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Deal or No Deal? Modelling the Impact of Brexit Uncertainty on UK Private Equity Activity

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Given uncertainty in policy, particularly around Brexit, how do private equity (PE) firms investing in the UK behave? Analysing their response is vital for understanding the impact on investment per se and designing policy that limits uncertainty. Building on the recent work of Mike Wright and co-authors, we explore the effect of uncertainty measures on UK PE activity and the channels that transmit uncertainty to the PE market. After developing hypotheses that link the 'PE activity and uncertainty' relation via a real options, interim risk or moral hazard channel, we employ a novel dataset on PE targets and non-targets over the 2010–2019 period. We find that uncertainty, especially new measures closely aligned to Brexit, have negatively affected PE activity in the UK. Moreover, the transmission of such uncertainty occurs primarily through the real options channel and through greater uncertainty arising from prolonged interim periods of PE deals (i.e. the interim risk channel). Our results imply that the present and ongoing uncertainty in Brexit policy will continue to depress PE activity and by extension, investment and growth in the UK. Policymakers are urged to resolve such uncertainties.

Introduction

> … for management researchers, Brexit provides a natural experiment to explore the effects on PE of a major exogenous shock. (Wright *et al.*, 2016: 682)

The Brexit vote to leave the European Union (EU), recorded at the UK referendum of 23 June 2016, was a momentous event. Largely unexpected by most academics, practitioners and policymakers, the result led to a considerable rise in uncertainty for UK business in general.[1] Such Brexit-related uncertainty is different to prior uncertainty shocks due partially to its length, magnitude and political complexity (Bloom *et al.*, 2018, 2019) and the ongoing and widespread impact is still being debated and evaluated. So far, the focus has typically been on the detrimental economic effects of Brexit (e.g. Bloom *et al.*, 2019; Born *et al.*, 2019; Hassan *et al.*, 2020; Hill, Korczak and Korczak, 2019; McGrattan and Waddle, 2020; Steinberg, 2019; Van Reenen, 2016) and the related impact on banks and financial markets (e.g. Berg *et al.*, 2019; Davies and Studnicka, 2018; Hudson, Urquhart and Zhang, 2020; Schiereck, Kiesel and Kolaric, 2016).

Recent work by Wright *et al.* (2016) explores the impact of uncertainty from the Brexit referendum on the UK private equity (PE) market, noting that the UK PE market is the largest in Europe. In particular, they highlight that whilst in the years that followed the global financial crisis

[1]The referendum outcome was a largely unexpected event as the leaders of the three largest parties in the UK and the majority of MPs were pro-remain. We thank an anonymous reviewer for this point.

A free video abstract to accompany this article can be found online at: https://youtu.be/-SKsZwgy9Mc

(GFC) of 2007/8, the PE market recovered to pre-crisis activity levels, deal values fell precipitously in 2016, reflecting higher uncertainty. Moreover, the paper posits early in the Brexit debate that the referendum result produced an extraordinary shock, damaging market confidence and likely impairing PE funds' returns as well as their ability to fundraise and relatedly, their reliance on debt availability. In contrast, the future activities of UK PE firms may be subject to less regulation, possibly generating a deregulation premium, and the EU will no longer necessarily be able to inhibit UK state aid. Hence, Wright *et al.* (2016) conclude by stressing that Brexit generates both threats and opportunities for PE activity in the UK and creates 'an exciting new research agenda' (p. 685) for researchers in entrepreneurial finance.[2]

Building on the work of Wright and co-authors, and other existing literature on PE (e.g. Cumming, Peter and Tarsalewska, 2020; Hotchkiss, Strömberg and Smith, 2014; Kaplan and Strömberg, 2009; Lerner, Sorensen and Strömberg, 2011; Leslie and Oyer, 2009; for an excellent review see Gilligan and Wright, 2020), our paper investigates two associated research questions. Firstly, what is the effect of uncertainty and, in particular, Brexit-related uncertainty, on PE activity in the UK? Secondly, what are the channels that operationalize the transmission of uncertainty to the PE market? In terms of measuring activity, we follow others (e.g. Wright *et al.*, 2016)[3] in defining PE as the 'risk capital employed to finance the acquisition of mature businesses via a leveraged buyout (LBO)'. Less straightforward is the identification of an appropriate analytical framework, given that the conceptualization and measurement of uncertainty is a non-trivial task. To circumvent this, we employ a set of uncertainty measures, including the Bloom *et al.* (2019) Brexit Uncertainty Index (BUI) and the Baker, Bloom and Davis (2016) Economic Policy Uncertainty (EPU) index.

Our analysis is performed on a novel dataset that we construct by conflating several data sources. We collect data on buyout investors and targets from S&P Market Intelligence and Capital IQ, identifying UK targets acquired by PE buyout firms over the 2010–2019 period and following standard deal classification criteria from the existing literature (see Axelson *et al.*, 2013; Faccio and Hsu, 2017). Subsequently, we employ Capital IQ, Compustat Global and Orbis databases to obtain data for the necessary accounting and financial fundamentals of our sample targets. After matching targets to available accounting data, we obtain a sample of 765 UK targets. Moreover, to provide a suitable control group to these targets, we consider all UK firms with analogous size characteristics, generating a final dataset of 290,022 firms.

To derive appropriate hypotheses, we follow Bonaime, Gulen and Ion (2018) and Adra, Barbopoulos and Saunders (2020) in drawing on related literature, including: work positing that uncertainty will increase the real options to delay investment (cf. Gulen and Ion, 2016; Quigg, 1993); notions of an interim risk channel of uncertainty (see Bhagwat, Dam and Harford, 2016), where periods of high uncertainty widen the interim period occurring between announcement and completion of an acquisition (or buyout deal); and principal–agent theory, whereby greater uncertainty can lead to increased moral hazard if limited partners' (principals') ability to control general partners (agents) is impaired. In doing so, our investigation sheds light on the impact of uncertainty for PE and entrepreneurial finance (e.g. Brown, Linares-Zegarra and Wilson, 2019; Cumming and Zahra, 2016; Wright *et al.*, 2016), the general economic and financial effects of uncertainty (e.g. Baker, Bloom and Davis, 2016; Bonaime, Gulen and Ion, 2018; Drobetz *et al.*, 2018; Gulen and Ion, 2016) and related issues of effective policy for supporting investment during periods of higher uncertainty due to exogenous shocks.

