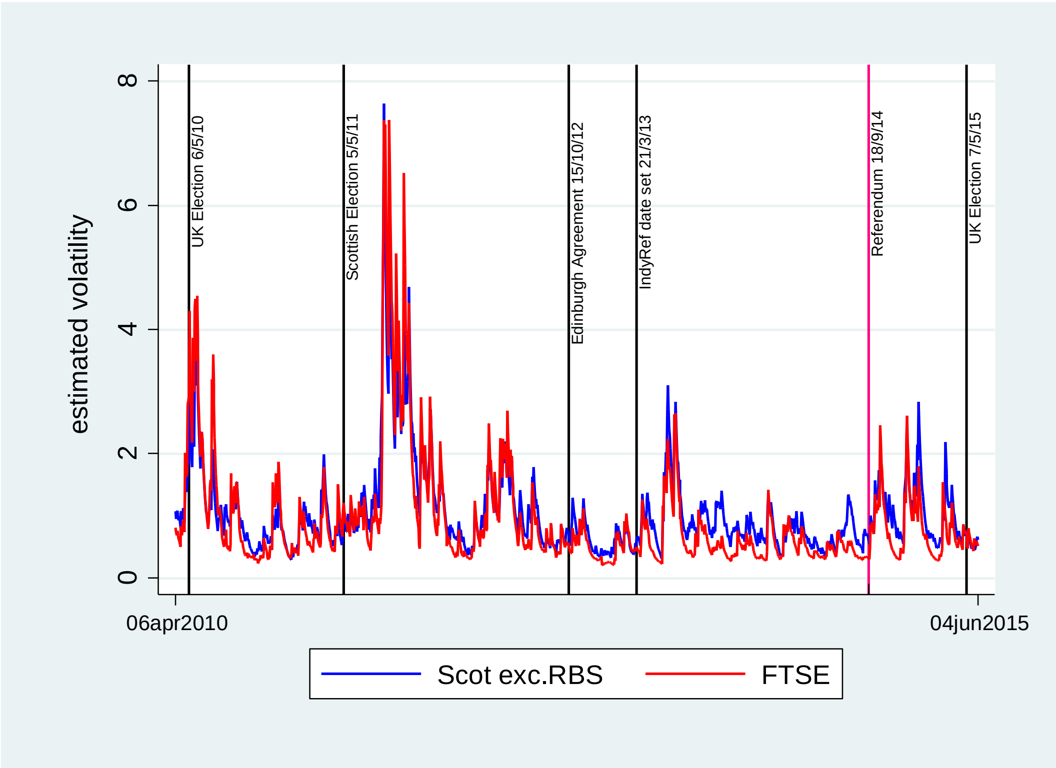


Looking at the volatility of the series as a whole, we find that the two series tend to be highly correlated with each other. This is unsurprising. Most listed companies operate in global markets and are impacted by the same issues – e.g. swings in stock market sentiment in Wall Street. Similarly, given the close linkages between the Scottish and rUK economies, the economic outlook for the UK will be highly correlated with the economic outlook for Scotland. We also find however, that the Scottish series tends to be slightly more volatile: the blue line (showing volatility in the Scottish series) lies above the red line (showing volatility in the FTSE). The date of the independence referendum is indicated on the graph with a red vertical line and text label. It's clear that the absolute level of volatility was actually relatively low at this point in time in comparison to some other periods within the sample period. For example, the volatility associated with the European debt crisis of 2011 can be clearly identified in the chart as can the political uncertainty following the result of the UK general election in 2010 – the UK first election to end in a hung parliament for 36 years - which eventually led to the formation of the Conservative led coalition, see Cawood (2013).

The above results are somewhat sensitive to the inclusion/exclusion of RBS. As mentioned previously, there are special factors to take into consideration. RBS shares prices have a big impact on the Scottish series firstly given its sheer scale (the share price series attracts large market capitalization weights). There are also well known factors that affect changes in the RBS share price at various points in our sample period, not least reflecting regular debates about whether the government would or would not begin to sell some of its 85% stake in the bank. For these reasons our preferred Scottish index, which can allow us to focus more clearly on the impacts of the independence referendum on Scottish stock market volatility, is the series that excludes RBS (and this was the series used exclusively in the bi-variate models reported in section 6.1).

