Erasmus University Rotterdam
Erasmus School of Economics

Master thesis Economics of Management and Organizations

Unbrexity?

A study on the differential impact of uncertainty arising from the U.K. referendum on investment behavior for firms in the construction and manufacturing industry across the U.K.

Max van den Bosch

Name: Max van den Bosch
Student number: 343338
Supervisor: dr. J. Delfgaauw
Second Assessor: dr. A. Erbahar

Abstract

This study assesses whether increased uncertainty caused investments to decrease during the United-Kingdom's post-referendum period. It offers two unique features. First, although the relation between uncertainty and investments has been well studied, none has tested this relationship by comparing two opposing industries in terms of openness to international trade. Second, the period in aftermath of the referendum-announcement of a potential Brexit, ranging from 27th of May 2015 until 23rd of June 2016, caused record-high uncertainty for any actor across the U.K.'s economy, thereby enabling this study to not only implement a frequently used proxy for such uncertainty measure, but to implement and test the validity of this proxy with a variable that truly signals uncertainty. By using quarterly panel data from 333 firms operating in the United Kingdom, this study shows that uncertainty is significantly and negatively related to investments during the post-referendum period, whereas no significant relationship was found for the overall sampling period. Specifically, this relationship is found to be significant for the manufacturing industry only. Hence, these findings only partly support the option-value approach of investments, which argues that firms have an option to either invest gradually or to completely postpone investments, thereby creating the possibility to retrieve information on future developments. However, this study illustrates that industries differ significantly in dealing with this option. Further, this study shows that, first, the proxy for uncertainty estimates a steeper coefficient compared to the alternative estimation for the post-announcement period, and second, that this proxy does not seem to capture the relationship between uncertainty and investment at the overall sampling period. Hence, it is discussed that the validity and practicality of such a proxy is limited.

JEL classification: D22, D24, E22, E66
Keywords: Differential impact uncertainty, investments, option-approach, Brexit, referendum.

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1. Introduction

This paper aims to study the effects of nationwide uncertainty on investments, whereby uncertainty is typically assumed to harm investment behavior for firms across an economy. Specifically, firms form expectations on future outcomes whereby investment decisions are aligned to these expectations. Then, as uncertainty increases firms may receive rather noisy signals on these future outcomes, thereby making it more difficult to form a well-profound prognosis. As a response, typically known as the option-value of investments, firms will alter the investment strategy in order to gain information on the future outcomes. Instead of investing as was initially planned, firms will choose to either completely postpone an investment or to take a more gradual, incremental approach. This cautious behavior will enable firms to gradually evaluate the alignment between the investment and the updated future expectations. This study additionally motivates that this option-approach is mostly present in uncertainty periods that have a common end-date compared to periods that have not.

A recent period known to be subject to high, economic wide uncertainty is the period subsequent to the referendum announcement at the 27th of May 2015. At this date, Britain's Queen Elizabeth II announced that a referendum will be scheduled asking its population whether the United Kingdom (U.K.) should remain the European Union or not (Gross & Winning, 2015). As the next section will graphically motivate, this period, ending at 23rd of June 2016, has experienced a record-high uncertainty since 1997 (Bloom, 2016). That is, the Economic Policy Uncertainty Index (EPUI), which will be introduced in the next section, reached a score higher than this score during the financial crisis or any other event since 1997. Combined with poll-trackers that indicate an equal distribution of votes both in favor and against of the so called Brexit, it serves as an utmost suitable period to study whether uncertainty is negatively associated to investments. For example, in their quarterly reports on developments of aggregate demand, the Bank of England (2016) shows that investment intentions, arguably being an important component of aggregate demand, have dropped significantly across the manufacturing industry since the referendum-announcement was made.

A limited number of studies have already sought to forecast the potential, mostly negative, consequences of a Brexit (Dhingra et al., 2016a, 2016b; Dhingra et al., 2015; Tielmann & Schierick, 2016). For instance, Bououiyour & Selmi (2016) tested the relationship between uncertainty arising from the referendum on European equities. By using data from Google Trends, they forecasted that Germany will potentially suffer most, followed by France and the U.K. itself. Nevertheless, this increasing uncertainty can have major implications for any economy, both nationally and internationally (Chadha, 2016; Gill & Sakhuja, 2016). Although previous studies have focused on the effects of potential future outcomes of a referendum, none, to my knowledge, have sought to test the effects of this uncertainty on business behavior during the post-announcement period. Namely, it has never occurred in history that a country has faced such uncertainty accompanied by seemingly unknowable probabilities of outcomes, in this case the outcome of the referendum.

Returning to the option-approach of investments, it is exactly this uncertainty that influences firms to either continue, postpone, withdraw or to choose to gradually continue with investments. To be more specific, firms could not easily form sound expectations on future business developments, on for instance international trade stability, as these developments were mainly dependent on whether the people of the United Kingdom choose to leave or remain being a member of the European Union.

The objective of this paper is to address the following questions: in terms of investments, how do firms across the United Kingdom respond to such increase in uncertainty? More specifically, do firms show a contraction in investment growth since the announcement-date? Do firms indeed adjust their investments according to the expectations of the option-approach of investments, both before and after the announcement? Does increased uncertainty, caused by the referendum, relate to a change towards gradual or postponed investments? To examine these issues, this study uses an Ordinary Least Squares (OLS) with fixed effects transformation as well as a Two Stage Least-Squares (TSLS) on a panel of 333 U.K. companies, operating in both the manufacturing industry as well as the construction industry. This cross-sectional analysis takes into account a treatment-effect, whereby the manufacturing industry serves as the industry to be 'treated'. This makes the relationship between uncertainty and investments more visible, since this relationship is expected to show divergent results among both industries.

First, the results show that during the complete sampling period, there is no significant relationship between uncertainty and investments. Focusing on the post-announcement period, however, the results show that uncertainty is indeed negatively and significantly related to investments, and as was hypothesized, this relationship is present for the manufacturing industry only. As will be discussed, these results are in line with the option approach of investments. These results point towards the option approach of gradually adjusting the capital stock instead of completely postponing it.

This study may have multiple theoretical and empirical contributions. Briefly, this study addresses the appearance of a differential impact of uncertainty on investments, thereby showing that the option-approach does not hold in general but is perhaps influenced by factors such as for example openness in terms of export and FDI. In contrast, for example, Teisberg (1993), Blond et al., (2007), Ghosal (1995) and Leahy & Whited (1995) found a significant relationship between uncertainty and investments. However, they have focused on one industry only, thereby not recognizing potential cross-sectional differences. Moreover, Serven (1997) and Ferderer (1993) found a similar relation between uncertainty on investments, although they tested this by using aggregate cross-country data. A study closely related to this study is that from Ghosal & Loungani (2000). They tested this relationship by studying differences in this relationship between small and large firms, all within the manufacturing industry. They found that both firm sizes show significant relationships, although this relationship is stronger for large firms. Acknowledging differences in this relationship between firm size, they discuss that industry characteristics may potentially cause such difference. Within this theoretical area, this cross-sectional study is therefore one of the first to acknowledge such differential impact by comparing the two aforementioned divergent industries as a measure of treatment effect. Second, this study, unlike the aforementioned studies, takes the opportunity to study this uncertainty-investment relationship during an actual period of grand scale uncertainty, thereby not limited to estimations with a merely *suggested* proxy for this uncertainty, but rather to employ estimations that include a measurement that truly captures the announcement-effect. The above mentioned studies on uncertainty all implemented merely a proxy for uncertainty which was only theoretically tested. Consequently, by means of comparison, this study employs such proxy and thereby creates the ability to discuss the validity of such proxy.

Implications of this study range from economical to political. Namely, as this topic is highly recent, the outcome of this study may address certain consequences for businesses and policies that perhaps were not highlighted before. More specifically, uncertainty may have drastic effects not only on investments, but also on for instance firm performance (Cowgill & Zitzewitz, 2014) and job satisfaction (Luthans et al., 2008). Hence, as is advocated by Pindyck (1990), the implications of investment behavior are indeed influenced by uncertainty, but should be governed by policies in the form of for example interest rate policies. Moreover, if investments deteriorate as a response to the referendum, it may expose their vulnerability to the European Union, and hence, may be a warning for countries such as Spain, France and Greece and specifically at this time of writing, Italy, in holding a referendum. In other words, if uncertainty deteriorates the degree of investments, it consequently deteriorates economic activity (Cukierman, 1980) which then, as well, could function as a warning for those countries tempted to hold a referendum.

This paper is organized as follows: section two briefly motivates the importance of this study by graphically showing key developments in the UK since the announcement of the referendum. Section three first defines uncertainty and subsequently discusses theoretical and empirical research. Section four discusses the main dependent and independent variables, thereby theoretically arguing the function and expectations of these variables. Section five elaborates the methods used and the required adjustments. Section six explains the data, motivates the sector focus and then briefly discusses the descriptive statistics. Consequently, section seven analyses the empirical results and is followed by both a discussion and conclusion.

2. Preliminary Facts on Referendum

As the topic of the referendum is very recent, empirical studies are therefore very limited. This section, however, first discusses some empirical studies and newspapers that are yet available, highlights background information and elaborates the development toward such a referendum. The subsequent section graphically motivates and discusses some preliminary facts of the referendum underlining the relevance of this study. This is discussed according to three developments prior and during the referendum period.

2.1 Background literature

The uncertainty in this study arises from the announcement that a referendum is going to take place in the U.K. This referendum asked the people of the U.K. whether they think the U.K. should leave the European Union (EU) or not. Although the topic of the referendum is recent, the developments towards it show a long history.

Shortly after the U.K. became part of the European Economic Community (EEC) in 1973, it held a referendum in 1975 with the similar question (Iyengar, 2016). With a total of 67% of the votes in favor of the EEC, the U.K. remained being part of this community. Many politicians have tried to hold another referendum since then, but have all failed up until 2015. By then, former U.K. prime-minister David Cameron had rejected calls sequentially to hold a referendum. Only since his second term as U.K. prime-minister, for which holding a referendum was a determining factor for being re-elected, the European Union Referendum Act 2015 was introduced to the British Parliament as a start of the process. May 27th, 2015, Britain's Queen Elizabeth II announced that a referendum will be scheduled asking her people whether the U.K. should remain the European Union or not (Gross & Winning, 2015). The referendum date was eventually set to June 23rd 2016, approximately thirteen months later.

The goal of a potential leave from the European Union, known as 'Brexit', was for the U.K. to renegotiate deals with the EU (Gross & Winning, 2015). More specifically, the Independence Party and later also half of the Conservative Party's members of Parliament (MP's) have campaigned to leave the EU for many years, because according to them, the EU imposed too many legislative restrictions and charged a membership fee too high compared to the benefits of this membership (Hunt & Wheeler, 2016). Other main arguments advocate recovering sovereignty and democracy of the U.K. and its people, thereby also trying to regain control over migration policies.

Furthermore, no specific plan for exiting from the European Union had been prepared by either side of the Brexit campaigns. The discussion regarding Brexit was first triggered by David Cameron in his Bloomberg speech in 2013. Consequently, it means that at least three years of preparation were available, although only after the referendum date it became publicly known that no party had prepared for this. Obviously, this stimulates uncertainty as no party can forecast the potential policies or the different forms of negotiations, whether that will be hard or soft.

Although only the U.K. has held a referendum, which, on 23rd of June 2016 resulted in the U.K. leaving the EU it is not a phenomenon restricted to the U.K. only. Namely, alongside with the U.K. there is widespread criticism and strong opposition against the EU among most European member states. This is known as Euroscepticism, primarily present in Spain, France and Greece (Payne, 2016). Although the financial crisis of

2008 is frequently addressed as the primary cause of the increase in Euroscepticism, Serricchio, Tsakatika & Quaglia (2013) argued that, according post 1992-trends, national identity and political institutions have been primary causes instead. Emanuele, Maggini & Marino (2016) have also found significant results on the relationship between failing institutions, such as party system instability, and Euroscepticism. Nevertheless, regardless the causes of Euroscepticism, a referendum on whether to leave the EU or not in combination with a rise in this Euroscepticism places much emphasis on the functioning of the EU. Particularly, once such a referendum is held by a member state, then, intuitively, the threshold is lowered for successive referenda, especially by those member states with high degrees of Euroscepticism.

2.2 Facts and Figures

The first graph on the next page shows the opinion-trackers on potential votes across the U.K. This tracker measured the people's opinions on the referendum during the post-announcement period. The black solid line indicates the vote in favor of remaining in the U.K, whilst the dotted line indicates a vote in favor of leaving. As can be studied from this graph is that, on average, both outcomes remain closely related to each other. For instance, at October 28th and 29th of 2015, both lines were nearly intersecting around the 41% of total votes for the particular opinion. This indicates that both outcomes of a referendum seemed equally likely, indicating uncertainty on the potential outcome of this referendum. In other words, the introduction described the process of the previous referendum in the United Kingdom in 1973, whereby 67% of the votes were in favor of staying in the EEC (Iyengar, 2016). If the process towards such outcome showed a similar distribution of opinions, then an outcome of staying in the EEC is potentially more likely compared to the opinions for the latest referendum. So, throughout the referendum-period opinions were distributed evenly so that uncertainty was rather high in forecasting the outcome.

Whether this expectation is in accordance with an actual rise in uncertainty can be studied by using an index for economic policy uncertainty. This Economic Policy Uncertainty Index (EPUI) is measured by incorporating three uncertainty components. The first component quantifies the total volume of papers from the top ten national newspapers that discuss policy-related economic uncertainty. The second component measures federal tax regulations that are expected to be adjusted in short-term, enhancing uncertainty regarding federal tax developments. The third component takes the dispersed opinions from multiple institutions on economic forecasters, with higher dispersion or disagreements indicating higher uncertainty.

Figure 2 shows the monthly development of the EPUI since 2008, with the gray dotted line indicating the European Union and the black solid line indicating the uncertainty across the United Kingdom. The vertical dotted line approximates the date of the referendum-announcement. At first, uncertainty in the United Kingdom dropped significantly towards the average European level. From that moment onwards, uncertainty increased exponentially towards a record-breaking height compared to earlier levels of uncertainty (Bloom, 2016). The uncertainty average for the European Union shows a co-movement in equal direction, expected to be partly caused by the referendum.

Comparing these developments with the changing investment intentions in figure 3 among firms in the manufacturing industry across the U.K., measured by the Bank of England's (2016) quarterly surveys, it shows that the referendum-announcement, graphed by the solid black line, is accompanied with a sharp decrease in investment intentions. Hence, uncertainty as measured by the Economic Policy Uncertainty Index has indeed increased since the announcement in May, although it seems to come with a certain lag. The graphs show that, as a response, firms in the manufacturing industry indeed have decreased investment intention.

Given this brief elaboration on the preliminary facts and developments, it appears that the referendum-announcement has indeed raised uncertainty across the country. The movement of voters on whether to vote in favour or against European membership underlined the reasoning of economic-wide uncertainty, as both outcomes seemed equally likely during the entire period. In conclusion for this section, these facts emphasize the relevance of this study, as such announcement may have severe effects in causing economic wide uncertainty.