We find that Brexit uncertainty negatively affects UK PE activity, primarily arises from policy, foreign exchange (FX) and chief financial officer (CFO) (firm-level) uncertainty, and transmits through real options and interim risk channels. These results imply that the industries most deeply affected are those relying on fixed assets, durable goods or heavily exposed to the EU, because of their export/import activities. We also find that the impact and transmission of uncertainty varies according to the different nature of uncertainty itself. Different types of uncertainty have different degrees of persistence or lead to longer deal

[2]Policymakers, analysts and PE practitioners have expressed concerns about the implications of Brexit. See, for example, Bank of England (2019); British Private Equality and Venture Capital Association (2019); Deloitte (2016).

[3]The same paper notes that LBOs represent about three-quarters of total UK merger and acquisition activity.

interim periods, therefore 'scaring off' potential PE investors. These considerations lead us to urge policymakers to address uncertainty arising from Brexit whilst encouraging a more holistic view of uncertainty 'types' and channels.

The rest of the paper is structured as follows. The next section considers the extant literature and theoretical underpinnings of our work, whilst the third section provides an overview of the data. The fourth section presents the empirical methodology and results on the effects of uncertainty on PE buyout activity, whilst the fifth section explores the channels of transmission. The final, sixth section concludes.

Literature and theoretical underpinnings

Uncertainty

As noted in the Introduction, the conceptualization and measurement of uncertainty, and in particular policy-related economic uncertainty, is not straightforward. Baker, Bloom and Davis (2016: 1598) comment, 'We aim to capture uncertainty about *who* will make economic policy decisions, *what* economic policy actions will be undertaken and *when*, and the economic *effects* of policy actions (or inaction) – including uncertainties related to the economic ramifications of "noneconomic" policy matters, for example, military actions'. Most likely, types of uncertainty (e.g. policy, Brexit, pandemic, monetary and fiscal) will affect individual sectors of the economy differently and display varying degrees of persistence. For this reason, when analysing such uncertainty, it is crucially important to model the economic effect of various uncertainty measures and their related transmission mechanisms.

In this paper, we address this issue by collecting a set of measures, reflecting differing (but potentially overlapping) aspects of uncertainty. Firstly, the Baker, Bloom and Davis (2016) EPU index quantifies UK policy-related economic uncertainty by examining the frequency of the words 'uncertain' or 'uncertainty', 'economic' or 'economy', as well as other policy-relevant terms, such as 'policy', 'tax', 'spending', 'regulation', 'Bank of England', 'budget' and 'deficit' in the 11 most popular UK newspapers. Secondly, we include an index created by the Bank of England on UK macroeconomic uncertainty which reflects the economic uncertainty of British households and companies. More specifically, this combines macroeconomic measures of economic and financial market uncertainty with survey data collected by the Bank of England on households' and firms' short and medium-term expectations.

Our third and fourth measures capture financial market uncertainty: specifically, sterling option-implied volatility (i.e. exchange rate uncertainty) and the FTSE All-Share option-implied volatility (i.e. stock market uncertainty). Both measures are likely to, at least partially, reflect Brexit-related expectations of investors. Our fifth and final measure attempts to explicitly identify uncertainty arising from the Brexit referendum. In contrast to indices described beforehand, the Bloom *et al.* (2019) BUI is built using surveys to the CFOs of approximately 3,000 UK businesses, therefore capturing company-level uncertainty.

Uncertainty and the level, value and likelihood of LBOs

Wright *et al.* (2016) remark that in the first half of 2016, UK PE deal values decreased significantly and suggest that this reflected higher macroeconomic uncertainties, in part due to the uncertainties surrounding Brexit. They argue that in this environment, PE firms find it difficult to both raise investment and obtain debt (e.g. via banks or debt funds). This funding squeeze, when combined with potentially fewer buyout opportunities, can lead to a reduction in the overall number as well as the value of deals. In any case, Ljungqvist, Richardson and Wolfenzon (2020) and Malenko and Malenko (2015) find that buyouts significantly accelerate when credit market conditions ease. Extending this work, Axelson *et al.* (2013) examine capital structure theories using cross-sectional factors and showing that credit conditions are the main driver of PE acquisitions.

In a more general context of US mergers and acquisitions (M&As), Bonaime, Gulen and Ion (2018) show empirically that policy-related economic uncertainty is negatively associated with M&A activity. Several theoretical rationales for the linkage are investigated, including the real options channel (see Bloom, 2009), the interim risk channel (Bhagwat, Dam and Harford, 2016) and moral hazard framing (Duchin and Schmidt, 2013). We shall explore these potential transmission

channels for uncertainty in more detail below but when combined with earlier arguments that relate uncertainty to worsening credit conditions, they lead to our first hypothesis.

H1: Greater uncertainty significantly reduces the level, value and likelihood of PE buyouts.

Of course, it could be that greater uncertainty causes PE firms to simply delay investment, rather than engage in an actual reduction. However, there is some *prima facie* evidence that the effects of policy-related economic uncertainty (including Brexit) can be long-lasting. For example, Bloom *et al.* (2019: 2) suggests, 'Brexit is unusual in that it generated persistent uncertainty – three years after the original vote, the UK had not left the EU, there was still no clarity on the eventual outcome […]'. Such persistence in uncertainty can lead to persistent effects on variables of interest, and this leads to our second hypothesis.

H2: Greater policy uncertainty, including Brexit, presents persistent and negative effects on PE firms' buyout likelihood.

The real options PE transmission channel

In the next three subsections, we examine the transmission channels of uncertainty to the UK PE market. To begin, we note that when uncertainty is higher, the value of the real options to delay investment increases (cf. Gulen and Ion, 2016; Quigg, 1993). In a buyout context, this implies that when uncertainty is elevated, PE firms could have a greater incentive to postpone buyouts. As a result of this argument, PE firms performing buyouts during periods of elevated uncertainty are either those for which delaying investment is more costly or those that cannot delay the investment. This has important implications in terms of the bargaining power between buyer (PE firm) and seller (portfolio firm management/shareholders), since it potentially increases the bargaining power of the seller. Within this theoretical framework, the value of the option depends on three main factors. Firstly, the degree of investment irreversibility – clearly, the less reversible the investment, the higher the value of an option to delay. Secondly, the cost of postponing the buyout. For example, and as is suggested by Grenadier (2002), delaying investment is considerably more expensive when the target firms operate in a highly competitive industry, where a delay could lead to competitors' appropriation of part of the benefits (profitability) yielded by the investment project. Finally, the extent to which uncertainty affects the investment target (i.e. the PE portfolio target). Bloom *et al.* (2019: 2) emphasizes, 'The vote for Brexit was a largely unexpected event and we observe that it has had a heterogeneous impact on firms according to their pre-referendum exposure to Europe'. In this spirit, we argue that the incentive to delay investment when uncertainty arises is likely greater for industries that are more exposed to Brexit (e.g. those relying more on the external trade sector). Taken together, these arguments lead to our third hypothesis.