Figure 2b compares the FTSE series with the estimated conditional volatility from the preferred model of stock returns in the Scottish index that excludes the RBS, again over the full sample period. Some interesting features are now noticeable. Firstly, the estimated volatilities are now broadly the same for the first part of the sample (i.e. the blue and red lines are very close to each other). This adds to the evidence of the similarity of the volatility processes presented in section 6.

Figure 2b: Estimated Conditional Volatilities of Stock Returns
(Scottish index excludes RBS)



However, in common with earlier results reported in Table 6, the conditional volatilities seem to diverge in the period running up to the referendum and beyond, with the Scottish series tending to be more volatile than the FTSE. This can be seen more clearly in Figure 3a, which zooms in on the period from June to December of 2014, a period spanning 3 months prior to the Independence referendum and 3 months after. Figure 3b plots a relative measure of estimated volatility, calculated as the percentage deviation in the Scottish series from the FTSE series: a positive number here means that the estimated level of volatility is higher in the Scottish series whilst a negative number indicates that volatility in higher for the FTSE series.

Figure 3b shows that there was a rise in the estimated volatility of the Scottish series relative to the FTSE series in the immediate run up to the date of the independence referendum. In particular there is a very clear jump up in the volatility of the Scottish series when trading reacted to the YouGov poll published in the Sunday Times on 7th September that put the Yes campaign in the lead. Heightened volatility then continued until polling day, but receded immediately after the referendum result was known. It is also clear from charts 3a and 3b that the referendum did not signal the end of the story. There is further evidence of heightened relative volatility while the Smith Commission process was ongoing, and a peak on the date of publication of the Commission's report and recommendations[9].

[9] There is also a clear spike in FTSE volatility, and decline in the relative volatility of the Scottish series on 15th October 2014 – this reflected the large one day sell-off in major stock markets. At the time this was widely attributed to worries about global growth after the release of weak economic data and to fears that the Federal Reserve would soon seek to normalise monetary policy, ending its QE bond-buying programme and potentially raising interest rates.

Figure 3a: Conditional Volatilities of Stock Returns
Scottish index excluding RBS and FTSE all share index June to December 2014