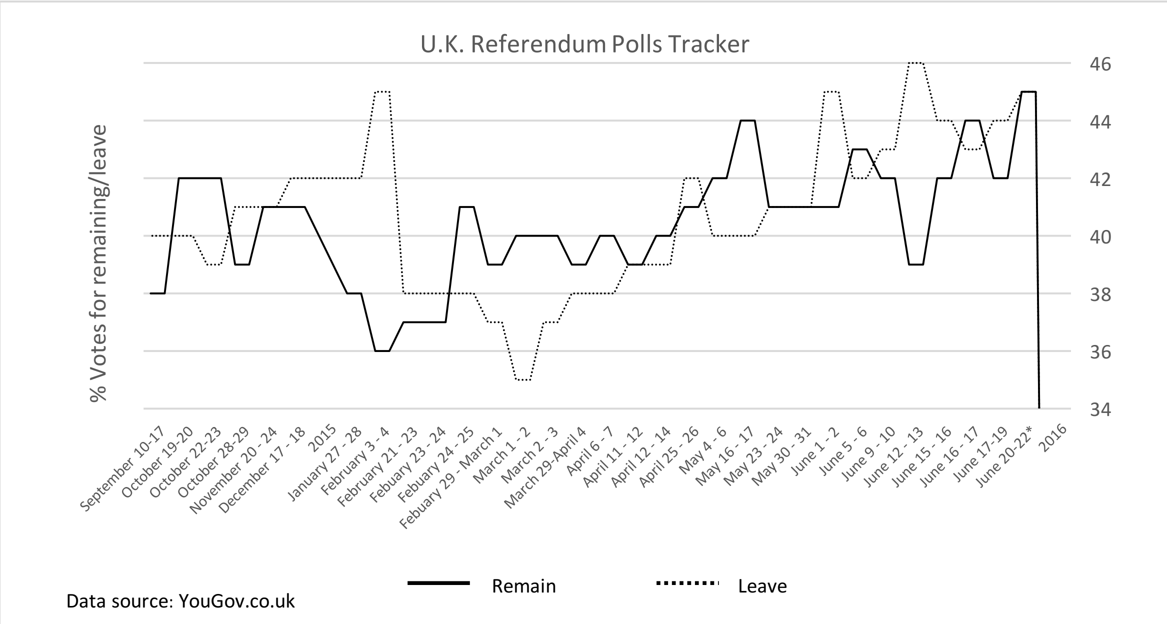

Figure 3. Referendum Polls tracker in the United Kingdom (YouGov.co.uk, 2016)

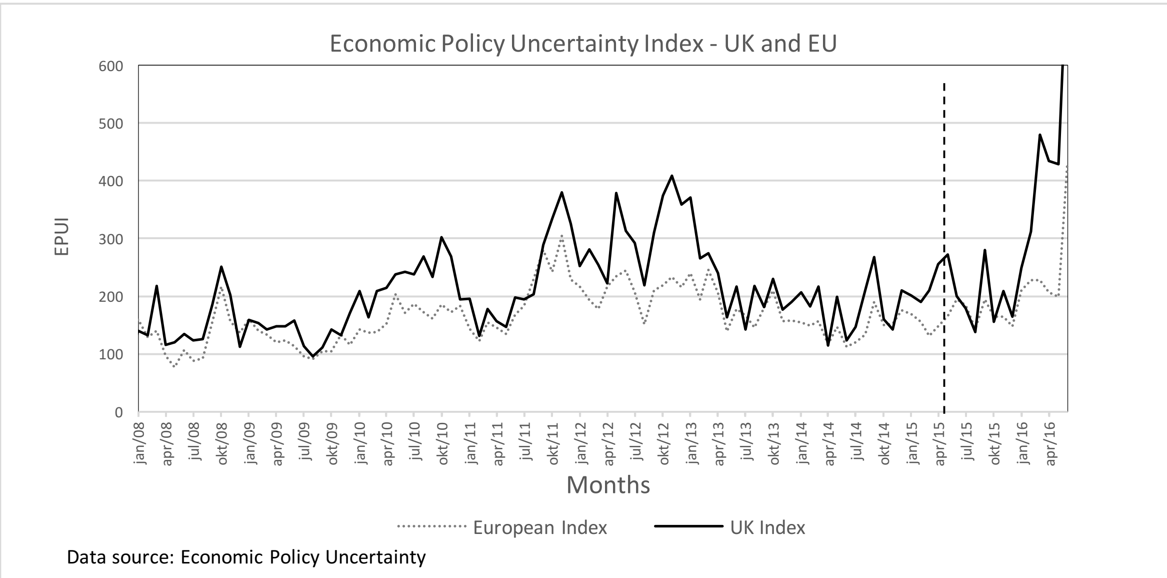

Figure 2. Shifts in the Economic Policy Uncertainty Index for the United Kingdom (Economic Policy Uncertainty, 2016).

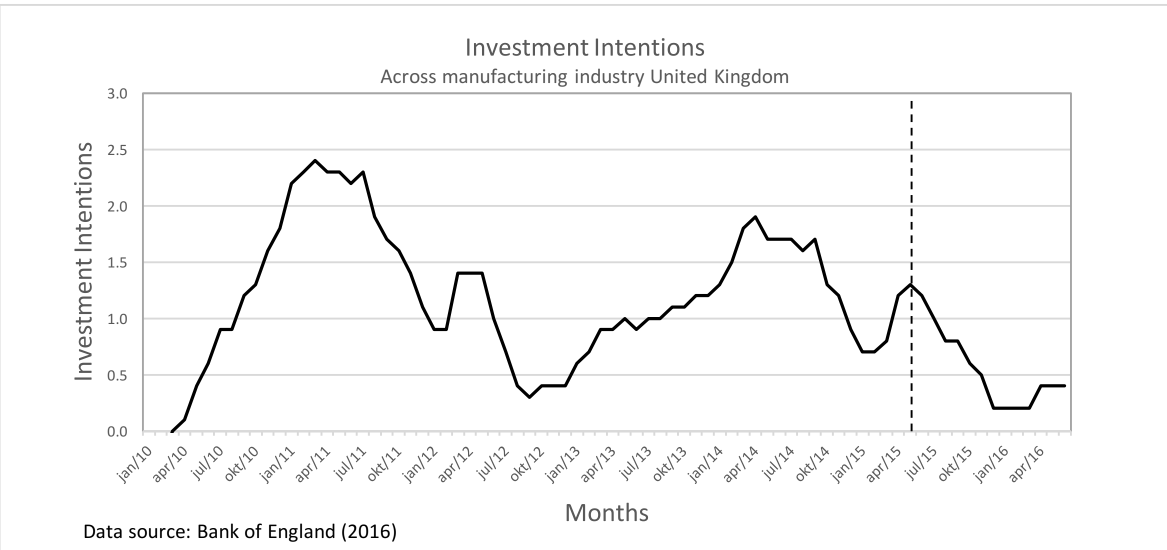

Figure 1. Investment intentions for manufacturing firms across the United Kingdom (Bank of England, 2016).

3. Literature

This section discusses literature that is covered in the study on investment behavior. Specifically, this section first disentangles and briefly discusses three different types of uncertainty in order to become more specific in studying its relationship with investments. Next, the economic framework of transaction costs economics will be discussed because this theory argues that certain costs are made whenever uncertainty rises. Continuing on this framework, some prominent and conventional investment behavior theory will be elaborated upon and consequently its advances will be discussed.

3.1 Uncertainty

Before discussing the related literature on the relationship between uncertainty and investment behavior, it is crucial to define the uncertainty this paper uses. Knight (1921) was one of the first to study uncertainty of economic actors, thereby acknowledging three different types of uncertainties: opportunity recognition, opportunity discovery and opportunity creation. Opportunity recognition is defined as knowing potential future outcomes for which probabilities can only be calculated, whereas with opportunity creation future outcomes can only be identified by trial and error. Opportunity discovery, however, is known as 'true uncertainty' wherein future outcomes are unknown and unknowable (Cohen & Winn, 2004). Typically, a peculiarity of investments is that these investment projects are paired with certain beliefs about the state of the world (Hirshleifer, 1965) and are allocated to certain probabilities to the outcomes of these investments (Serven, 1996). Moreover, investments are not done by trial and error as such an investment bears high sunk costs. Second, investments are certainly not pushed through without further knowledge on the state of the world and without having the ability to obtain probabilities of investment outcomes. Hence, uncertainty in this paper is in accordance with the second type of uncertainty, opportunity recognition, whereby probabilities for outcomes can only be calculated.

In the explanation on the existence and function of firms, Coase (1937) introduced the transaction cost theory arguing that firms exist when markets lack efficiency. His theory suggests a crucial importance between markets and firms, namely that firms exist where they exhibit lower transaction costs than markets. More specifically, firms have a greater ability to produce information at lower transaction costs, transform this information in order to utilize and consequently to maximize this utility (Groenewegen, 2004). Although much literature categorizes transaction costs differently (Milgrom & Roberts, 1987, p.6; Nooteboom, 1992), the essence is best described in the categorization by Groenewegen, Spithoven & Van den Berg (2010, p.22). They categorize transaction costs as (1) information costs, (2) adaptation- and negotiation costs and (3) contract- and monitoring costs. Any change in the value of these transaction costs is determined by three dimensions, namely a) the frequency of the transaction, b) the degree of uncertainty amongst a transaction and c) the degree of asset-specificity characterized by a transaction (Williamson, 1998, p.36). Although the theory on transaction costs is rather far reaching and may require additional specifications, only the aforementioned elements of this theory are of importance in this study and, hence, this illustration is therefore sufficient.

As this theory suggests, an increase in uncertainty amongst a transaction causes transaction costs to increase, or more specifically for this paper, to increase information costs. In other words, as uncertainty increases, firms may increase their effort to obtain information regarding, for example, future demands. Obtaining information on future demands is essential, as demand depends not only on existing abundance or scarcity of goods, but additionally on current expectations of future businesses (Keynes, 2007, ch. 22). Hence, acquiring information is essential to decrease uncertainty and ultimately to promote firm performance. The interrelationship of uncertainty and information has been the main focus for many fields of studies, such as the study for investment behavior and organizational theory. The importance of gathering information when investment decisions are made, and which thus requires information costs, will become clear in the next section where the option-approach of investments is introduced.

3.2 Investment Theories

To start with investment theory, a brief summary will be given on what conventional investment theory has suggested thus far and consequently how it evolved over time. This study tests the impact of uncertainty on investments. Hence, this section elaborates crucial factors that explain this relationship and the causes of adjusting the level of investments.

Starting in the sixties, conventional investment theory focused on two particular, somewhat equivalent approaches in explaining the uncertainty-investment relation (Serven, 1996). The first one is that investment behavior was determined by a cost-of-capital approach, whereby the desired stock of capital is retrieved by equating the marginal product with the marginal cost. The second approach focuses on the ratio of the capitalized value of the marginal unit of capital relative to its replacement cost; the current market price of capital (Abel, 1985, Lang et al., 1989; Leahy & Whited, 1995; Wolfe & Sauaia, 2003). This ratio is known as Tobin's q. Both approaches required the assumption of adjustment costs in order to transform the analysis from a *static* approach (Cukierman, 1980; Hirshleifer, 1965) towards a *dynamic* approach involving expectations about the future (Pindyck, 1988, 1990; Lucas & Prescott, 1971; Abel, 1983; Demers 1991). Rather essential, these costs of adjustment were assumed to be convex (i.e. increasing marginal cost of capital) with ambiguous results on the sign for the investment-uncertainty relationship, both empirically and theoretically. That is, although this convexity assumption, among others, was a point of interest in many studies (Lucas & Prescott, 1971; Pindyck, 1990; Demers 1991; Ghosal & Loungani, 2000) it was frequently found to be of insignificant effect on investment intentions (Abel, 1983, 1985; Leahy & Whited, 1995; Bloom, Bond & Van Reenen, 2007). This has urged the theories on the uncertainty-investment relationship to be improved, whereby criticism was based on three essential improvements (Serven, 1996).

First, most investments are partly or completely irreversible (Cukierman, 1980; Baldwin, 1982; Bernanke, 1983; Demers 1991; Ingersoll & Ross, 1992; McDonald & Siegel, 1986; Teisberg, 1993; Pindyck, 1988, 1990): initial investments are, once made, suck costs. In other words, capital can not be recovered completely when it is invested. Second, conventional theory has ignored the influence of uncertainty on investment decisions and their future awards. Investors are therefore bound to estimation, and hence the best they can do is to obtain certain probabilities to outcomes (Hirshleifer, 1965). Third, investors have the possibility to control the timing of investments. Put differently, they have the possibility to postpone investments and thus to acquire more information on possible future outcomes (Baldwin, 1982; Demers, 1991; Ingersoll & Ross, 1992). Arrow (1968) was one of the first to note the irreversibility of investments. He argued that this irreversibility was the primary cause of gradually adjustment of the capital stock, i.e. investments. Moreover, Demers (1991) has found that accounting for the irreversibility of investments, anticipation of receiving more information and learning the true state of demand lead to cautious investment behavior. This causes adjustment costs to be positively related to investments and secondly, causes capital stock to indeed adjust gradually. This gradual or incremental adjustment of capital stock for firms facing uncertainty of any kind was also discussed by Pindyck (1988), arguing that successive investments should be regarded as investments which attribute to the marginal product independently. That is, each individual project faces a certain threshold level of marginal profitability which must be met in order to continue gradually adjusting towards the desired stock of capital (Pindyck, 1988, 1990; Serven, 1996). However, Demers (1991) argued that there would be no gradually adjusting of the capital stock if the price of capital were to change suddenly, indicating a limited effect of the cost of capital effect on investments. In conclusion, different views on investment behavior are identified which in some aspects, insofar, give rather ambiguous results on the formation of the capital stock. Yet a rather shared view is that, according to these advances on investment theories, investment behavior is typically addressed to be gradually adjusted, predominantly because of this irreversibility. This new peculiarity of investments caused the emergence of a new approach towards investment theory.

This new approach towards investment theory arising from the irreversibility feature is the so-called option-approach (Abel et al., 1996; Serven, 1996; McDonald & Siegel, 1986). Specifically, this views an investment opportunity as an option to decide when and whether to buy a certain asset at different chosen points in time. It thereby creates the ability to offset such an investment choice to an alternative of postponing or not investing at all. This option underlines the value of postponing the investment and enhances the value of acquiring more information (Arrow & Fisher, 1974; Ingersoll & Ross, 1994). It thus balances the returns of investments against the alternative value of acquiring more information. This opportunity cost is highly sensitive to uncertainty and is easily affected by changing economic conditions. Therefore, it can have larger effects on investments than for instance changing policies in interest rates (Pindyck, 1990; Ingersoll & Ross, 1992). As is in conjunction with the 'investment pause' regularly observed in the aftermath of policy adjustment programs in developing countries, a lack of confidence in an economy is reflected in weak and delayed investments, and it consequently requires policy reforms to recover investments (World Bank, 1993).