H3: Greater uncertainty increases the real options value for PE firms to delay investment.

Interim risk channel of uncertainty

Next, we explore the interim risk channel of uncertainty, proposed by Bhagwat, Dam and Harford (2016). They posit that in periods of higher uncertainty, interim periods between the announcement and completion of an acquisition tend to be wider. Longer interim periods significantly discourage M&As – and of course LBOs and management buyout (MBOs) – since equity prices are highly volatile in the interim period. Indeed, target price volatility strongly enhances the risk for the acquirer in a public-to-private transaction (i.e. leading to less convenient buyout terms) and moreover, can increase the cost of bank financing and the risk of breaking debt covenants.

Considering the persistence of policy-related economic uncertainty and the related Brexit referendum, we suggest that PE investors could have decided to delay (or dismiss) buyout investment in the UK because of the greater interim risk imposed by the inherent complexities in the relationship between EU and UK (e.g. market access, labour market rules, regulatory changes and so on), leading to our fourth hypothesis.

H4: Greater uncertainty is transmitted to the PE buyout market via the interim risk channel.

At this point, it can be noted that several transmission channels can co-exist; therefore, any evidence of an interim risk channel would not contradict evidence for the real options channel.

Moral hazard channel

Lastly, we consider the existence of a moral hazard channel of uncertainty, as suggested by Duchin and Schmidt (2013). According to this theoretical framing, greater uncertainty can lead to greater moral hazard incentives if limited partners' (principals') ability to control general partners (agents) is impaired, creating 'empire-building incentives'. Lower control can motivate general partners to invest in deals of lower quality and try to 'rip off' target companies' profit and cash holdings. The question of whether PE buyouts are optimal for portfolio target firms has been the subject of extensive academic and policymaker debate,[4] with considerable evidence of greater 'value-destroying' deals when moral hazard incentives are at play. Of course, it is perhaps likely that the moral hazard channel is not the primary transmission channel of (Brexit) uncertainty; however, some effects from this channel may still play a role in buyout decisions. This leads to our fifth hypothesis.

H5: Greater uncertainty is transmitted to the PE buyout market via the moral hazard channel.

Data

Data on buyouts

To identify UK PE targets from 2010 to 2019, we first use data from S&P Market Intelligence and Capital IQ and the methodology outlined in Axelson *et al.* (2013) and Faccio and Hsu (2017). This approach recognizes PE buyouts based on the deal structure adopted in the acquisition of the portfolio firm, the target's country of incorporation and the investment stages adopted by the PE investor[5] (see Appendix A in the online supporting information for more details on dataset construction).

Second, we use Capital IQ, Compustat Global and Orbis to obtain several accounting measures that are potential drivers of PE buyouts in the UK. These include total assets, return on assets (ROA), leverage and cash-to-assets (see Section B.1.2 in the online supporting information). This information is available for 765 target firms – constituting our sample of UK target portfolio firms – and allows for a rich set of firm-specific control variables.

This study covers three main categories of buyouts: LBOs, going private transactions and MBOs. These constitute 25% of all PE activity in the UK, a significant portion, over the period of analysis (2010–2019)[6] and consisting of a total buyout volume of US$180 trillion.

Among buyouts, LBOs constitute the large majority of PE transactions in the UK and reach a maximum of 92% in 2013 (see Table 1, Panel A). As is evident from Figure 1, after the Brexit referendum in 2016 we observe a slowdown in UK buyout activity, with a substantial decrease in investment amounts; this coincides with a reduction in the absolute numbers of these types of deals (see Table 1, Panel B). Going private transactions reach their peak in 2019, when the percentage of funds invested almost equals that of LBOs (see Table 1, Panel A). In Figure 1 we also juxtapose buyouts in the UK and the rest of the world (RoW). Noticeable differences between the two series appear to correspond with phases of elevated uncertainty, over both the whole sample period and those periods associated with Brexit.

To form an appropriate control group for UK PE targets, we obtained the universe of all UK (listed and unlisted) firms from Orbis and information on their financial statements, industry sector, age and so on. In a further refinement, we only consider UK firms with similar size characteristics to our PE targets (see Appendix C in the online supporting information). We merged this refined dataset with our data on UK PE targets, generating a final annual frequency sample of 290,022 firms from 2010 to 2019

Measures of uncertainty

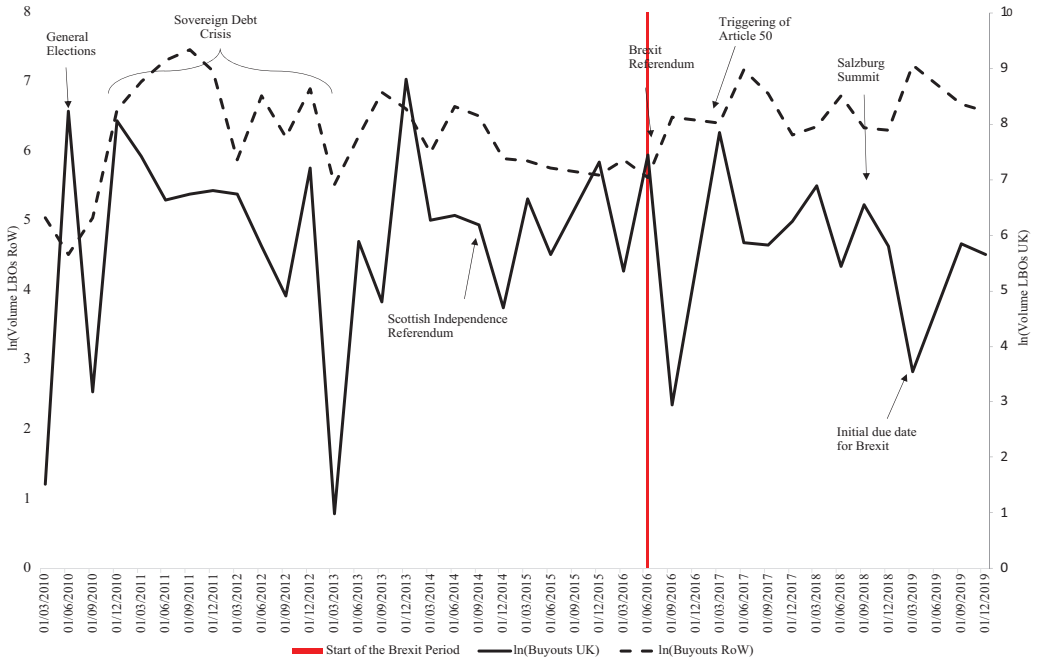
As discussed earlier, different types of uncertainty will have differing effects on separate sectors of the economy and are likely to display varying degrees of persistence. Therefore, we collect a set of uncer-