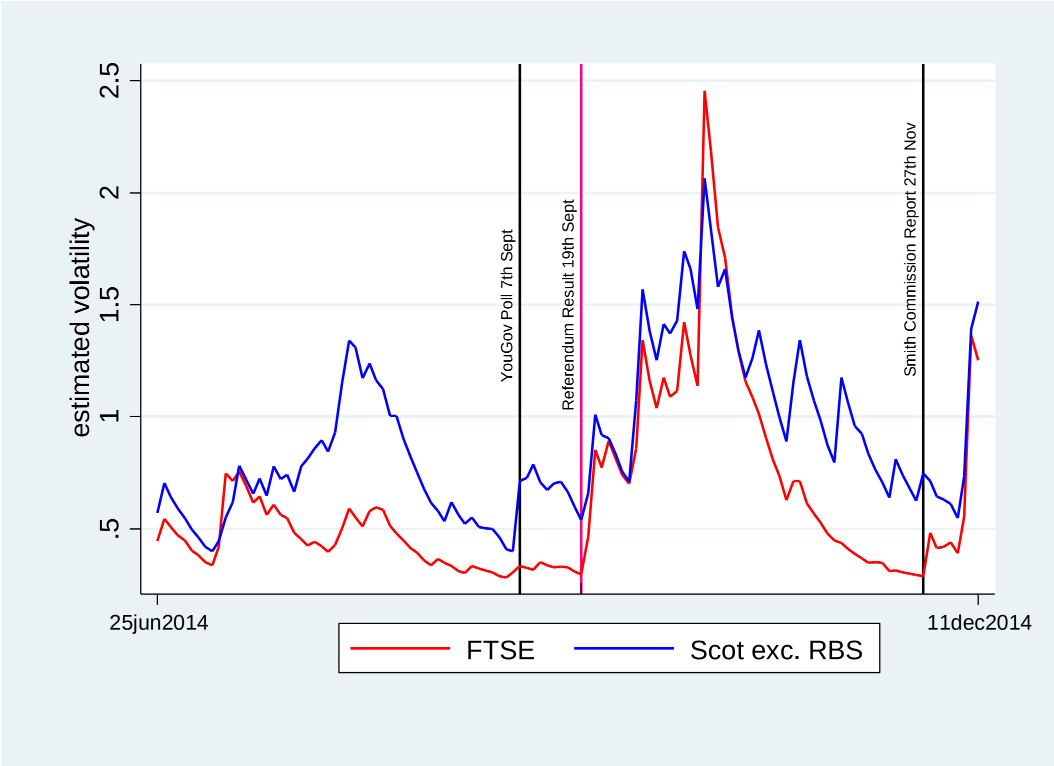
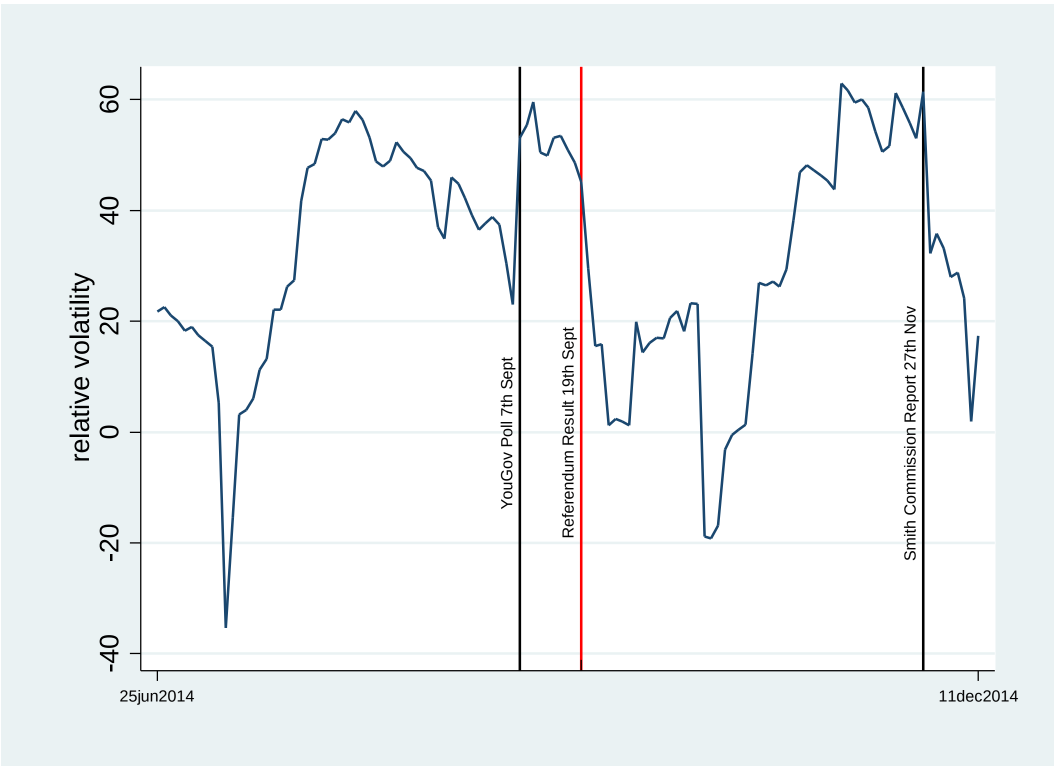


Figure 3b: Relative Conditional Volatilities of Stock Returns
Scottish index excluding RBS and FTSE all share index June to December 2014



7. Robustness Checks

In this section we check the robustness of the key findings set out above. As explained in section 4, the finance sector makes up a large, and growing, part of the capitalisation weighted Scottish stock price index over the sample period examined here. In order to examine whether our key results reflect volatility in this sector or are spread more widely across Scottish shares, we construct a Scottish index that excludes the share prices of all the Scottish listed companies operating in the finance sector.

In addition, we have previously noted that the oil and gas sector has historically had a strong presence among Scotland's listed companies and has also been subjected to particular challenges over the sample period. In order to check whether the volatility experienced in this sector is affecting the overall results we construct another index that excludes oil and gas companies from our main Scottish index. The effects of running the analysis on these indicies are summarised in Figure 4.

Our final check is based on an index that removes the three largest Scottish listed companies by share capitalisation i.e. the Royal Bank of Scotland (RBS), Scottish and Southern Electricity (SSE) and Standard Life. As indicated in Table 2, at the time of the independence referendum these three companies accounted for over 60% of total market capitalisation. Constructing a new index that excludes these companies allows us to check whether the key characteristics in the movements in estimated volatility identified above are dominated by movements in the share prices of the largest companies, or are spread more widely. Figure 5 presents a summary of the results.