The option-approach may sustain a better fit in explaining investment behavior of firms. Intuitively straightforward, when an investor acquires certain assets that are an irreversible expenditure, it kills the option to obtain more information that could possibly include information on the profitability of this investment (McDonald & Siegel, 1986). Moreover, under irreversibility, higher uncertainty reduces the responsiveness of firm's investment intentions when there is a contraction in demand (Bloom, Bond & Van Reenen, 2007). Consequently, the traditional Net-Present-Value (NPV) rule requires to be modified (Serven, 1996) because, if not, it leads to over-investment (Baldwin, 1982). Namely, this rule argues that an investor should proceed with his investment when the discounted value of the investment exceeds the purchase and installation costs (Serven, 1996). Obviously, this standard rule does not account for the option to postpone the investment. Hence, the rule requires to be modified in order for investors to proceed if and only if the discounted value of the investment exceeds not only the purchase and installation costs, *but also the value of keeping the option available* (Baldwin, 1982).

As is empirically tested to be of influence in explaining business cycle fluctuations by Bernanke (1983), agents must make a tradeoff in receiving the extra returns received from early commitments against the benefit of increased information gained by waiting. As previously mentioned, the availability of this option is of particular interest when uncertainty plays a major role, and as such, it suggests that the option value can be considerable (McDonald & Siegel, 1986). This option value is the main area of interest in this study, as it is expected that the referendum caused increased uncertainty so that firms were triggered to operationalize the option to either gradually invest or completely postpone investments. Intuitively, in line with the definition of opportunity recognition, firms hold beliefs about future developments, thereby incorporating probabilities that indicate expectations of the future state of the world. These beliefs are then balanced with the probabilities that indicate deviations from this future state of the world. As uncertainty increases, it increases the boundaries wherein all possible situations may take place. That is, if uncertainty increases to a higher extent, firms may be less likely to hold precise expectations on future outcomes, as it is partly unknown. If, additionally, the high-uncertainty period is recognized to have a commonly known end-date, like in this study, then firms are expected to either gradually invest, referring to the threshold argument of investments, or are expected to indeed postpone investments until the duration of the high-uncertainty period comes to an ending, for which the date is known. In other words, anticipating on the end of such period, firms may want to choose to 'survive' this high-uncertainty, thereby minimizing the risk of misaligning investments with true future outcomes (Blond et al., 2007; Serven, 1996). Intuitively, if on the other hand such an end-date is not known, this may weaken the relationship between uncertainty and investments because firms may accommodate to these circumstances, especially if this period has already taken on a considerable duration. Hence, the option value may be substantial when uncertainty is increasing, which is a dominant deterrent in terms of the adjusted NPV-rule for investments. Indeed, since this investment decision rule is extended with the option value, uncertainty can become a crucial deterrent. That is, investors choose to maximize the present value of return adjusted for uncertainty (Arrow & Lind, 2014). By focusing on the post-referendum period as a period with a known end-date and increased uncertainty, it is then expected that firms show to employ the option of either gradually invest or completely postpone investments.

3.3 Empirical Studies

Regardless of the amount of theoretical studies on the subject of explaining investment behavior, especially for the uncertainty-investment relationship, empirical evidence is rather limited due to the complexity of for instance modelling the irreversibility of investments. This section gives a brief overview on the, among others, rather dominant empirical studies.

On a micro-economic level, Teisberg (1993) tried to empirically test the presence of this option value for investments in electric utilities, which are typically assumed to require long lead times during which the value of the project is uncertain. This study then showed that firms, next to abandoning or delaying an investment project, also have an option to alter the *type* of investment. In line with gradually adjustment of investments, firms appeared to focus on smaller projects with shorter lead times, such that the expected rate of return has limited possibilities to fluctuate over time (also see Demers, 1991). Rather interesting, the same study also showed that a higher cost allowance on abandoned projects in a static model typically do not increase the incentive to invest in a multistage, dynamic model for multiple investments.

Leahy & Whited (1995) have studied a panel of U.S. manufacturing firms and found a negative effect of uncertainty on investments and showed it to be consistent with the theories of irreversible investment. They have shown that uncertainty lowered investments primarily through the changing replacement costs: Tobin's q. Moreover, they found no positive effect of the convexity of the marginal product of capital on the level of investments, in contrast to theory. In conclusion, they argued that, according to their study, the theory of irreversibility was left as the most likely explanation on the uncertainty-investment relationship.

On industry-level, Ghosal & Lougani (1995) estimated the impact of price uncertainty on investments using a panel of U.S. manufacturing industries. For an industry pooled estimation they found no significant effect of this relationship. However, disentangling such estimation into different subindustry-characteristics[1] uncovered a rather interesting difference. Namely, for industries with a high degree of product market competition it was found for uncertainty to have a significant and strong, negative relationship with investments, in opposite to non-competitive industries. Regardless of this difference, these results are broadly consistent with investment theories that explain the uncertainty-investment relationship in terms of irreversibility of capital investment.

In another study, Ghosal & Lougani (2000) studied the differential impact of uncertainty on investments between small and large firms across the United States, thereby using profit volatility as their main measure of uncertainty. They found that this relationship is significantly greater for industries dominated by smaller firms which could possibly be explained by theories related to irreversibility, financing constraints and risk preferences. Explaining differences in the uncertainty-investment relationship across differences in firm size, however, was argued to stem from different causes. Namely, different industry structures may impose different levels of sunk costs, hence relating to a different respond of uncertainty on investment. Alternatively, they argue that a small firm size restricts the accessibility to the capital market, thereby moderating investment behavior.

On an aggregate level, Pindyck & Solimano (1993) tested the relationship between both economic indicators, such as inflation and its volatility, and indicators for political uncertainty on the volatility of capital adjustments. They tested the importance of the irreversibility by testing the dependency on the earlier mentioned threshold on the levels on uncertainty. This exercise revealed a moderate effect of marginal profitability of capital on investments. Moreover, they tested that inflation has significant impact on this volatility of capital profitability.

These studies have all focused on the uncertainty-investment relationship in different fashions. Regardless the focus on either aggregate, industry or firm specific data, it indeed shows that uncertainty lowers investments. If an uncertainty-investment relationship was to be found, it would potentially stem from either changing replacement costs (measured as Tobin's Q), convexity of both the marginal cost and profitability of capital or the presence of limited reversibility and gradual investments (the option-approach). And as was just highlighted, this study focuses on the potential presence of the option-approach as it is expected that firms may either postpone or rather gradually adjust the capital stock as a respond to a temporary increase in uncertainty.

[1] Ghosal & Loungani (1995; 2000) did not focus on comparing the uncertainty-investment relationship between industries, but between different subindustries within that of the manufacturing.

As was briefly discussed, this study contributes by, first, testing this relationship during a period of grand scale uncertainty, thereby being additionally able to compare these results to previous papers that have used only a proxy to measure such relation (Blond et al., 2007; Ferderer, 1993; Ghosal, 1995; Ghosal & Loungani, 2000; Leahy & Whited, 1995; Serven, 1997; Teisberg,1993). Second, instead of focussing on cross-country level, like Serven (1996) and Ferderer (1993) or to limit the focus on one industry only, like Blond et al. (2007), Ghosal (1995), Ghosal & Loungani, 2000 or Leahy and Whited (1995), this study instead employs firm specific data to perform a cross-sectional analysis on two seemingly divergent industries as a measure of treatment effect. Moreover, next to being of potential value to society in analyzing the economic effects of a EU-referendum announcement, this study is particularly valuable in the field of investment economics as it tests the well-studied uncertainty-investment relationship in a highly, more recent and relevant environment.

4. Main dependent and independent variables

4.1 Measuring Uncertainty

There is a wide body of literature that has tried to explain the relation between investment behavior and uncertainty either by focusing on aggregate macroeconomic data (Ferderer, 1993), industry-specific data (Ghosal, 1995; Ghosal & Loungani, 1995, 2000) or firm-specific data (Leahy & Whited, 1995; Barro, 1989; Morck et al., 1990). As uncertainty remains challenging to measure empirically, most of these studies have attempted to explain this relation by using the stock market return, known as volatility, as a proxy for uncertainty (Barro, 1989; French et al., 1987). Yet others have tried to explain this relationship by including Tobin's q as a proxy, as this value determines the demand for capital and hence, investment-inducing behavior (Barro, 1989; Wolfe & Sauaia, 2003). Furthermore, Ferderer (1993) used risk premium as measure for uncertainty and argued that this risk premium, when compared with Tobin's q, has a greater and more significant effect on investments. Barro (1989) empirically proves that the volatility as a proxy for uncertainty outperforms Tobin's q. Nonetheless, other studies have shown that either one or both of these proxies have ambiguous, non-significant effects on investment behavior (Leahy & Whited, 1995; Wolfe & Sauaia, 2003; Ferderer, 1993). This ambiguous and non-significant effect of both proxies on investment behavior stems from the fact that both proxies include stock market values, that have movements that can be explained by numerous causes that are hard to identify (Bouiyour & Selmi, 2016). Accordingly, Blanchard, Ree & Summers (1990) argue that any study that incorporates stock market variables must take into account the effect of investor sentiment, which might explain a crucial amount of non-fundamental movement in the stock market. Namely, they showed that managers largely ignored market valuation signals when this signal differed from their own perception of fundamentals. In related studies, Morck et al. (1990) and Galeotti & Schiantarelli (1994) as well found a significant effect of investor sentiment on stock market valuations. This finding is in line with the theoretical approach of Scharfstein & Stein (1990), who argue that investors are subject to herd behavior, therefore again ignoring the market valuation signals. In highlighting the absence of both an investment collapse after the crash of 1987 or sharp increase in investment during the stock market boom in the late 1920's, Barro (1989) argued that this absence might be explained by factors such as investor sentiment or

other non-fundamental influences on the stock market. Hence, stock market movements are influenced by, among other factors, fads and bubbles. Such a proxy would therefore not measure uncertainty optimally.
Rather more recent studies have shown that, instead of Tobin's q or risk premium, taking the conditional standard deviation of a variable as a measure of its uncertainty is an economically and empirically satisfying method (Aizenman & Marion, 1999; Bond et al., 2003; Ghosal, 1995; Ghosal & Loungani, 1996, 2000; Leahy and Whited, 1995). In line with those studies, this study will use an equal method whereby not stock return volatility is measured, but the residuals of profit volatility as a measure of uncertainty (Orlik & Veldkamp, 2014). As those studies have highlighted that such a proxy for uncertainty measures uncertainty to a greater extent than stock market volatility, this study will therefore use this proxy as well.

Accordingly, this proxy is calculated by using the quarterly standard deviation from a firm's profit function

$$\pi = \frac{(Operating\ Income\ Before\ Taxes - Cost\ of\ Goods\ Sold)}{(Operating\ Income\ Before\ Taxes}$$

$$\pi_{i,t} = \lambda_0 + \lambda_1 T + \lambda_2 \pi_{i,t-1} + \lambda_3 \pi_{i,t-2} + \epsilon_{i,t}$$

where $\epsilon_{i,t}$ is the unsystematic component from the profit function, T is a linear time-trend and $\pi_{i,t}$ is the firm's profit in time t. To create an uncertainty time-series from this profit function, the unsystematic component, or called risk, is taken from 5 consecutive quarters and then averaged to get the uncertainty measure for the quarter following those 5 quarters. In other words: to retrieve the uncertainty measure for, for example, the third quarter in 2010, the residuals were collected from the five preceding quarters and taken the average of:

$$\text{Uncertainty}_t = \frac{\epsilon_{i,t-5} + \epsilon_{i,t-4} + \epsilon_{i,t-3} + \epsilon_{i,t-2} + \epsilon_{i,t-1}}{5}$$

As such, the residuals of the profit function from the quarters two to four from 2009 and quarters one and two from 2010 (totaling to five quarters) were taken to determine the uncertainty measure for the third quarter of 2010. Consequently, as the first available quarter in the data is the second quarter of 2009, the first five quarters were lost for observations and therefore, the time-series for uncertainty starts at the third quarter of 2010. The remaining quarters add up to a maximum of 24 observations of uncertainty per firm.

However, Ghosal & Loungani (2000) argue that this uncertainty in terms of profit deviation may be endogenous to industry specific characteristics such as different degrees of competition. As they then advocate[2] the inclusion of energy price *uncertainty*[3] as an instrument for the potential endogeneity of uncertainty on investment behavior,

[2] Ghosal & Lougani (2000) argue that different characteristics of industries, e.g. competition, may affect the degree of uncertainty. More specifically, they argue that both uncertainty of the bank rate and energy prices have direct effect on profits. The bank rate in the UK, however, has been set to change only once during the sample period and was therefore excluded form the model directly after having tested that it has no significant effect.
[3] Calculated in similar fashion as how uncertainty is measured. That is, they take the five period average unsystematic component of the energy prices estimated on a time trend and the energy prices lagged for one and two periods.

this study will show in later sections that an instrumental variable regression for dealing with this endogeneity is not required here since the uncertainty variable does not appear to be endogenous[4].

4.2 Measuring Investments

In order to define what influence uncertainty has on the investment behavior of firms across two sectors, it is crucial to define the investment proxy as well. Although a measure of investment is intuitively straightforward, there are multiple methods of measurements used among different studies. Particularly interesting is the extensive study of Hsiao & Li (2012) who highlight the large variety of investment measures and consequently tested twelve frequently used methods from representative studies. They found that the simplest accounting method that includes property, plant and equipment (PPE) has most significant effect as an investment measure, and thereby argue that other methods have insignificant effect or that those methods are industry specific only. Specifically, they endorse the use of *growth of gross PPE* because this measurement has the highest correlation to different benchmark values across all industries. Hence, this study uses this variable to measure the degree of investments and takes such growth rate as the percentage growth of the level of PPE of the current period compared to the level of PPE one year earlier. That is, the percentage growth of PPE over four quarters. An alternative would be to calculate growth rates over one, two or three quarters. However, as was discussed in the theoretical section, investments come rather gradually and it is therefore intuitive to measure such growth over at least one year (Ghosal & Loungani, 2000). These alternatives were tested individually and indeed; the results show that the model performs better with growth rates over four quarters.

4.3 Control variables

Following the empirical strategy of equivalent studies on the uncertainty-investment relationship such as Ghosal & Loungani (2000), Blond et al., 2007; Fuss & Vermeulen, 2004; Morck et al., 1990, this study includes several control variables that may capture the effect of uncertainty on investment behavior. First of all, frequently discussed as being a stylized fact, investments show persistence. That is, investment decision from a previous period are expected to have influence on investment decision in the current period. Hence this study includes the lagged variable of gross growth of PPE. To sustain linearity, both the current and lagged PPE growth were measured in logarithms.

Second, some authors advocate the inclusion of both current and lagged cash flow scaled by PPE (e.g. Ghosal & Loungani, 2000), and argue that no difference in performance is shown when cash flow were to be replaced by sales growth. However, as is discussed by for instance Bloom et al. (2007) and Hsiao & Li (2012), including sales growth outperforms the inclusion of cash flow as a control variable. Both variables were tested and indeed, it showed that the model including sales growth has more predictive power compared to the model with cash flow.