[4]Poul Rasmussen (former Danish Prime Minister and author of the European Commission's Alternative Investment Fund Managers Directive) stated that, '"leveraged buy-outs" leave the company saddled with debt and interest payments, its workers are laid off, and its assets are sold … benefiting neither workers nor the real economy' (Rasmussen, 2008: 130–132).

[5]There is no country restriction for PE firms.

[6]Other deal structures include: acquisition financings, add-on, asset acquisitions, other corporate acquisitions/divestitures, follow-on offerings, growth capital transactions, initial public offerings, mergers, private investment in public equity, private placement transactions, recapitalizations and other unclassified activities.

(a) Natural logarithm of total buyout volume



(b) Yearly moving average

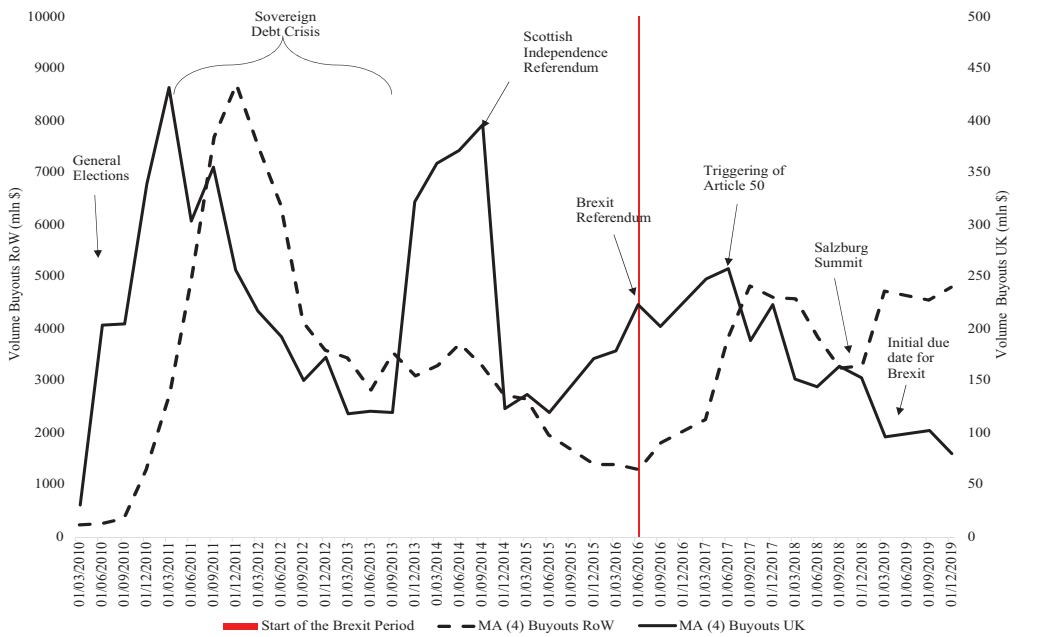


Figure 1. Buyout activity in the UK vs. the rest of the world (RoW): (a) natual logarithm of total buyout volume; (b) yearly moving average [Colour figure can be viewed at wileyonlinelibrary.com]

Notes: *The figure uses all deals with structure of leveraged buyout, management buyout and going private transactions. These are presented in (a) as the natural logarithm of the total number of buyout deals and of the total buyout volume in USD mn in the UK vs. in the RoW. In (b), we present instead the 12-month moving average of the total number of buyout deals and of the total buyout volume in USD mn in the UK vs. in the RoW. Both (a) and (b) indicate a strong deviation of the two series after the Brexit referendum. This is particularly elevated after the triggering of Article 50.*

Table 1. Investment in PE buyouts

Date	Going private	LBO	MBO	Total
Panel A: Percentage invested in each PE buyouts structure				
2010	10%	74%	16%	100%
2011	6%	70%	24%	100%
2012	12%	78%	10%	100%
2013	0%	92%	8%	100%
2014	8%	80%	12%	100%
2015	0%	89%	11%	100%
2016	14%	81%	5%	100%
2017	22%	72%	6%	100%
2018	31%	66%	3%	100%
2019	43%	56%	1%	100%
Panel B: Total number of PE buyout deals in the UK				
2010	9	160	70	239
2011	12	188	86	286
2012	10	173	79	262
2013	1	178	67	246
2014	7	234	99	340
2015	1	193	70	264
2016	4	184	59	247
2017	6	178	65	249
2018	4	196	57	257
2019	7	166	48	221

Notes: In this table we present British PE buyouts disaggregated in their individual deal structure: going private, LBO, MBO. In Panel A, we report the portion PE investment allocated to each of the three deal structures reported above in a given year. In Panel B, we report instead the total number of buyout deals in the UK in a considered year. Once again, we disclose both the aggregate number of deals in a given year and the individual amount of deals as divided: going private, LBO, MBO. The numbers of deals in Panel B include multiple purchases of the same target in a given year. In this case, each deal is considered as separate, even if it involves the same target.

tainty measures, which we explore in more detail below.

Policy-related economic uncertainty. Our first measure is the EPU index of Baker, Bloom and Davis (2016). The index measures domestic uncertainty derived from British newspapers by examining the frequency of words identifying several dimensions of uncertainty related to government. To extract the monthly value of policy uncertainty, the index is then normalized to obtain a standard deviation of 1 and a mean 100 before 2011.