Figure 4: Relative Conditional Volatilities of Stock Returns
Scottish indices and FTSE all share index, June to December 2014

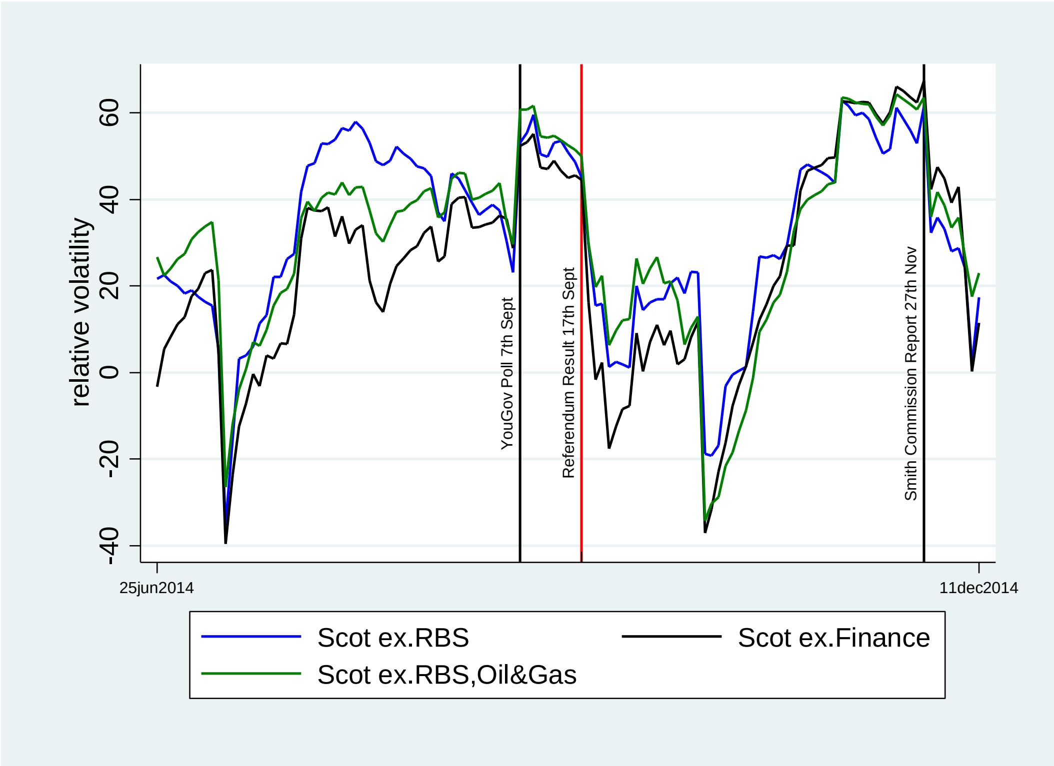
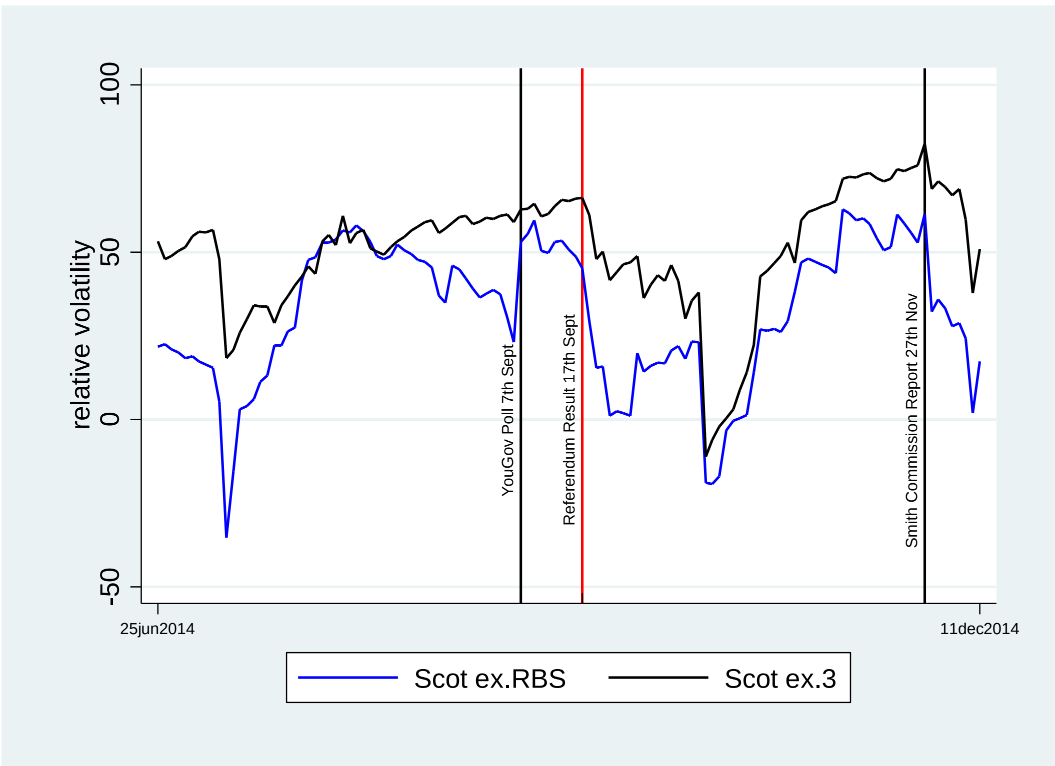