The effect of sales growth on investments is rather intuitive. Namely, as sales increase, firms may want to invest to increase the production capacity to fulfill the increasing demand (Blond et al., 2007; Fuss & Vermeulen, 2004; Morck et al., 1990). Hence, sales growth is expected to have a positive effect on investment

[4] Since the validity of such instrument cannot be tested but can only be supported by profound economic reasoning, it is assumed, given their arguments, that such instrument is indeed a valid, exogenous instrument.

behavior. Moreover, compared to other European countries, the effect of sales growth seems to be persistent particularly in the United Kingdom (Bond et al., 2003). Hence, the lagged variable is included as well.

Third, similarly to the empirical strategy of Ghosal & Loungani (2000), growth of private gross fixed capital formation (GFCF) is used as a measure to capture economic fluctuations. Namely, as capital formation in the residential sector causes growth of GDP, it in turn causes capital formation in the business sector (Wen, 2001). Similar to nonresidential investments, investments in the residential sector are characterized as being persistent as well, hence the lagged version is included in the model.

Fourth, the growth of UK aggregate nonresidential energy prices is included. As is argued by Hamilton (2005), changes in energy prices may not only be conveyed through consumers' expenditure, but especially so through changes in firm's investment expenditures. Namely, energy prices are expected to affect nonresidential investments via two channels (Kilian, 2008). The first channel is that marginal costs of production increase as a consequence of increasing energy prices. Bernanke (1983), for instance, shows in a partial equilibrium model that firms tend to postpone investments to wait for these prices to return to initial lower levels. Secondly, the demand for a firm's output decreases when energy prices increase. That is, consumer expenditures drop in response to rising energy prices. However, a consistent increase in energy prices may as well *increase* investments because firms may want to invest in energy-saving equipment (Barsky & Kilian, 2004). Hence, it is expected that energy prices may influence the decision for firms to invest.

Lastly, the model includes a dummy to represent the period before and after the referendum-announcement. The dummy takes the value of zero for those observations before 27th of May 2015, the day that the Queen publicly announced that a referendum will be held in the future on whether the UK should remain or leave the European Union. This dummy equals one to define the period after the Queen's announcement. As this data contains quarterly observations, this would raise a potential methodological issue since the announcement date takes place in the second month of the second quarter. Nevertheless, it is expected that shortly prior to the announcement date, any rise in uncertainty could have been initiated by rumors regarding such announcement. Inspection of the previously mentioned Economic Policy Uncertainty Index (EPUI) indeed shows a small increase in the uncertainty index for the UK in April. Henceforth, the dummy variable will take the value one from the second quarter of 2015 onwards. Although this increase could have been caused by numerous reasons, it is expected that including the announcement in the second quarter or even the third will only have marginal effects on the results. The intuition behind this dummy is that the post-announcement period increased economic-wide uncertainty and is therefore expected to have a negative effect on investments. As the graph on the EPUI suggests, indeed this announcement increased uncertainty. Hence, in later sections, this dummy will be included as a potential alternative measure of uncertainty. How this measure of uncertainty relates to the previously discussed measure of uncertainty and what methodological implications this might have on the estimation will be explained in later sections.

Table 1: Glossary and definition of variables

Variable	Effect	Definition
$\Delta PPE_{i,t}$	#	Dependent variable. The logarithm of the growth of PPE over four quarters, i.e. one year.
$Uncertainty_{i,t}$	−	The logarithm of the conditional standard deviation of profits over five quarters.
$Energy\ Price_t$	−	Logarithm of growth of aggregate industry energy prices for electricity, gas and solid fuels, excluding Climate Change Levy (CCL), seasonally adjusted.
$GFCF_t$	+	Growth rates of Gross Fixed Capital Formation in the United Kingdom.
$Sales\ Growth_{i,t}$	+	Percentage growth of sales of one period compared to the previous period.
Brexit	−	Dummy variable with value 1 indicating the post-announcement period, 0 otherwise.

5. Methods

This section discusses the methodological issues for this study. First, three models for Ordinary Least Squares (OLS) estimations will be highlighted. Consequently, the selection for these different models will be motivated. The second subsection argues the choice between an OLS fixed-effect transformation against the option for an OLS random-effect transformation. As a guidance for the choice on one of those estimators, next to theoretical motivations, the Hausman test will be conducted. Accordingly, a fixed effects transformation is tested to perform relatively better compared to the random effects transformation. However, such a fixed effects transformation has crucial consequences on the model, specifically because it was suggested above to include a lagged dependent variable. Hence, this section, instead of the section above, discusses these implications and motivates a solution.

5.1 The Model

This study uses the Ordinary Least Squares (OLS) with fixed effects and clustered variance-covariance matrix. The two regression functions below are the representative models, in equal order as to the structure of this study.

A. $\Delta PPE_t = \alpha + \beta_1 Uncertainty_t + \beta_2 GFCF_t + \beta_3 GFCF_{t-1} + \beta_4 Energy_t + \beta_5 Sales_t + \beta_6 Sales_t + \beta_7 \Delta PPE_{t-1} + \epsilon_{i,t}$

This model measures the effect of the uncertainty proxy on the logarithm of PPE growth, henceforth called investments, for both industries combined and separated. For notational purposes, this study names PPE in discussions rather than PPE growth or ΔPPE, although it is directed to the growth of PPE since this is the measure for investments. As a guidance for the effects of additional control variables, this model will first be estimated with growth of gross fixed capital formation (GFCF) as control variable only. Next, this estimation is repeated until all additional control variables are included.

In short, the first-differenced logarithm of growth of Property, Plant and Equipment (PPE) over four quarters is the proxy for investment growth. Uncertainty is measured by the conditional standard deviation over the five preceding quarters compared to quarter t and is also measured in logarithms. It is the first main-dependent variable to measure the uncertainty-investment relationship. Energy is registered as the aggregate industrial/nonresidential energy prices for excluding the climate change levy (CCL) and is used as a control variable. GFCF is the measure that controls for economy-wide investments and thereby controls for economy-wide fluctuations. Sales denotes firm specific sales growth to capture firm-specific performance fluctuations. Additionally, the Brexit dummy takes value 1 to denote the post-announcement period and will take value 0 to denote the pre-announcement period.

However, since the aim of this study is to test the relationship between uncertainty and investments during the post-announcement period, it requires the modification of the third model. A first and intuitive possibility is to interact the uncertainty proxy with the Brexit dummy variable. The inclusion of this interaction term then measures the uncertainty-investment relationship for the post-announcement period compared to the period before the announcement. However, since it is expected that the referendum itself generated increasing uncertainty, it would be empirically unattractive to include this interaction term. That is, if both the uncertainty and dummy variable measure uncertainty[5], such interaction would bias the estimation of the uncertainty effect on investment behavior. Hence, instead of interacting both terms, a more attractive solution is to instrument the uncertainty proxy with the Brexit dummy in model A using a two stage least squares estimation. Additional motivation will be given in later sections.

Consequently, as the Brexit dummy measures the effect of uncertainty on investments during the post announcement period, it becomes empirically attractive to test the validity of the former proxy of uncertainty as compared to the latter. That is, the uncertainty proxy will be replaced with the Brexit dummy, since it was just mentioned that this dummy is an attractive measure to capture uncertainty in the post-referendum period. Section seven evokes a discussion on this issue in greater detail. Hence, this results in the following and final regression function:

B. $\Delta\text{PPE}_{\text{t}} = \alpha + \beta_1\text{Brexit}_t + \beta_2\text{GFCF}_{\text{t}} + \beta_3\text{GFCF}_{\text{t-1}} + \beta_4\text{Energy}_{\text{t}} + \beta_5\text{Sales}_{\text{t}} + \beta_6\text{Sales}_{\text{t}} + \beta_7\Delta\text{PPE}_{\text{t-1}} + \epsilon_{i,t}$

5.2 OLS: Random or Fixed effects

As this study uses panel data containing 333 UK firms, it is imperative to adjust this model of this dataset accordingly. Namely, studying the relationship between uncertainty and investment behavior among firms for a dataset containing a large number of firms, it is intuitive that such modeling must take into account firm-specific information. As was discussed in the theoretical section, firms have idiosyncratic characteristics that may be determined by for instance managerial abilities or output market conditions (Serven, 1996). That is, the model must allow for the intercepts terms of all individual firms to vary across all firms, i.e. take into account the heterogeneity of individual firms.

[5] That uncertainty is expected to have increased during the post-announcement period is discussed in earlier section, showing that the economic policy uncertainty index has increased. Hence, including this dummy is expected to represent uncertainty during this period.

Such a model that allows for individual intercepts to vary is known as a fixed effects (within) estimator (Verbeek, 2012, p.377). Another possibility for panel data is to model the data as such that it can be estimated with the random effect estimator: estimation with an appropriate random error term that summarizes all factors affecting the dependent variable, but that have been omitted as regressors (Verbeek, 2012, p.381). The functional forms of both models are as follows;

Fixed effects model: $y_{it} = (\alpha + u_i) + X'_{it}\beta + v_{it}$

Random effects model: $y_{it} = \alpha + X'_{it}\beta + (u_i + v_{it})$

where u_i is a fixed or random effect specific to the individual firms that are not included in the model. As can be easily seen, this individual effect is added to the constant for the fixed effects model, whereas it is added to the errors for the random effect model. In other words, the former model tests individual differences in intercepts assuming equal slopes and intercepts across individual firms (Verbeek 2012, p.378).

Moreover, as the main interest of study is to measure the effect of uncertainty on investments during the post-announcement period, it is not possible to use a time fixed effects model since the main independent variable is time-variant[6]. Thus, in accordance with the data, the fixed effects model is favored over the random effects model as this data indeed contains individual firms, which are expected to differ substantially due to the arguments given above.

To check which model fits the data best, although merely as a guidance[7], the Hausman test is conducted whereby it tests the null hypothesis that the intercept and estimators are uncorrelated. It then compares two estimators: one that is consistent both under the null- and alternative hypothesis and one that is consistent (and mostly efficient) under the null hypothesis only. A significant difference between those two models indicates that the fixed effects model should be used (Verbeek, 2012, p.385). Table 8 (see appendix) shows the results of this test. The Chi-square statistic of 126.80 clearly indicates that the null hypothesis is rejected, thereby indicating, as expected, that the fixed-effects model should be used.

Then, since the fixed-effects model will be used, it has two estimation options. First, this model can be estimated using the Least Squares Dummy Variable (LSDV) regression, which includes multiple dummies in the model for every firm in the sample (Verbeek, 2012, p.377). However, this will become rather problematic given the large number of firms in the dataset. Hence, the second, alternative model will become rather useful: the 'within' estimation. This estimation procedure does not include dummies, although the intuition remains similar. That is, it uses deviations from group means, i.e. it uses the variation within each individual firm instead using numerous dummies. More precisely, this estimation procedure is as follows:

$$(y_{it} - \bar{y}_i) = (x_{it} - \bar{x}_i)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_i)$$

where $\bar{y}_i$ is the mean of the dependent variable, in this case growth of PPE, of the individual firm i, $\bar{x}_i$ is the mean of all variables included for individual firm i and $\bar{\varepsilon}_i$ is the mean error of individual firm i. Hence, this model

[6] Applying similar reasoning will restrict the inclusion of a time trend into the model, particularly for the models that include the Brexit dummy. Nevertheless, those models that do not include this variable were tested both with and without a time trend. Including such time trend, however, did not result in significant differences in estimation. Hence, for consistency of the models particularly with the Brexit dummy included, this study therefore omits such time trend.

[7] Discussed by for instance Verbeek (2012), such Hausman test is merely an indication of whether to choose fixed or random effects. Hence, it is not conclusive. Yet, the outcome of this score in combination with the raised discussion above, it seems indeed that the fixed effects model seems most suitable.

shows that this estimation technique allows for differences in firms' individual characteristics. Additional econometric explanation, of for instance the within transformed standard errors, will be omitted because such discussion is beyond the scope of this study.

Moreover, later sections will discuss modifications to this model in terms of heteroskedasticity and autocorrelation, and advocates the use of clustered data. Besides, since it is expected by Ghosal & Lougani (2000) that uncertainty is endogenous, they suggested an Instrumental Variable (2SLS) regression. Hence, such regression will be tested as well. However, it will be discussed and consequently tested that this model does not suffer from endogeneity. This study therefore chooses to use the OLS method instead.

5.3 Adjusting the dependent variable for Fixed Effects

Although it is tested and motivated that these data are best-served by fixed effects, this raises a crucial methodological issue. That is, it was discussed that investments show persistence and it was therefore advocated to include the lagged dependent variable of investments. However, including the lagged dependent variable in a fixed effects model may cause potential bias, the so-called Nickell Bias. That is, although the fixed effects transformation (the within transformation) eliminates unobserved individual effects, it does not completely eliminate estimation bias (Behr, 2003; Moyo, 2015). Namely, the lagged dependent variable is correlated with the error term of the fixed effects causing dynamic panel bias (Roodman, 2006). To circumvent this issue, it requires the dependent variable to be adjusted accordingly.

This solution is found in first-differencing the dependent variable, with the advantage that this method, just as the fixed effects transformation, still eliminates individual effects (Verbeek, 2012, p.379). This method is particularly useful if growth of PPE suffers from serial correlation, which is the case as will be shown, and is still expected to perform relatively well (Bertrand et al., 2002). Thus, the previously discussed models A and B will be modified accordingly:

$$\Delta \mathrm{PPE_t} = \alpha + \beta_1 Z_t + \beta_2 \mathrm{GFCF_t} + \beta_3 \mathrm{GFCF_{t\text{-}1}} + \beta_4 \mathrm{Energy_t} + \beta_5 \mathrm{Sales_t} + \beta_6 \mathrm{Sales_t} + \beta_7 \Delta \mathrm{PPE_{t\text{-}1}} + \epsilon_{i,t}$$

$$\Delta \mathrm{PPE_t} - \Delta \mathrm{PPE_{t\text{-}1}} = \alpha + \beta_1 Z_t + \beta_2 \mathrm{GFCF_t} + \beta_3 \mathrm{GFCF_{t\text{-}1}} + \beta_4 \mathrm{Energy_t} + \beta_5 \mathrm{Sales_t} + \beta_6 \mathrm{Sales_t} + \epsilon_{i,t}$$

C. $$\mathrm{D.}\Delta \mathrm{PPE_t} = \alpha + \beta_1 Z_t + \beta_2 \mathrm{GFCF_t} + \beta_3 \mathrm{GFCF_{t\text{-}1}} + \beta_4 \mathrm{Energy_t} + \beta_5 \mathrm{Sales_t} + \beta_6 \mathrm{Sales_t} + \epsilon_{i,t}$$

Where Z_t denotes either the uncertainty proxy in time t or the Brexit dummy. Intuitively, this measures the growth of investments compared to the growth of investments of the previous period, hence: differenced[8]. Figure 4 on the next page illustrates the interpretation of this transformed variable, where the growth of PPE is compared with the difference between growths. That is, both black dotted lines depict the original measure of investments, taken

[8] This transformed dependent variable now consists of two parts, growth of PPE for both periods. Consequently, the uncertainty proxy and the control variables may relate to either the growth of PPE, investments, or the difference in growth of PPE, the growth of investments. Such measurement makes interpretations rather difficult because it is unclear whether the uncertainty proxy and control variables are related to the growth of PPE or its differenced variant. However, whether it is the *growth* or the differenced *growth*, if any significant and negative relationship is to be found it will signal the presence of the option approach of investments. Alternative estimations do exist that allow the inclusion of the lagged dependent variable as a control, thereby enabling to measure growth of PPE individually instead of transforming it to the differenced growth of PPE. However, as will be discussed in the concluding sections, these estimations are beyond the scope of this study and may yield only limited improvements.

as the growth of the level of PPE compared to that of the previous period. In this example with arbitrary values, the growth of PPE is one for the period $t-1$, as PPE grows from four to five in periods $t-1$ to $t-2$. PPE growth for period t takes the arbitrary value of nine: the difference between the levels of PPE in periods t and $t-1$. Now, the transformed measure takes the difference of the growth of PPE for period t as is depicted by the solid grey square on the right. This is measured by taking the difference of both growth rates

$$\Delta\text{PPE}_t - \Delta\text{PPE}_{t\text{-}1} \rightarrow 9-1=8.$$

where the difference of eight is interpreted as follows: period t sustained a growth of investments of eight *higher* compared to the investment growth of the previous period, $t-1$.