The index cleverly captures a dimension of uncertainty (sentiment) concerning government policies that were previously difficult to quantify. As reported in Baker, Bloom and Davis (2016), at a macro level, the EPU index displays a high correlation with popular uncertainty measures (e.g. implied stock market volatility) and a lack of bias towards newspapers' political orientation. Moreover, the EPU index seems to have some success in predicting variations in employment and investment. As a result, this measure of uncertainty is widely used in the extant economic and finance literature.

As shown in Figure 2, the EPU index increased at the start of the GFC and most strikingly, we can observe a sharp increase during 2016, at the time of the Brexit referendum. The 'Brexit period' itself seems to be characterized by more volatility in the EPU index.

Index of macroeconomic uncertainty. Our second measure of uncertainty is an index of macroeconomic uncertainty produced by the Bank of England (cf. Haddow *et al.*, 2013). The index considers a wide range of dimensions of uncertainty, which are aggregated by the bank using principal component analysis and subsequently, retrieving the first principal component. In more detail, the index includes the 3-month option-implied volatility of the FTSE All-Share index, and the 3-month option-implied volatility of sterling–euro and sterling–dollar export-weighted exchange rates, as generic proxies of overall corporate sector uncertainty. It also incorporates the dispersion of annual

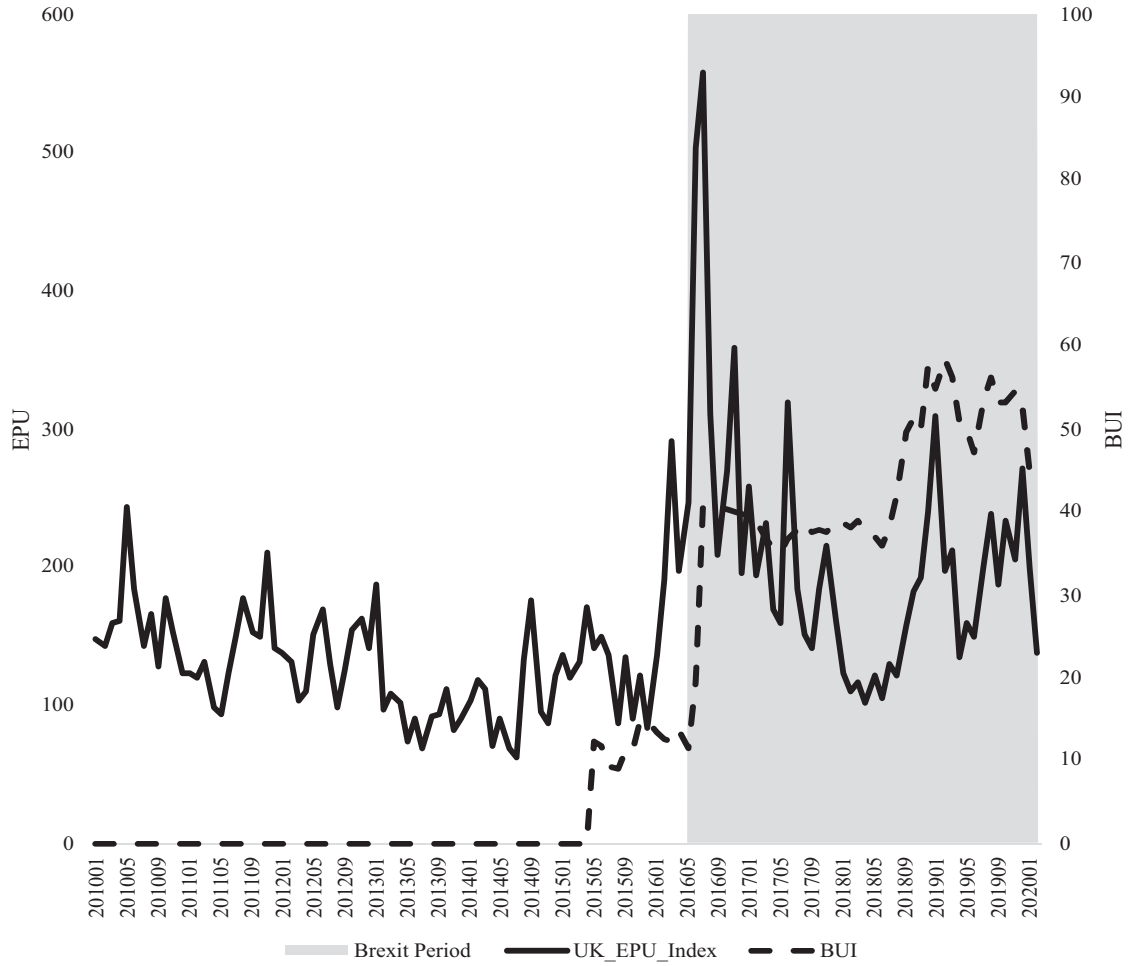


Figure 2. Brexit uncertainty and UK economic policy uncertainty

Notes: *Monthly data are used for this figure. EPU and BUI represent the indices of economic policy uncertainty and Brexit uncertainty, respectively. The shaded area corresponds to the period onwards from the Brexit referendum.*

company earnings GDP growth forecasts, which provide a supply-side measure of private sector uncertainty. Lastly, as a proxy for demand-side uncertainty, the measure uses several surveys assessing businesses' expectations and sentiment, such as: (i) the GfK unemployment expectations balance; (ii) the CBI 'demand uncertainty limiting investment' score; and (iii) the number of press articles citing 'economic uncertainty'. The former two surveys are used by the bank to assess the impact of greater unemployment and households' precautionary savings on domestic demand; the latter is meant as a barometer of the 'public mood'.

FTSE All-Share index and sterling option-implied volatility. We separately include the FTSE All-Share index and sterling option-implied volatility (described above) in our regression models as indicators of financial (stock and FX) market uncertainty. Equity option-implied volatility is one of the most popular measures of financial market uncertainty. The underlying idea is that the higher the uncertainty about the future performance of the UK stock market, the higher the price that investors – including PE investors highly exposed to their target performance – would be prepared to pay for options hedging their risk. This measure, therefore, provides a forward-looking measure of investors' expectations after an uncertainty shock.