Figure 5: Relative Conditional Volatilities of Stock Returns
Scottish indices and FTSE all share index, June to December 2014



The exclusion of the SSE and Standard Life along with RBS clearly does have an impact on the results. The jump that followed the publication of the YouGov poll on 7th September 2014 is now less evident, instead there was a steadier climb in relative volatility as the referendum date approached. Also, the post referendum decline in relative volatility it is not as pronounced and, aside from the October downward spike mentioned earlier, the relative volatility of the smaller Scottish listed companies is estimated to have reached a local peak on the publication of the Smith Commission report, with a lesser decline thereafter. Suffice to say that we have provided some tentative evidence that smaller listed Scottish companies may have been more severely impacted by heightened volatility around the time of the independence referendum than their larger counterparts. Further exploration of these differences is left for future work.

8. Conclusions

This paper has made a number of contributions to the existing literature. First, it has identified Scottish companies listed on the London Stock Exchange over a period that included the Scottish independence referendum and constructed a capitalisation weighted Scottish stock price index. Second, it has investigated the volatility of stock returns of Scottish companies listed on the London Stock Exchange as compared to the volatility of daily returns using the FTSE all share index around the time of the independence referendum. The estimated models were shown to provide a good description of time varying conditional volatility over the sample period. Third, through exploring how the volatility of stock returns evolves in the run up to and after the referendum, this paper contributes to the wider literature on the impacts of political uncertainty outside 'normal' election cycles.

Key findings are firstly that we cannot reject the null hypothesis that the conditional volatility of FTSE and Scottish (ex. RBS) stock returns can be characterised by the same GARCH parameters up to a sample period ending in late 2013; and second, that as the referendum date approaches this result is overturned, with the strength of the rejection increasing for the last 5 months prior to the referendum. Together these results suggest that while the volatilities of Scottish and FTSE all share indicies have similar characteristics up to late 2013, there is evidence of significant divergence in the later part of the sample. A closer look reveals that in the run-up to the independence referendum, the relative volatility of Scottish stock returns increased, reaching a peak after 7th September when the polls suggested the referendum race was too close to call. The volatility of Scottish stock returns then fell immediately after the referendum result but climbed again in the run up to the release of the Smith Commission report which provided information on proposed "extensive new powers" for the Scottish Parliament. The reaction of financial markets at this time demonstrates that the referendum did not entirely resolve the uncertainty that both companies and investors faced with respect to future policy.

We have shown that these key results are robust to inclusion/exclusion of RBS; of companies in the Oil & Gas sector; and of all companies in the Financial Services sector. We have also presented some tentative evidence that once the three Scottish companies with highest market capitalisation are excluded, the post referendum decline in stock market volatility is more muted, with the volatility of the remaining companies' stock returns reaching a (local) peak on at the time of the publication of the Smith Commission report. Further exploration of possible differential impacts of referendum related uncertainty on Scottish companies of different sizes is left for future research.

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