To summarize, change in uncertainty is expected to relate to changing levels of investments. These investments are measured to be part of the growth of PPE, so that uncertainty relates to this growth of PPE. Different levels of uncertainty may thus imply different levels of PPE. However, growth of PPE may be influenced by variables other than just investments, predominantly by depreciation expenses[9]. Then, if PPE grows with an amount of x due to increasing investments, but is consequently deducted by total depreciation expense, ε, then the net value of PPE growth becomes $x-\varepsilon$, which potentially and particularly for depreciation underestimates the total increase in investments. As such, some studies deflate total PPE by the total value of depreciations. Nevertheless, as is argued by for instance Hsiao & Li (2012), different accounting methods, and the fact that some firms report only small or even zero values for depreciation, may potentially cause even greater noise for such measure of investments. The authors then tested and conclude that both net and gross growth of PPE remain the most suitable measure for investments.

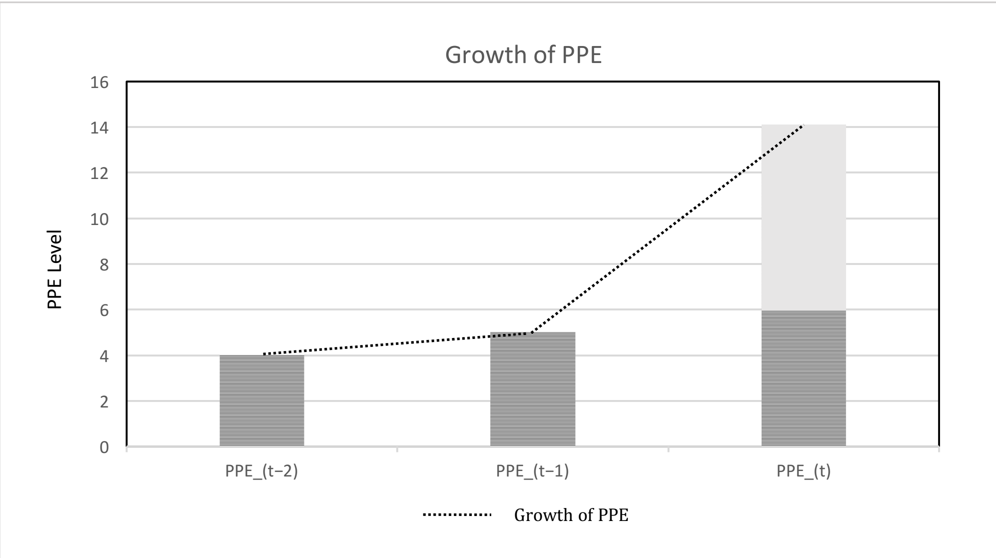

Figure 4: Example on Growth versus Difference in Growth of PPE

To conclude, the lagged dependent variable was required to be omitted from the model as this may cause dynamic panel bias. This section has discussed a potential solution by differencing PPE growth as a dependent variable.

[9] The data in this study uses Net PPE: the level of property, plant and equipment after netting out total depreciation. Hence the notion that growth of PPE may predominantly be influenced by depreciation instead of other factors, mostly with minor influences.

Although causing cumbersome interpretations, this method is able to partly incorporate the expected persistency of investments. Regardless of the potential noise in this measure predominantly caused by depreciation, it is excepted to be negligible.

6. Data

6.1 Information on Data

The data used in this study is extracted from the COMPUSTAT database, covering quarterly data from the UK from the second quarter of 2009 until the latest quarter available for the referendum period, in this case the second quarter of 2016. Consequently, the dataset is arranged in long- instead of wide format and is therefore sorted by firm ID and quarters. Instead of using firm names, all names have been transformed to arbitrary ID numbers Additional data on energy prices and gross fixed capital formation is gathered from the Office for National Statistics (ONS). The dataset initially contained 10.217 observations, which were filtered by transforming outliers to missing values, filtering for firms that did not have data registered at all and filtering those firms that were inactive during the post-announcement period. Second, as for the uncertainty proxy, the first five quarterly observations were lost for any firm since the first quarterly observation for firm i required the five preceding quarters. Consequently, the remaining dataset contains 6829 observations from 333 UK companies for 24 time-series for both the manufacturing and construction industry. More specifically, this dataset contains 26 firms registered in the construction industry and 307 firms registered in the manufacturing industry.

The data in this study is unbalanced. This means that observations are randomly missing across firms in the dataset. However, since the numbers of missing data is limited compared to the total size of the dataset, this will not have significant effects on the parameter estimates.

6.2 Sector Focus

As previously mentioned, this study compares the uncertainty-investment relation for two industries since the day the referendum was announced. As this uncertainty is expected to be of particular value especially in sectors that are (partially) focused on European markets, it is then crucial to determine what sectors to select for such study. Thus, one sector should be characterized to be highly influenced by international trade stability (particularly EU-stability), whereas the compared-with sector should reflect a domestic oriented market, which is perceived to be stable regardless of international trade fluctuations. Therefore, any deviation in investment intentions caused by uncertainty is seen from a perspective of two divergent industries in terms of international trade sensitivity. Yet the question then is, how is an industry measured to be highly internationally oriented and dependent, instead of only domestically oriented? Intuitively, such measure would be to study either total exports per sector or total outward foreign direct investment (FDI) per sector. However, as research has shown, those two measures are to be perceived as two different *strategies* for firms to serve international markets and thus require for both to be studied (Pfaffermayr, 1996; Head & Ries, 2004; Zhang, 2005). Compared to export, outward (horizontal) FDI is a strategy to engage in foreign markets by duplicating existing production facilities whereby the possibility is created to serve foreign demand locally (Oberhofer & Pfaffermayr, 2011). As for this difference, as suggested by the Office for National Statistics (ONS), (2012), it is crucial to distinguish such two strategies because particularly for the (financial) service sector it is the outward FDI which functions as primary strategy, and hence would ultimately lead to wrong conclusions if only export values were studied to determine international orientation. It thus depends on the particular sectors to be studied to determine the degree of international orientation and dependency.

Accordingly, by analyzing reports from the Office for National Statistics (2016), a clear division emerges between two sectors by incorporating both outward FDI and exports. Namely, as previously mentioned, the service sector accounts for more than 60% of total outward FDI from which 26% devoted to financial services. However, although this sector is so highly internationally orientated and hence interesting to include, this study will not focus on this sector due to a lack of data. Nevertheless, according to the same report, another industry might be as interesting as the service industry: the manufacturing industry. Namely, this industry accounts for over 65% of total exports from UK, thereby ranking first regarding exports. Focusing on outward FDI, manufacturing ranks second with more than 16% of total outward FDI. Moreover, the quarterly bulletin from the Bank of England (2006) shows that the manufacturing industry from the UK scores highest on an 'openness' scale compared to the European Union and the United States. Hence, the manufacturing industry serves as an eligible sector that could potentially be most vulnerable to uncertainty as it is internationally orientated most compared to other sectors within the UK. The sector that it is compared with is the construction sector, as this sector has both lowest FDI and lowest exports compared to all other sectors (HM Government, 2013; BIS, 2012). This sector is primarily focused on the domestic market, and exports in this sector are mainly from professional knowledge transfers (BIS, 2012). Moreover, sales of machinery and equipment across markets are registered under the manufacturing industry rather than for construction.

Conclusively, a negative shock in investments due to increased uncertainty across markets is expected to be significantly greater in the manufacturing- rather than the construction sector, as only the former sector is measured to be internationally orientated to a much higher degree. Moreover, attracting FDI has a multiple of factors that are of influence, from which predictable behavior, trustworthiness and commitment from government institutions appear, among others, to be of high influence and thus essential in this study (Hsiao & Shen, 2003). Appointing firms to the according sector was done by using the Standard Industry Classification (SIC) codes. Firms in the construction industry were registered between the two-digit industry codes 15 and 17, whereas firms in the manufacturing industry took the industry codes between 20 and 39.

6.3 Summary Statistics

This section gives a brief overview of the summary statistics of the variables for the estimation sample after having filtered the data. The variables used are the logs of PPE growth, uncertainty and growth of industrial energy prices, the normal growth rates of sales, gross fixed capital formation and the Brexit dummy.

Observations shows that all means are positive, only the mean of sales growth being close to zero. This means that, on average, firms have zero-percentage sales growth. Growth of GFCF is also moderate, as this indicator only changes incrementally. Consequently, its standard deviation remains small as well.

As normality-indicators, the scores of both skewness and Kurtosis are included. The skewness score indicates asymmetry of the distribution around the mean, the Kurtosis-score is a measure that indicates the sharpness in the height of the distribution curve. The skewness score is supposed to be in the range of -2 and 2 to show a normal univariate distribution. As for this score, all variables except for both the uncertainty and the energy variable, are skewed somewhat to the right and have a score relatively close to zero. Equivalently for the Brexit dummy, it is skewed to the right yet with a relatively high score of 1.5. However, it is still well within the range. Uncertainty scores a rather large score of approximately -2.5, indicating a left skewed distribution. Although it is not in range, it crossed boundaries only marginally which is expected to form no methodological issues. The kurtosis score shows positive values for all variables indicating, compared to the normal distribution, a slightly smaller distribution with thin tails and a higher peak for the Energy variable, GFCF and the Brexit dummy. On the other hand, growth of PPE, uncertainty and sales growth report a rather high score for the kurtosis. This suggests a distribution that is flat-shaped with fat tails.

Table 2 of summary statistics show relatively suitable scores to assume a normal univariate distribution. All but two of the variables are slightly skewed but show scores close to zero. Additionally, the kurtosis score shows a positive score of around two for three out of six variables, for those indicating thin tails and a somewhat sharp peak. The remaining variables have distributions that are rather fat-tailed and a relatively flat-shaped.

Table 2: Summary Statistics

Stats	Log (ΔPPE)	Log (Uncertainty)	Log (Energy)	Sales Growth	Growth of GFCF	Brexit
Mean	0.1491	2.6025	4.698	0.0147	0.0881	0.1988
Median	0.1092	2.6078	4.7084	0	0.0893	0
Max	2.9088	2.7017	4.7736	1.45	0.1292	1
Min	-1.9607	2.3000	4.5558	-1	0.0542	0
Std. Dev	0.3729	0.0433	0.0555	0.2120	0.0212	0.3992
Sum	982.77	14839.51	32083.23	93.9446	595.56	1358
Obs.	6593	5702	6829	6376	6756	6829
Skewness	1.0489	-2.4846	-0.6532	0.8412	0.04220	1.5089
Kurtosis	14.4063	14.0057	2.6630	14.0246	2.1172	3.2769

7. Results

This section shows and discusses the results that are achieved through several different methods of estimation. The starting point of this section is the regular OLS model with fixed effects, and it is discussed and shown why such fixed effects model is implemented. Consequently, some estimating restrictions are relaxed in order to estimate the data properly without losing consistency and creating potential bias. Moreover, the methodological issue of endogeneity as raised in the article of Ghosal & Longani (2000) will be discussed and tested for validity against the alternative of the initial OLS fixed effects model with cluster-robust standard errors. As it is then shown that, assuming exogeneity of the instrument, the uncertainty variable does not suffer from endogeneity, this section advances with the OLS method and additionally includes the growth of aggregate industry energy prices. Appropriately, the model will be expanded in order to capture the effect of the uncertainty-investment relation after the referendum-announcement was made. It is then discussed how to capture such relation with the estimated proxy for uncertainty, and it is questioned whether this proxy is still suitable for use when the announcement effect is studied. Accordingly, this uncertainty measure will be replaced with the Brexit dummy for the last three models. The models will test this relation for both industries combined and both industries separated.

7.1 Correlation Matrix

As the preceding section discussed the descriptive statistics of all variables, this subsection will briefly discuss the correlation matrix. Table 3 reports the output for the correlation of all variables. As is shown, all but the Brexit – Fuel correlation show relatively low values, indicating that there is no concern for multicollinearity. However, the correlation between Brexit and Fuel is rather high, reporting a value of -0.63. Nevertheless, it may not cause methodological issues. That is, only values larger than a correlation of approximately 0.9 may seriously indicate multicollinearity as this may result in estimates with unreliable standard errors and even an unexpected sign (Verbeek, 2012, p.44; Wooldridge, 2009, pp. 95 – 96). Yet, although such indicator is not conclusive and merely functions as a guideline, the Variance Inflator Factor (VIF) is calculated for all variables, whereby a factor less then ten indicates that there is no multicollinearity issue. The results show that there is no reason for concern: all factors circle around a VIF value of two.

Table 3: Correlation Matrix

	Log (Uncertainty)$_{i,t}$	Log (PPE Growth)$_{i,t}$	GFCF$_t$	Sales Growth$_{i,t}$	Brexit	Log (Energy Price)$_t$
Log(Uncertainty)$_{i,t}$	1.0000					
Log(PPE Growth)$_{i,t}$	-0.0478	1.0000				
GFCF$_t$	0.0028	-0.0055	1.0000			
Sales Growth$_{i,t}$	0.0180	0.0571	0.0132	1.0000		
Brexit	0.1127	-0.0027	-0.1307	0.0014	1.0000	
Log(Energy Price)$_t$	-0.0186	0.0109	0.0086	-0.0379	-0.6246	1.0000

Moreover, although the VIF indicator does not function as a conclusive measure for multicollinearity issues, it can in addition to only economic reasoning be concluded that such correlation produces no empirical concern. Hence, to conclude, all estimators produce relatively low correlations making them suitable for estimation.

7.2 OLS Fixed Effects

Table 4 shows the output for the first three models. The first model is a fixed effects model with limited control variables included, whereas the second model adds cluster-robust errors. Henceforth, all models include these cluster-robust errors. The third model expands the second model by adding an additional control variable.