In the wake of the Brexit referendum, UK investors and businesses observed drastic variations in the value of sterling. In October 2016, during the so-called 'sterling flash crash', the dollar rate fell below $1.20 (as low as 1.15$), reaching the low-

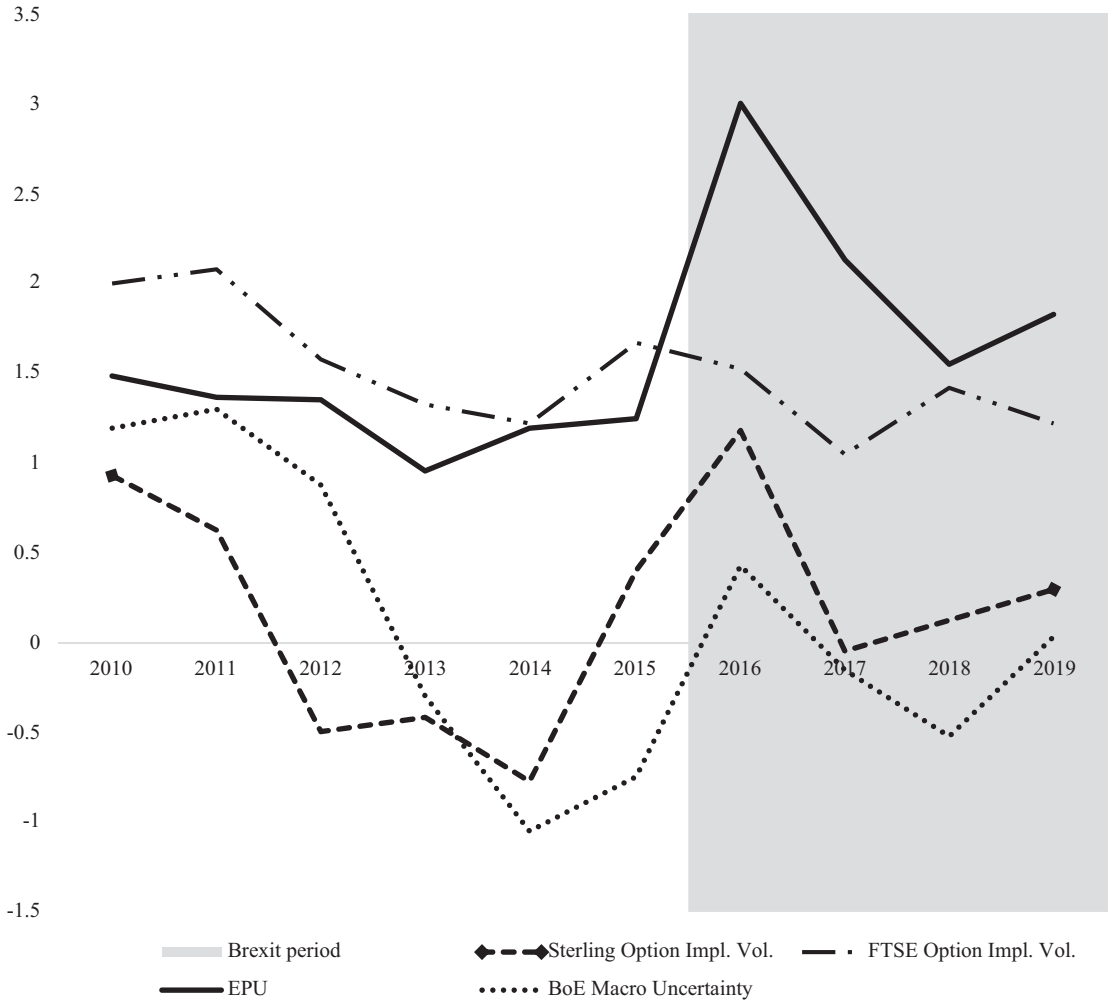


Figure 3. Other measures of uncertainty in the UK

Note: *Annual data are used for this figure.*

est value since 1985, and experienced an unprecedented level of volatility. Sharp variations in the exchange rate significantly affect UK businesses, by impacting their export prices – reducing their export-related revenues – and increasing the cost of imported production input. For PE firms, a significant decrease in operating financial performance reduces the incentive to invest in UK businesses. In Figure 3, we show the time-series pattern of uncertainty across all the previously described measures.

Brexit Uncertainty Index. In an attempt to isolate the effect of Brexit-specific uncertainty on UK firms, we employ the Bloom *et al.* (2019) BUI. This index is built using survey data from the Decision Maker Panel (DMP), a monthly survey performed on a wide sample of UK firms across several industries. Through the survey, the authors estimate the extent to which Brexit has been affecting British firms, which industries have been more impacted and how.[7] The BUI crucially extends the scope of the DMP by estimating the portion of firms heavily affected by Brexit uncertainty – measured as the percentage of CFOs reporting Brexit in the top three sources of uncertainty in the DMP survey.

[7]This is accomplished by asking detailed questions to CFOs on their exposure to Brexit (e.g. by asking about their share of sales to the EU, their share of EU exports or the share of EU migrants in their workforce) and their expected percentage change in performance in comparison to the previous fiscal year (Bloom *et al.*, 2019, 2020).

BUI, therefore, provides a relatively clear-cut identification of the transmission of Brexit uncertainty to the UK corporate sector.

In Figure 2, we present a graphical representation of the BUI, alongside the EPU index. Compared to the EPU index and other indexes of uncertainty, uncertainty captured by the BUI remains elevated and even increases following the referendum. Notably, the highest values of Brexit uncertainty appear in 2018–2019 (i.e. close to the original deadline for Brexit negotiations), when more than 50% of all CFOs surveyed in the DMP report Brexit as one of the top three sources of uncertainty for their firm.

Other macroeconomic and industry specific control variables

In line with Valkama *et al.* (2013), we also include several macroeconomic and industry control variables. According to the authors, these are in fact important drivers of buyout returns in the UK – in particular target industry growth fundamentals, which explains most of the heterogeneity in PE investors' performance.[8] Our first macroeconomic control is a proxy for the UK economic activity (henceforth 'Investment Opportunity Index'). This is computed using several proxies of the future performance of the economy, such as: (i) the agents' survey of investment intentions, Confederation of British Industry (CBI) survey on investment intentions, Bank of England's general economic situation expectations survey; (ii) Bank of England's household personal financial situation expectations survey and unemployment projection (inverted); and (iii) Bank of England one year-ahead GDP growth forecast at market rates. To avoid multicollinearity issues, without losing information, we compute the first principal component of the series reported above. We also control for market liquidity using the UK TED spread, employing data collected from the Bank of England.