The second column (model 1) of table 4 shows the output for both industries combined for the fixed-effects model, with limited control variables included. This output shows that uncertainty is not significantly related to investment behavior of firms[10]. That is, the coefficient does not statistically differ from zero. Although this model functions as a preliminary regression, the results are not in accordance with the expectations from the theory, since it was expected that uncertainty is negatively related to investment behavior. Equivalently, both the current and lagged GFCF show no significance. The output for the R-squared is omitted for all models since no value can be attached to such measure in panel-data estimation.

However, as is typically the case for panel-data models, it is expected that the model suffers from both heteroskedasticity and serial correlation. Hence, before proceeding to include additional control variables, the full model must be tested for the presence of both effects and consequently to be adjusted accordingly. Therefore, a test on the full model is performed to check for the presence of heteroskedasticity according to the Modified Wald Test. This test calculates a test statistic for groupwise heteroskedasticity in the residuals for fixed-effects models whereby the null hypotheses indicates homoskedasticity. Moreover, to test for serial correlation in this linear panel-level model, the Wooldridge test for serial correlation is applied. This test has been empirically tested to have good size and power for reasonable sample sizes (Wooldridge 2010; Drukker, 2003). Both tests show that the model suffers from both heteroskedasticity and autocorrelation. To correct for this presence, a standard procedure is to include White standard errors or to allow for Newey-West/HAC standard errors and as such, make the model consistent against heteroskedasticity and autocorrelation since the random variables are not independent and/or identically distributed. Additionally, Bertrand et al. (2002), Hoechle (2007) and Stock & Watson (2007), for example, endorse to cluster the model by groups as they argue it to be more efficient compared to only adjusting the standard errors to be robust. Namely, it relaxes the assumption that observations are independently drawn. More specifically, clustering only requires that the observations *across* clusters are independent. These adjustments correct for both heteroskedasticity and autocorrelation. Compared to the fixed effects transformation that address the potential impact of unobserved heterogeneity on the conditional mean, clustering accounts for potential correlation between individual firm's errors over time (Judson & Owen, 1996).

[10] This study does not numerically interpret insignificant result since these do not statistically differ from zero.

Table 4: OLS Fixed effects output

Dependent: D.Log(ΔPPE)$_{i,t}$	OLS 1 (Total)	2 (Total)	3 (Total)
Log(Uncertainty)$_{i,t}$	0.0906 (0.101)	0.0906 (0.109)	0.0160 (0.118)
Log(GFCF)$_t$	-0.021 (0.012)	-0.021 (0.013)	-0.016 (0.012)
Log(GFCF)$_{t-1}$	-0.001 (0.012)	-0.001 (0.009)	0.004 (0.09)
Log(Energy Price)$_t$			-0.150** (0.0632)
Constants	-0.217 (0.265)	-0.217 (0.286)	0.668 (0.513)
N	5233	5233	5233
#Firms	313	313	313

(Robust) standard errors in parentheses
Dependent Variable: Differenced log of PPE growth
Model 1: Output for OLS Fixed Effects (FE) for the total industry
Model 2 and 3: Output for OLS FE with
Clustered Variance-Covariance Matrix (VCE) for the total industry
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The third column (model 2) in table 4 shows the output for this OLS fixed-effects model with robust, clustered standard errors. All coefficients and signs remain unchanged, but the standard errors have increased compared to the first model. Such increase of standard errors is typically the case when data is clustered. Put different, regular OLS shows a downward bias if the model is not clustered by groups (Wooldridge, 2003).

The third model in table 4 is the equivalent of model 2, although with the inclusion of the logarithmic growth of aggregate nonresidential energy prices. The value of the coefficient for uncertainty decreases whilst the standard error has increased. For the current GFCF variable, it is observed that both the value of the coefficient and standard error decrease. The opposite holds for the lagged GFCF: the value of the coefficient has increased combined with a decreased standard error. Yet, none of those variables are significant. In contrast, however, is the significant and negative relationship of energy prices with investments. That is, one percent increase in energy prices relates to 0.15% reduction in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. This is in conformity with the theory as explained in previous sections: an increase in energy prices may increase marginal costs of production and, additionally, decreases aggregate consumer spending. As a decrease in consumer spending does not exercise additional pressure on a firm's production capacity, it depresses the required adjustment of capital. It does not, however, underline the theory that firms want to substitute their equipment in return for energy-saving equipment. This effect is perhaps present in a longer-term sample set since, intuitively, this sort of investment is longer-term oriented.

Before proceeding to the model's expansion, it is, however, imperative to consider the discussion raised by Ghosal & Lougani (2000). That is, uncertainty might be endogenous and could potentially be instrumented by the uncertainty on energy prices. Since the exogeneity of such instrument cannot be tested empirically, the validity must be underlined by profound economic reasoning. Briefly, using numerous related studies, Ghosal and Loungani argued that uncertainty in energy prices may affect investment decisions of firms as they, for example, will want to wait for prices to decrease. Hence, it is subject to uncertainty as these investments depend on the timing of such price decrease. This instrument is calculated according the same method as in obtaining the profit uncertainty measure used in this study, i.e. taking the conditional standard deviation of a variable as a measure of its uncertainty. Assuming exogeneity of this instrument, the Durbin-Wu-Hausman test adjusted for cluster-robust fixed effects panel data was performed to test for endogeneity of uncertainty. This test compares both OLS and IV estimation and determines the difference between those two models. If the models are different enough, the null hypothesis of exogeneity will be rejected thereby indicating that the OLS model is consistent (Baum, Schaffer & Stillman, 2003). The output from this test (see Table 9 in the appendix), which is denoted as the endogeneity test for endogenous regressors, shows a p-value of 0.1396 which does not reject the null hypotheses in favor of exogeneity of uncertainty and consistency of the OLS method. In other words, the variable uncertainty (named luncertainty2 in the table for practical reasons) does not suffer from endogeneity, so that this study continues using the OLS fixed effects model with cluster-robust standard errors.

Then in contrast to using *uncertainty* of industry energy prices, the methodological section raised a brief motivation to include the *change* in industry energy prices into the model as an explanatory variable. In short, changing nonresidential energy prices were expected to affect the level of nonresidential investments in two ways: through a contraction in consumer demand as a respond to increasing energy prices, and second, it increases the marginal cost of production. Hence, changing energy prices are expected to affect the degree of investments directly rather than to be channeled through uncertainty.

7.3 OLS Fixed Effects – Overall

This subsection considers models four to six in table 5. These models extend the earlier models by including both the current and lagged version of sales growth. The full model consequently tests the relationship between uncertainty and investments, for the industries combined as well as separated.

The fourth model of table 5 reports the output of the OLS fixed-effects model with cluster-robust standard errors. Uncertainty remains insignificant, indicating that the coefficient does not significantly differ from zero in the relationship with investments. Inclusion of both versions of sales growth, however, does increase the coefficient whilst decreases the standard errors of uncertainty, indicating an improved estimation compared to the third model.

Similar changes can be observed for both the current and lagged GFCF, where especially the former version now shows a marginal significance at the 90% confidence interval. These results show that one percent increase in GFCF relates to a decrease of 0.02% in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. However, this is at odds with what was expected according to theory, since a rise in GFCF would signal economic growth, hence causing increased investments. Nevertheless, this variable deserves little interpretation since it is only significant at such small confidence level given the large number of observations.

Energy prices, though, remain significant and negatively related to investments within the 95% confidence interval. That is, one percent increase in energy prices relates to 0.17% reduction in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. Moreover, the additional control variable Sales Growth shows a significant and a somewhat steep, negative relationship with investments. Namely, one percentage-point increase in sales growth relates to 5.9% increase in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. Hence, firms may want to invest to increase the production capacity to fulfill the increasing demand. The lagged version of sales growth, however, is not statistically different from zero.

The inclusion of sales growth alternated the estimates only marginally. If it were, in contrast, that sales growth and uncertainty are highly related through for instance changing demand, causing increased uncertainty, then the estimates for uncertainty were expected to show a more sensitive respond to the inclusion of sales growth. Since this is not the case, it seems rather more likely that sales growth indeed, in accordance with theory, may be directly related to investments.

As comparison, it is interesting to study the difference between models five and six. That is, model five represents the uncertainty-investment relationship for the manufacturing industry; model six shows the output for the construction industry. As the difference in the number of observations between the construction- and the manufacturing industry is rather large, it is therefore straightforward that the results for the manufacturing industry are closely related to those for both industries combined. Specifically, the results for models five and six show no significant relationship between uncertainty and investments for both industries, although the sign of uncertainty for only the construction industry is directed to what is expected according to theory.

Proceeding in studying the differences between model five and six in table 5, the manufacturing industry indeed shows a significant relationship between both energy prices and sales growth, similar to the previous models, although in contrast with the construction industry. For the manufacturing industry, one percent increase in energy prices relates to approximately 0.19% reduction in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. Moreover, it shows that on the 90% confidence interval, one percentage-point increase in sales growth relates to 6.3% reduction in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. In terms of the number of significant estimators, it shows that estimations for the construction industry perform rather poorly, perhaps reflecting the limited number of firms observed as compared to that of the manufacturing industry. Nevertheless, the total amount of observations for the construction industry is sufficient in order to test for significance relationships. Moreover, an interesting point to note is the difference between both industries' constants. That is, the construction industry has a higher positive constant compared to that of the construction industry, indicating higher growth of investments regardless of the level of uncertainty.

Table 5: OLS Fixed effects output table

Dependent: D.Log(ΔPPE)$_{i, t}$	OLS			OLS		
	1 (Total)	2 (Total)	3 (Total)	4 (Total)	5 (Manuf.)	6 (Constr.)
Log(Uncertainty)$_{i, t}$	0.0906 (0.101)	0.0906 (0.109)	0.0160 (0.118)	0.0250 (0.115)	0.0808 (0.115)	-0.618 (0.514)
Log(GFCF)$_{t}$	-0.021 (0.012)	-0.021 (0.013)	-0.016 (0.012)	-0.020* (0.011)	-0.019 (0.012)	-0.020 (0.035)
Log(GFCF)$_{t-1}$	-0.001 (0.012)	-0.001 (0.009)	0.004 (0.09)	0.008 (0.009)	-0.009 (0.009)	-0.002 (0.031)
Log(Energy Price)$_{i, t}$			-0.150** (0.0632)	-0.172*** (0.0593)	-0.189*** (0.0615)	-0.0243 (0.221)
Sales Growth$_{i, t}$				0.0593* (0.0314)	0.0633* (0.0338)	0.0299 (0.0728)
Sales Growth$_{i, t-1}$				0.00269 (0.0120)	0.00456 (0.0130)	-0.0132 (0.0177)
Constants	-0.217 (0.265)	-0.217 (0.286)	0.668 (0.513)	0.748 (0.484)	0.681 (0.483)	1.765 (2.313)
N	5233	5233	5233	5069	4585	484
#Firms	313	313	313	310	284	26

(Robust) standard errors in parentheses
Dependent Variable: Differenced log of PPE growth
Model 1: Output for OLS Fixed Effects (FE) regression
Model 2 to 6: Output OLS FE with Clustered Variance-Covariance Matrix (VCE)
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7.4 OLS Fixed effects – IV

The main focus of this study is to test whether the announcement of the referendum caused such high uncertainty, that firms have withdrawn or postponed their investment plans. As previous results have indicated, this relationship does not appear to be significant over the whole sample period. The question for this study and particularly this section, however, is whether a possible relationship exists between uncertainty and investments during the post-announcement period. In other words: do firms indeed postpone or withdraw investment plans when uncertainty increases? As was discussed in preceding sections, this is tested by instrumenting the uncertainty proxy with the Brexit dummy. By instrumenting uncertainty with the dummy variable, it enables the model to test the relationship between uncertainty and investment during the post-announcement period only, whilst preserving the original uncertainty proxy. Hence, this subsection shows the output for 2SLS estimations with fixed effects and cluster-robust standard errors. Similar to the preceding section, the output is divided into three subgroups: 1) the total of both industries; 2) the manufacturing industry only and 3) for the construction industry only. Again, if any significant relationship is to be found, it is expected to be found for the manufacturing industry. This section ends with a brief motivation to implement the alternative measure of uncertainty, for which it is expected to capture the uncertainty effect since the referendum-announcement to a greater extent.

First of all, to test whether uncertainty has a negative relationship with investments during the post-announcement period, it is imperative to graphically check whether the uncertainty proxy has indeed increased during that period as compared to the preceding period. Figure 5 illustrates this by comparing the uncertainty values for both periods by interacting these with the Brexit dummy. Thus, value zero on the x-axis denote the pre-announcement period whereas the value of one on the x-axis denotes the post-announcement period. The striped line depicts the fitted values, showing that uncertainty has increased on average during one period to the other, although only marginally. Specifically, uncertainty takes a marginally higher average value in the post-announcement period compared to that of the pre-announcement period. This graphical motivation briefly supports the subsequent analysis on the uncertainty-investment relationship, supporting the notion that uncertainty has increased, at least marginally. Consequently, instrumenting uncertainty with the Brexit dummy remains to serve as a suitable method to estimate the uncertainty-investment relationship during the post-announcement period. How the Brexit dummy is used as an instrument for uncertainty is shown in the third appendix, where both the first and the second stage regressions are formulated.

Models seven to nine from table 6 report the output for this instrumental variable estimations. All three models clearly show a strong increase in the value of the uncertainty coefficient. Moreover, in contrast to the earlier models, model seven now shows that uncertainty is negatively related to investment growth. Namely, a one percent increase in uncertainty relates to an approximate 0.37% reduction in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. Thus, there is a significant and negative relationship between uncertainty and investments for both industries together during the post-announcement period. This is a first indication that firms indeed postpone investments in order to retrieve more information regarding future expectations. As in earlier models, although now with a steeper coefficient, energy prices are again significant and negatively related to investments on the 99% confidence interval. That is, one percent increase in energy prices relates to a reduction of approximately 0.24% in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. Growth of sales remain significant with a marginally smaller value of the coefficient as to model 4, albeit again on the smaller 90% confidence interval.