As industry-specific controls, we use the industry median of proxies for equity valuation (i.e. 36-month cumulative stock return) and volatility (i.e. standard deviation of the former variable), as indicators of industry performance. We include industry median Tobin's q as an additional forward-looking proxy of firms' valuation, where a high Tobin's q indicates high valuation periods. Lastly, to create proxies for industry-level economic shocks, we combine CRSP and Compustat Global databases and follow Harford (2005) to construct each of the 48 Fama and French (1997) industries (see Appendix B in the online supporting information).

Empirical methodology and results

The response of PE buyouts to different measures of uncertainty

In this section we examine investment dynamics at the firm level. Specifically, using a logit model, we estimate the probability of a buyout – investing in an LBO, MBO and/or going private transaction – as a function of the mean level of uncertainty in the previous year, after controlling for numerous determinants of PE investment. In our logit regression model therefore, $Y_j = 1$ if a given firm j receives a buyout in year $t + 1$; $Y_j = 0$ if firm j does not receive a buyout. Subsequently, we estimate the probability of $Y_j = 1$ given a set of firm-level, industry-level and macro-level independent variables in the following manner:

$$P(Y = 1|x_1, x_2, \ldots, x_n) = f(x_1, x_2, \ldots, x_n). \quad (1)$$

Uncertainty and the likelihood of a buyout. The results of our baseline logit estimations, presented in Table 2, support H1 since for several uncertainty measures, greater uncertainty significantly reduces the likelihood of PE buyouts the following year.

In particular, the EPU index, sterling option-implied volatility and BUI (see Table 2, columns 1, 3 and 5, respectively) are negatively signed and statistically significant, the first and latter measure at the 1% level. In other words, increases in these three measures significantly reduce the likelihood of UK PE buyouts in the upcoming year. Turning to the marginal effects of the considered logit models (at the mean), consider the case of BUI, the most explicit measure of Brexit uncertainty.[9] Here, a 1% increase in BUI leads to a mean marginal decrease in the likelihood of buyouts in the following year of about 0.016%, corresponding to approxi-

[8] Valkama *et al.* (2013) find that in the UK economic performance, industry growth and stock market returns are the main predictors of PE buyout returns.

[9] See Table A.6 in the online supporting information for the marginal effects.

Table 2. Uncertainty and PE buyout activity

	(1) Buyout t+1	(2) Buyout t+1	(3) Buyout t+1	(4) Buyout t+1	(5) Buyout t+1
Policy uncertainty (EPU)	−0.280 ***				
	(0.089)				
Macro uncertainty		−0.032			
		(0.099)			
Sterling option-implied volatility			−0.165 **		
			(0.071)		
FTSE option-implied volatility				0.062	
				(0.172)	
Brexit uncertainty (BUI)					−0.108 ***
					(0.026)
Investment opportunity	−0.096 *		−0.073		−0.014
	(0.057)		(0.057)		(0.034)
Industry shock	0.354 ***	0.356 ***	0.368 ***	0.354 ***	0.377 ***
	(0.078)	(0.078)	(0.080)	(0.078)	(0.077)
TED spread	−1.451	−0.501	−1.011	−0.616	
	(0.911)	(0.885)	(0.931)	(0.939)	
Industry cumulative returns	−0.771 ***	−0.696 ***	−0.808 ***	−0.641 **	−0.531 **
	(0.222)	(0.249)	(0.237)	(0.251)	(0.234)
Industry cumulative STD returns	0.237	0.418	0.501	0.325	−0.399
	(0.598)	(0.602)	(0.588)	(0.613)	(0.640)
Industry q	0.443 ***	0.440 ***	0.412 ***	0.451 ***	0.499 ***
	(0.094)	(0.094)	(0.098)	(0.095)	(0.090)
Total assets	0.004 ***	0.005 ***	0.004 ***	0.005 ***	0.005 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ROA	0.005 ***	0.005 ***	0.005 ***	0.005 ***	0.005 ***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Leverage	−0.000	−0.000	−0.000	−0.000	−0.000 *
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cash-to-asset	−1.593 ***	−1.593 ***	−1.593 ***	−1.592 ***	−1.590 ***
	(0.254)	(0.255)	(0.255)	(0.255)	(0.253)
Constant	−6.640 ***	−7.295 ***	−7.159 ***	−7.385 ***	−7.243 ***
	(0.328)	(0.254)	(0.265)	(0.321)	(0.196)
Observations	412,622	412,622	412,622	412,622	412,622

Notes: The table displays the results of our baseline logistic regression of the likelihood of a buyout (buyout t+1) on economic policy uncertainty (column 1), macro-economic uncertainty (column 2), sterling option-implied volatility index (column 3), FTSE All-Share option-implied volatility index (column 4) and Brexit uncertainty (column 5). All regressions are supplemented with several controls for industry and target-specific economic fundamentals. In each regression, the dependent variable assumes a value of 1 if at time t+1 a certain target firm is the object of a buyout, and 0 otherwise. All independent variables are continuous and measured instead at time t. Further in-depth information on the variables included in this table is reported in the Section B.1 of the online supporting information. ***, **, * mark regression coefficients significant at the 1%, 5%, 10% level. Standard errors are reported in parentheses.

mately 79% of the unconditional probability of a buyout during the Brexit period.

By contrast, in Table 2, both the Bank of England macroeconomic uncertainty index and the FTSE All-Share option-implied volatility are not significant at the 10% level (see columns 2 and 4). We gently attribute this finding to the different components and forecast horizons of the uncertainty measures; for example, the FTSE All-Share option-implied volatility might be considered a short-term indicator. In any case, such a result sheds light on the importance of considering differences in indicators of uncertainty when assessing impact on domestic economic activity and investment.