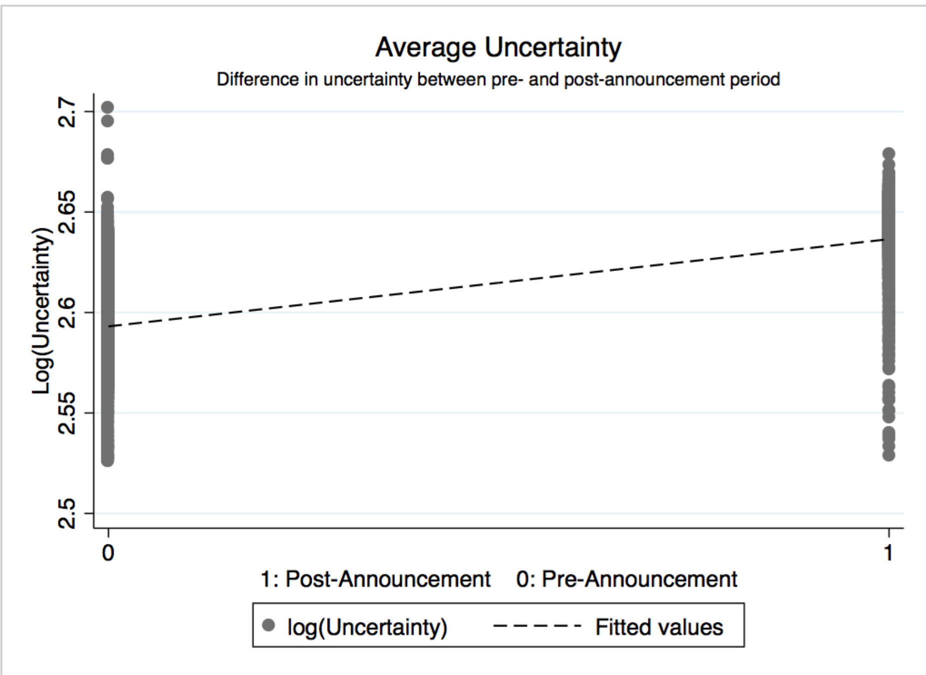

Figure 5: Average increase of Uncertainty since referendum-announcement

Table 6: Output for OLS Fixed Effects

Dependent: D.Log(ΔPPE)$_{i,t}$	OLS Overall			OLS Overall			IV Post-announcement		
	1 (Total)	2 (Total)	3 (Total)	4 (Total)	5 (Manuf.)	6 (Constr.)	7 (Total)	8 (Manuf.)	9 (Constr.)
Log(Uncertainty)$_{i,t}$	0.0906 (0.101)	0.0906 (0.109)	0.0160 (0.118)	0.0250 (0.115)	0.0808 (0.115)	-0.618 (0.514)	-0.371** (0.187)	-0.323* (0.196)	-0.850 (0.602)
Log(GFCF)$_t$	-0.021 (0.012)	-0.021 (0.013)	-0.016 (0.012)	-0.020* (0.011)	-0.019 (0.012)	-0.020 (0.035)	-0.013 (0.011)	-0.012 (0.012)	-0.015 (0.034)
Log(GFCF)$_{t-1}$	-0.001 (0.012)	-0.001 (0.009)	0.004 (0.09)	0.008 (0.009)	-0.009 (0.009)	-0.002 (0.031)	0.009 (0.009)	0.010 (0.009)	-0.003 (0.031)
Log(Energy Price)$_{i,t}$			-0.150** (0.0632)	-0.172*** (0.0593)	-0.189*** (0.0615)	-0.0243 (0.221)	-0.238*** (0.0693)	-0.256*** (0.0728)	-0.0627 (0.229)
Sales Growth$_{i,t}$				0.0593* (0.0314)	0.0633* (0.0338)	0.0299 (0.0728)	0.0540* (0.0314)	0.0573* (0.0337)	0.0302 (0.0727)
Sales Growth$_{i,t-1}$				0.00269 (0.0120)	0.00456 (0.0130)	-0.0132 (0.0177)	0.00168 (0.0120)	0.00339 (0.0130)	-0.0131 (0.0181)
Constants	-0.217 (0.265)	-0.217 (0.286)	0.668 (0.513)	0.748 (0.484)	0.681 (0.483)	1.765 (2.313)	2.087*** (0.740)	2.034*** (0.772)	2.550 (2.558)
N	5233	5233	5233	5069	4585	484	5069	4585	484
#Firms	313	313	313	310	284	26	310	284	26

(Robust) standard errors in parentheses
Dependent Variable: Differenced log of PPE growth
Model 1: Output for OLS Fixed Effects (FE) regression
Model 2 to 6: Output for OLS FE with Clustered Variance-Covariance Matrix (VCE)
Model 7 – 9: Output for Fixed Effects (within) IV regression to measure uncertainty-investment relation in post-announcement period.
Log(Uncertainty)$_{i,t}$ instrumented with Brexit.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In contrast to the industry-combined uncertainty effect on investments in model seven, both models eight and nine in table 6 now show a weaker relationship with investments. This seems counterintuitive, as the estimates for the construction industry would depress the uncertainty estimates for the manufacturing industry in the combined model: model seven. Intuitively, it was expected for the manufacturing to show a significance level at least as equal to that of the aggregate model. Nevertheless, uncertainty shows a significant relationship with investments for the manufacturing industry, although at a smaller 90% confidence interval. That is, for the manufacturing industry, one percent increase in uncertainty relates to a reduction of approximately 0.32% in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. This is in line with the expectations among the differences in the uncertainty-investment relation between both industries, in contrast to the estimations in models four to six.

Moreover, both energy prices and current sales growth again show significant result for the manufacturing industry with approximately equal numerical interpretations. However, the coefficient of uncertainty for the construction industry has increased coefficient compared to its previous estimate in model six, but shows an increased standard deviation as well. Thus, model nine performs rather poorly, showing significant effects on none of the variables.

This may be attributed to two potential causes. Briefly, the post-referendum period contains only five quarterly observations for each firm, a drawback especially present for the construction industry with its limited numbers of firms. However, it still meets the requirements to statistically test such relationship. Second, it may be attributed to the poor performance of either of the two uncertainty variables[11]. That is, either the uncertainty measure may be ill-suited to measure true uncertainty, or the post-referendum period shows a limited change in uncertainty. However, as is discussed both in chapter two and the previous section, the latter may not hold since these sources indicate the opposite. As such, the remaining potential cause of the poorly performing IV estimation may be attributed to the validity of the uncertainty measurement.

To conclude, this subsection showed that, on average, firms indeed lowered investments when uncertainty increased during the post-referendum period. Testing for both industries separately, however, shows that the relationship is significant for the manufacturing industry only. Nevertheless, it may indicate that firms in the manufacturing industry postpone investments in order to retrieve more information regarding future expectations. That is, it seems that they indeed employ the option value of investments. The next section briefly discusses the practicality of the uncertainty measure during the post-referendum period, and consequently motivates a potential solution.

7.5 OLS Fixed effects – Brexit

Previous sections have focused on the effect of uncertainty on investments, based on a well-defined proxy for uncertainty by taking the conditional standard deviation of a variable. As previous research has only *suggested* that this proxy serves as a good indicator (Aizenman & Marion, 1999; Bond et al., 2003; Ghosal, 1995; Ghosal & Loungani, 1996, 2000; Leahy and Whited, 1995), it has not been empirically tested, though, whether such proxy indeed captures uncertainty correctly. Simply put, such testing was not possible because no such large scale uncertainty has been detected for the last decades to be compared with. However, as argued earlier, the announcement of a referendum has created economy-wide uncertainty for nearly every actor within the system for which the probabilities of outcomes were unknown and equally likely[12] for any of those actors within the economy. Henceforth, any measure of uncertainty can be tested for by replacing this measure with the effect of the referendum announcement itself. In other words: instead of using a proxy for uncertainty, the uncertainty measure can now be replaced by estimating this relationship by simply testing whether the post-announcement *period* has significant effect on investments or not. Hence, the uncertainty measure will be replaced with a dummy variable that is equal to one to indicate the period after the announcement, and will remain zero to indicate the pre-announcement period. This section then concludes by comparing these estimation results to that of the previous section.

Results for the estimation with the dummy variable included is shown in table 7, again subdivided into the three representative groups. Starting with the aggregate of both industries in model 10, it shows that the Brexit dummy

[11] A combination of the uncertainty proxy and its instrument may as well be the cause of such underperformance. As will be discussed in the concluding chapters, such method may cause bias since firm-specific data is measured with non firm-specific data. However, implementing estimation techniques that account for such difference is beyond the scope of this study.

[12] Numerous institutions have tracked opinions and expectations in order to form expectations on the referendum outcome, as was shown in the section of preliminary facts. It showed that votes both in favour and against the Brexit were equally distributed during the whole period, indicating the difficulty in forming true expectations of the outcome. Hence, this could have increased uncertainty considerably.

is significantly and negatively related to investments on the 95% confidence interval. Because the interpretation of a dummy variable in a log – level model is somewhat different than the aforementioned models, it will be extensively illustrated. That is, for the pre-announcement period the regression equation would simplify to

$$\text{D.}\Delta\text{PPE}_\text{t} = \alpha + \beta_1\text{Brexit}_t + \beta_2 x'_{it}$$
$$\text{D.}\Delta\text{PPE}_\text{t} = 1.133 + 0 * \text{-}0.0198_t + \beta_2 x'_{it}$$
$$\text{D.}\Delta\text{PPE}_\text{t} = 1.133 + \beta_2 x'_{it}$$

where x'_{it} denotes all remaining regressors. For the post-announcement period, however, this regression equation would simplify to

$$\text{D.}\Delta\text{PPE}_\text{t} = \alpha + \beta_1\text{Brexit}_t + \beta_2 x'_{it}$$
$$\text{D.}\Delta\text{PPE}_\text{t} = 1.133 + 1 * \text{-}0.0198_t + \beta_2 x'_{it}$$
$$\text{D.}\Delta\text{PPE}_\text{t} = 1.113 + \beta_2 x'_{it}.$$

That is, ceteris paribus, the post-announcement period relates to a reduction in the growth of PPE compared to the growth of PPE from the preceding period, compared to the pre-announcement period. Specifically, the intercept of 1.133 is the log of the geometric mean of the differenced growth of PPE when Brexit equals zero, i.e. for the pre-announcement period. The exponentiated value of this mean is

$$\exp(1.133) = 3.104,$$

whereas this value for the post-announcement period becomes

$$\exp(1.113) = 3.043.$$

Hence, the change in the differenced growth of PPE from the pre-announcement period compared to the post-announcement period becomes:

$$\frac{\exp(1.113)}{\exp(1.133)} = 0.98$$

indicating, compared to the pre-announcement period, a decline of the differenced growth of PPE of 2% during the post-announcement period. An alternative calculation allows to directly see the relationship between the dummy and the dependent variable, namely to take the exponentiated value of the Brexit coefficient:

$$\exp(-0.0198) = 0.98,$$

thus showing equal results. In previous sections this value was interpreted directly from the output table without showing the exact exponentiated value of the coefficients, as both values are approximately equal. Hence, to continue, the results show a significant difference between the difference in growth of PPE when both periods are compared.

Similar to the models four and seven, model ten as well shows that both energy prices and sales growth are significantly related to investments. More specifically, one percent increase in energy prices relates to a reduction of approximately 0.24% in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus. Moreover, one percentage-point increase in sales growth relates to an increase of approximately 8% in the growth of PPE compared to the growth of PPE from the preceding period, ceteris paribus, which is a rather steep coefficient.

A comparison between both sectors is enabled if both models 11 and 12 are studied. Again starting with the Brexit dummy, it shows that it is significant and negatively related to investment growth for the manufacturing industry only on the smaller, 90% confidence interval. Thus, the post-announcement period relates to a reduction of approximately 1.8% in the differenced growth of PPE compared to that of the pre-announcement period. In other words, although both periods observe growth of investments, this growth is significantly smaller in the post-announcement period for the manufacturing industry. Although the coefficient for the construction industry is again larger than for the manufacturing industry, it is not significantly different from zero. Hence, no conclusion can be drawn whether this relationship is greater for the manufacturing industry or not, as long as it is not significant for the construction industry.

Moreover, equal to model 10, model 11 shows that energy prices and sales growth are again significant at the 99% confidence interval for the manufacturing industry, although showing steeper coefficients for both estimators. In contrast to the fourth model wherein the current GFCF showed a negative relationship with investments, this model actually shows the opposite. Namely, the lagged GFCF now shows a positive and significant relationship, although at the smaller 90% confidence interval. That is, a one percentage-point increase in GFCF from quarter $t-1$ relates to a 0.17% increase in the current differenced growth of PPE for the manufacturing industry. Hence, this shows that the aggregate investments show persistence, indicating a sort of hangover effect to firm-specific investments: since a current change in GFCF was expected to signal widespread economic fluctuations, it may cause firms to change their investments only from the subsequent quarters onwards. In other words, capital adjustments that follow economic fluctuations require some time, i.e. the hangover effect.

In contrast to the estimations for the manufacturing industry, the construction industry however, shows no significant results for any of the estimators. Hence, these estimators do not differ from zero in explaining their relationship with investments.

Thus briefly, the results show that uncertainty is negatively related to the manufacturing industry only, whereas the construction industry behaves rather robust against an increase in uncertainty. These results are in line with the expectations that were made previously whereby the manufacturing industry was expected to suffer most from increasing uncertainty in contrast the construction industry.

Table 7: Total Output

Dependent: D.Log(ΔPPE)$_{i,t}$	OLS Overall			OLS Overall			IV Post-announcement			OLS Post-announcement		
	1 (Total)	2 (Total)	3 (Total)	4 (Total)	5 (Manuf.)	6 (Constr.)	7 (Total)	8 (Manuf.)	9 (Constr.)	10 (Total)	11 (Manuf.)	12 (Constr.)
Log(Uncertainty)$_{i,t}$	0.0906 (0.101)	0.0906 (0.109)	0.0160 (0.118)	0.0250 (0.115)	0.0808 (0.115)	-0.618 (0.514)	-0.371** (0.187)	-0.323* (0.196)	-0.850 (0.602)			
Log(GFCF)$_t$	-0.021 (0.012)	-0.021 (0.013)	-0.016 (0.012)	-0.020* (0.011)	-0.019 (0.012)	-0.020 (0.035)	-0.013 (0.011)	-0.012 (0.012)	-0.015 (0.034)	-0.017 (0.011)	-0.017 (0.012)	-0.024 (0.036)
Log(GFCF)$_{t-1}$	-0.001 (0.012)	-0.001 (0.009)	0.004 (0.09)	0.008 (0.009)	-0.009 (0.009)	-0.002 (0.031)	0.009 (0.009)	0.010 (0.009)	-0.003 (0.031)	0.014 (0.009)	0.017* (0.009)	-0.001 (0.032)
Log(Energy Price)$_{i,t}$			-0.150** (0.0632)	-0.172*** (0.0593)	-0.189*** (0.0615)	-0.0243 (0.221)	-0.238*** (0.0693)	-0.256*** (0.0728)	-0.0627 (0.229)	-0.240*** (0.0793)	-0.252*** (0.0821)	-0.130 (0.299)
Sales Growth$_{i,t}$				0.0593* (0.0314)	0.0633* (0.0338)	0.0299 (0.0728)	0.0540* (0.0314)	0.0573* (0.0337)	0.0302 (0.0727)	0.0762*** (0.0270)	0.0805*** (0.0286)	0.0217 (0.0725)
Sales Growth$_{i,t-1}$				0.00269 (0.0120)	0.00456 (0.0130)	-0.0132 (0.0177)	0.00168 (0.0120)	0.00339 (0.0130)	-0.0131 (0.0181)	-0.00969 (0.0108)	-0.00893 (0.0115)	-0.0150 (0.0177)
Brexit										-0.0198** (0.0095)	-0.0175* (0.0099)	-0.0450 (0.0337)
Constants	-0.217 (0.265)	-0.217 (0.286)	0.668 (0.513)	0.748 (0.484)	0.681 (0.483)	1.765 (2.313)	2.087*** (0.740)	2.034*** (0.772)	2.550 (2.558)	1.133*** (0.376)	1.183*** (0.390)	0.665 (1.411)
N	5233	5233	5233	5069	4585	484	5069	4585	484	5633	5134	499
#Firms	313	313	313	310	284	26	310	284	26	323	297	26

(Robust) standard errors in parentheses
Dependent Variable: Differenced log of PPE growth
Model 1: Output for OLS Fixed Effects (FE) regression
Model 2 to 6 & 10 to 12: Output for OLS FE with Clustered Variance-Covariance Matrix (VCE)
Model 7 – 9: Output for Fixed Effects (within) IV regression to measure uncertainty-investment relation in post-announcement period.
Brexit instrumented for Log(Uncertainty)$_{i,t}$
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Discussion

The results of this study show a significant relationship between uncertainty and investments during the post-announcement period, whereas there is no such relationship found for the overall sample period. The results also show that firms remain investing during the post-announcement period, although this growth of capital is concave. Moreover, a difference was found in the relationship between uncertainty and investments among both industries. This difference between both industries is in line with the expectations and discussion of Ghosal & Loungani (2000), who argued that the relationship between uncertainty and investments could be sector-specific. These results and its interpretations are discussed below, starting with a brief description on the earlier described link between a firm's anticipation on future developments and the option-approach of investments. Consequently, I argue that given the results, the uncertainty-investment relationship may be time-dependent. This section then concludes with discussing the limitations and suggestions for future research.

The results indicate that the option approach is present during the post-announcement period. More precisely, the results show that investment growth shows a slowdown since the announcement was made, in line with the expectations conform the option-approach. This slower adjustment of the capital stock enables firms to align the investments with the true state of the world rather gradually and cautiously (Blond et al., 2007). These findings are in line with Blond et al. (2007), Demers (1991) and Serven (1997), arguing that firms may invest gradually, retrieve more information on economic developments and consequently decide whether or not to continue with the investments

These findings correspond to the definition of opportunity recognition; the type of uncertainty this study is subject to. As was discussed, opportunity recognition is defined as knowing potential future outcomes for which probabilities can only be calculated. Firms hold expectations or beliefs about future developments, thereby forming probabilities on whether the state of the world is 'good' or 'bad'. As uncertainty increases, it increases the boundaries wherein all possible expectations may occur. That is, if uncertainty increases to a higher extent, firms may be less likely to hold precise expectations on future outcomes, as it is partly unknown. Additionally, if this uncertainty increases, it alters a firm's way of investment to being more cautious (Blond et al., 2007). In line with the option-approach, firms may then decide to either gradually invest or completely postpone an investment until uncertainty returns to its initial levels.

In fact, the results show that a complete postponement of investments is absent during the post-announcement period, but rather show that firms behave according to the gradual adjustment and threshold approach. In other words, the results show that firms remain investing during the post-announcement period, although this growth is concave. This shows that firms gradually adjust their capital stock, and according to the threshold approach, firms then evaluate every incremental investment individually before deciding whether to continue investing, depending on a certain threshold level of expected profitability. This may cause investments to show a gradual growth, in line with the concavity of the growth of PPE from the results of this study.

Furthermore, as was for instance argued by Ghosal & Loungani (2000), it was expected that the uncertainty-investment relationship shows to significant relationship on the overall sampling period, although with a less steep coefficient compared to the post-announcement period. In fact, the EPUI index show a prolonged period of high uncertainty during the years 2011 to 2013 as shown in figure 2 (section 2), a score even higher than the European average. Instead, the relationship between uncertainty and investments *before* the announcement shows to be insignificant, regardless these high EPUI scores. Compared to the significant relationship during the post-announcement period, this may indicate, I argue that the uncertainty-investment relationship and more specifically the option approach, may be time-dependent: dependent on both the duration of the high-uncertainty period as well as whether this period has commonly known end-date or not. Intuitively, if the uncertainty period is in its early stage, firms alter their investment strategies to those just mentioned above because this changed level of uncertainty requires firms to adjust. The results indicate that, if the high-uncertainty period is recognized to have a commonly known end-date instead, then as was just discussed, firms decide to gradually invest rather than completely postpone this investment. Anticipating on the end of such period, firms may want to choose to 'survive' this high-uncertainty, thereby minimizing the risk of investments that are misaligned with true future outcomes.

In contrast however, firms may be reluctant to postpone investments and instead proceed to invest if the high-uncertainty period has already taken a considerable duration, as they might have accommodated to such high-uncertainty. This reluctance may even be stronger, with a moderating effect on the option-approach, when the high-uncertainty period does not know a commonly known end-date. This might explain the insignificant relationship between uncertainty and investments in both the overall sampling period as well as the period prior to the announcement only. Thus, the option-approach may still be present during a long period of high uncertainty, although this approach may be moderated since firms may accommodate, hence turning to have an insignificant effect.

It would, however, be interesting for future studies to test whether firms may recover to grow to their desired stock of capital when a period of high uncertainty has come to an end. More specifically, it would be interesting to study the uncertainty-investment relationship since it is known that the people in the U.K. voted to leave the European Union. This enables to test whether firms have indeed altered their investment plans only temporarily or whether it is merely a permanent decrease regardless of this uncertainty-period.

However, the results above show disconformity to the option approach as well. Namely, hypothesizing on a differential impact of uncertainty on investments, this study consequently motivated a potential refinement to the theory on investments, arguing that such relationship is possibly sector-specific, i.e. not generally applicable. This study has shown that the theory of the option-approach generally holds during the post-announcement period. But it seems not to hold, for every industry. That is, as the results show that the construction industry does not have a significant relationship with investments, it may indicate that there is something to it that may explain this difference, e.g. an industry's openness in terms of outward FDI and total export. These findings are in line with the discussion raised by Ghosal & Loungani (1995; 2000), arguing that different levels of product market competition within an industry may determine the degree of investments for that industry. Intuitively, in relation to an industry's openness in terms of trade, international orientation results in serving foreign markets that consequently increases competition. According to Ghosal & Lougani (1995; 2000), this influences the degree of investments and will consequently strengthen its relationship with uncertainty. Thus, as international orientation increases competition, it is in line with both the results and the arguments made by Ghosal & Loungani (1995; 2000).

This study, however, does have its limitations. Starting with the obvious, this study employs quarterly data. To improve the estimation on the uncertainty-investment relationship, it is recommended to replicate this study with monthly data since the post-announcement period is rather short. However, due to the limited possibilities of retrieving such data, this will most likely not be possible. Second, increasing the number of firms to observe for the construction industry could potentially result in improved performance of the estimates.

Third, results show that the coefficient of the Brexit dummy scored approximately 1.7 percentage-point lower compared to the coefficient of the uncertainty proxy instrumented with this Brexit dummy. This potential bias on either of the two estimations could stem from two causes. First, this bias could stem from the unaligned measures of both the Brexit and the proxy for the instrumental variable regression. More specifically, the uncertainty proxy is a firm-specific measure, whereas the Brexit dummy is not. It is a macro shock estimated on firm-specific data. The Brexit dummy would then serve as a good instrument only if the uncertainty proxy shows a strong increase during the post-announcement period. Hence, properly displaying the sudden change in uncertainty for this period. However, it was graphically motivated that this increase is only marginally. This makes the Brexit dummy a somewhat weak instrument, potentially causing this bias. Second, the bias could stem from the construction of the uncertainty proxy. As was just discussed, uncertainty is a key-component in being able to forecast *future* outcomes. It would therefore be more suitable to apply an uncertainty proxy that indeed captures *future* uncertainty, although this is empirically cumbersome. Instead, the advocated proxy for uncertainty is a measure of the average *past* five-quarterly fluctuations in profits. Uncertainty for time t is thus measured by the average profit fluctuations of period $t-1$ to $t-5$. Applying this measure to test the uncertainty-investment relationship for a period that contains only five quarters could therefore bias the estimates since only a sixth quarter would measure all fluctuations within the post-announcement period. This may explain the difference in coefficients between the uncertainty proxy instrumented with the Brexit dummy and the coefficient of the Brexit dummy itself. It should consequently result in a downward bias on the uncertainty proxy in models seven to nine. Instead, models seven to twelve show a steeper coefficient for the proxy than for the Brexit dummy in. Hence, this may indicate that the first source of bias is more likely. Nevertheless, it may be the additional cause to explain the insignificant relation between uncertainty and investment during the complete sampling period.

Lastly, since investments show persistence, it was suggested that the lagged version of PPE growth should be included into the model. However, since the models estimated use the fixed effects transformation, such inclusion of the dependent variable causes bias to the estimates, known as the Nickell Bias (Behr, 2003; Moyo, 2015; Roodman, 2006). That is, such estimation typically overestimates the true relationship between the explanatory variables and the main dependent variable. In order to overcome these issues, this study transformed the dependent variable to a first-differenced logarithmic growth of PPE. Alternative, more efficient methods of estimation that may potentially produce less bias are for instance the Anderson-Hsiao estimation, known as the First Differenced IV Estimation (FD2SLS), and the Arrelano-Bond's systematic or difference General Methods of Moments (GMM) estimation that include the lagged dependent variable into the regression and consequently instrument it by including higher order lags of that dependent variable (Anderson & Hsiao, 1989; Behr, 2003; Moyo, 2015; Roodman, 2006). The Anderson-Hsiao estimation, although very suitable for unbalanced datasets, was not implemented since this method requires strict homoskedasticity (Judson & Owen, 1996). As it was shown in earlier sections, this data suffers from heteroskedasticity and as such, does not suit this type of estimation. The other alternatives were considered as well, yet not employed. Namely, these cumbersome estimation techniques provide more efficient results but suffer in terms of parsimoniousness, especially within the bounds of this study. Consequently, replication of this study with the extension of using one of those alternative techniques is suggested.

Conclusion

This study tried to test whether firms decide to either postpone or gradually adjust investments as a respond to the increased uncertainty since the announcement of a referendum was made. Using a panel of 333 British firms, the results show that uncertainty is indeed negatively and significantly related to investments during the post-announcement period. More specifically, if uncertainty increases one percent, investments showed a decrease in difference of growth in investments of approximately 1.8% for the manufacturing industry during the post-announcement period. As a treatment effect, this industry was compared to the construction industry because this industry was expected to be rather robust against a rise in uncertainty. As expected, this industry shows no significant relationship between uncertainty and investments. As it was discussed in the previous section, these results are only partly in line with the predictions from the option-approach. That is, firms indeed choose to gradually invest as a respond to increased uncertainty, although this theory is not applicable to all industries.

Rather interestingly however, is that the uncertainty-investments relationship does not appear to be significant in general. Namely, studying this effect on the overall sampling period, the results show that this relationship does not appear to be different from zero. Uncertainty becomes significantly and negatively related to investments to the manufacturing industry only when first, uncertainty was instrumented with the Brexit dummy and second, when the Brexit dummy was implemented individually. In other words, the uncertainty-investment relationship is significant only during the post-announcement period, whereas this relationship is not significant when it is tested on the overall sampling period.

These results may be valuable for the discussion among other member-states that are appealed to initiate a similar referendum, specifically to this time of writing, Italy and France. Although this study has focused on uncertainty and investments during the post-announcement period only, such rise in uncertainty may influence other parts of an economy as well, not only through a reduction in investments. While this is merely a speculation, this study in fact showed that the period prior to the actual referendum date caused such high uncertainty, that it was negatively related to investments for at least the manufacturing industry.

Appendix A

Table 8: Hausman Test

	Coefficients (b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
luncertain~2	-.0647153	-.0547626	-.0099527	.0169716
lppegr2				
L1.	.7144994	.7626125	-.0481131	.0045024
lgfcf3				
--.	-.0127061	-.0145848	.0018786	.0004977
L1.	-.0003911	.0005966	-.0009877	.0001997
lsalesgr2	.0687281	.0713012	-.0025731	.0123696
salesgr2				
L1.	.0209666	.0228931	-.0019265	.0025917

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 126.80
Prob>chi2 = 0.0000
(V_b-V_B is not positive definite)

Appendix B

Table 9: Durbin-Wu-Hausman Test

```
Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity and clustering on firmID

Number of clusters (firmID) =        291                Number of obs =     4920
                                                        F(  6,    290) =   218.50
                                                        Prob > F      =   0.0000
Total (centered) SS      =  386.4876668                 Centered R2   =   0.5464
Total (uncentered) SS    =  386.4876668                 Uncentered R2 =   0.5464
Residual SS              =  175.3224368                 Root MSE      =    .1946

------------------------------------------------------------------------------
             |               Robust
     lppegr2 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
luncertainty2|  -.4258791   .1834356    -2.32   0.020    -.7854063    -.066352
             |
     lppegr2 |
         L1. |   .7424277   .0233688    31.77   0.000     .6966256    .7882298
             |
       gfcf3 |
         --. |  -.0799599   .1514297    -0.53   0.597    -.3767568    .2168369
         L1. |  -.1295359   .1097145    -1.18   0.238    -.3445723    .0855006
             |
    salesgr2 |
         --. |   .0497331   .0240754     2.07   0.039     .0025462    .0969199
         L1. |   .0318126   .0164752     1.93   0.053    -.0004782    .0641034
------------------------------------------------------------------------------
Underidentification test (Kleibergen-Paap rk LM statistic):             30.597
                                                   Chi-sq(1) P-val =    0.0000
------------------------------------------------------------------------------
Weak identification test (Cragg-Donald Wald F statistic):              151.996
                         (Kleibergen-Paap rk Wald F statistic):         35.555
Stock-Yogo weak ID test critical values: 10% maximal IV size             16.38
                                         15% maximal IV size              8.96
                                         20% maximal IV size              6.66
                                         25% maximal IV size              5.53
Source: Stock-Yogo (2005).  Reproduced by permission.
NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.
------------------------------------------------------------------------------
Hansen J statistic (overidentification test of all instruments):         0.000
                                                 (equation exactly identified)
-endog- option:
Endogeneity test of endogenous regressors:                               2.182
                                                   Chi-sq(1) P-val =    0.1396
Regressors tested:     luncertainty2
------------------------------------------------------------------------------
Instrumented:          luncertainty2
Included instruments: L.lppegr2 gfcf3 L.gfcf3 salesgr2 L.salesgr2
Excluded instruments: lnfuel
------------------------------------------------------------------------------
```

Appendix C

The model:	$\text{D.}\Delta\text{PPE}_\text{t} = \alpha + \beta_1\text{Uncertainty}_t + \epsilon_{i,t}$
First stage regression:	$\text{Uncertainty}_\text{t} = \alpha + \rho_1\text{Brexit}_t + \epsilon_{i,t}$
Second stage regression:	$\text{D.}\Delta\text{PPE}_\text{t} = \alpha + \beta_1\widehat{\text{Uncertainty}}_t + \epsilon_{i,t}$

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