Other control variables included in the regressions are portfolio targets' specific controls, such as the natural logarithm of the firm assets, ROA, firms' leverage (computed as liabilities-over-equity), and cash and equivalents-over-assets. As standard, some control variables are omitted from the regression if they display high correlation with the core explanatory variable of the regression, to avoid multicollinearity problems (see Appendix D

Table 3. The persistence of uncertainty effects

	(1) Buyout t+1	(2) Buyout t+2	(3) Buyout t+3	(4) Buyout t+4	(5) Buyout t+5
Panel A: Economic policy uncertainty					
Policy uncertainty (EPU)	−0.280 ***	−0.225 ***	−0.095	0.793 *	0.462
	(0.089)	(0.086)	(0.077)	(0.415)	(0.602)
Observations	412,622	362,609	311,788	261,615	214,549
Macroeconomic controls	Yes	Yes	Yes	Yes	Yes
Industry-level controls	Yes	Yes	Yes	Yes	Yes
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Panel B: Sterling option-implied volatility					
Sterling option-implied volatility	−0.165 **	−0.181 ***	−0.007	0.220 **	0.132
	(0.071)	(0.069)	(0.065)	(0.089)	(0.122)
Observations	412,622	362,609	311,788	261,615	214,549
Macroeconomic controls	Yes	Yes	Yes	Yes	Yes
Industry-level controls	Yes	Yes	Yes	Yes	Yes
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Panel C: Brexit uncertainty index					
Brexit uncertainty (BUI)	−0.108 ***	−0.101 ***	−0.077	−0.189	–
	(0.026)	(0.032)	(0.051)	(0.189)	–
Observations	412,622	362,609	311,788	261,615	–
Macroeconomic controls	Yes	Yes	Yes	Yes	–
Industry-level controls	Yes	Yes	Yes	Yes	–
Firm-level controls	Yes	Yes	Yes	Yes	–

Notes: The table displays the results of a logistic regression of the likelihood of a buyout in the future (buyout t+1; buyout t+2; buyout t+3; buyout t+4; buyout t+5) on economic policy uncertainty (Panel A), sterling option-implied volatility (Panel B) and Brexit uncertainty (Panel C). All regressions are supplemented with several controls for industry and target-specific economic fundamentals, which for space reasons are not presented. In each regression, the dependent variable assumes a value of 1 if at time t+1, t+2, t+3, t+4, t+5 a certain target firm is the object of a buyout, and 0 otherwise. All independent variables are continuous and measured instead at time t. Further in-depth information on the variables included in this table is reported in Section B.1 of the online supporting information.

***, **, * mark regression coefficients significant at the 1%, 5%, 10% level. Standard errors are reported in parentheses. We cannot produce 5-year ahead predictions, since the BUI is different from zero between 2015 and 2019 (i.e. the time window is too narrow).

in the online supporting information). In each regression we use robust standard errors clustered at the level of the buyout target (portfolio firm). Moreover, we include industry and firm-level variables measured in the previous fiscal year (t).

The persistence of uncertainty effect on buyouts. Following our baseline results in Table 2, we assess the persistence of the effect of an uncertainty shock on buyout activity. If greater uncertainty leads PE investors to delay investment, rather than reduce it, we would expect a reversal in the logit coefficient sign. Therefore, in Table 3, we re-explore our baseline regression, this time considering the likelihood of a buyout up to 5 years ahead (t+1, t+2, t+3, t+4, t+5), given an uncertainty shock at time t (controlling for industry and macroeconomic shocks).

We start our analysis on the persistence of uncertainty by analysing economic policy uncertainty, or EPU. As reported in Table 3, Panel A, we do not observe a sign reversal in the response to greater policy uncertainty in the three following years – although after 2 years the level of significance reduces. The coefficient sign of the EPU index changes in year t+4, indicating that after an event increasing policy uncertainty on average it takes 4 years for PE investment to recover (the PE investment receives a 4-year delay). This provides evidence for both the economic significance and persistence of a policy uncertainty shock to PE investment, which is in line with our H2. Additionally, we observe in Table 3, Panel B that sterling uncertainty significantly reduces the likelihood of a buyout for years (t+1 and t+2) with no significant reversal in t+3. As for the EPU index, we observe

Table 4. Comparing the impact of uncertainty on buyouts in the UK vs. the USA

	US sample			UK sample		
	(1) Buyout t+1	(2) Buyout t+1	(3) Buyout t+1	(4) Buyout t+1	(5) Buyout t+1	(6) Buyout t+1
Policy uncertainty (EPU)	0.090***			−0.288***		
	(0.030)			(0.087)		
Sterling option-implied volatility		−0.144***			−0.251***	
		(0.019)			(0.052)	
Brexit uncertainty (BUI)			−0.008			−0.080***
			(0.007)			(0.018)
Constant	−2.539***	−2.345***	−2.386***	−1.958***	−2.311***	−2.295***
	(0.397)	(0.398)	(0.395)	(0.131)	(0.015)	(0.021)
Observations	60,024	60,024	60,024	10,008	10,008	10,008
Industry-level FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table displays in columns 1, 2 and 3 the results of a fixed effect logistic regression of the likelihood of a buyout in the USA in year t+1 on several UK measures of uncertainty: EPU, sterling option-implied volatility and BUI. All regressions are supplemented with industry effects. In columns 4, 5 and 6, we repeat this model specification on our baseline UK buyouts sample to provide a clear comparison of the regression coefficients of our uncertainty measures. In both regression models, we do not include a control sample of firms that are never the target of PE buyouts.
***, **, * mark regression coefficients significant at the 1%, 5%, 10% level. Standard errors are reported in parentheses.

a sign reversal in the likelihood of a buyout 4 years after sterling uncertainty arose, which leads us to conclude that sterling uncertainty causes an average 4-year delay of PE buyouts. Finally, Table 3, Panel C presents the impact of Brexit uncertainty on the future likelihood of a buyout. In a strong confirmation of H2, one can observe that the response of 3-year-ahead buyout volume to BUI is negative and persistent. Eventually, it has no significant effect on the likelihood of a buyout in year t+4.

Overall, we observe that Brexit uncertainty leads to an average 4-year delay in PE buyout, after which investment is recovered. Following the second year ahead of the uncertainty event, the coefficient of year t+3 is often not significant, while that of year t+4 is instead positive and significant for the EPU and sterling uncertainty variables.

Country counterfactual using the US PE market. To further establish the findings, we re-run our analysis for a country that has not experienced Brexit and hence should not be negatively affected by the related uncertainty. Arguably, one could even postulate that the US market could have profited from Brexit by attracting PE capital. In such a context, the coefficient estimate on uncertainty measures associated with Brexit should be either insignificant or even positive.

For this purpose, we use the sample selection criteria adopted earlier (for UK PE targets) and create a comparable sample of US private equity target firms (exploiting the data from Capital IQ). As the Brexit uncertainty shock is specifically localized in Britain and the EU, testing our baseline models on this last sample may further validate our findings and support the lack of sampling bias in our results. Given the lack of identical firm and industry-specific variables in the new sample, we perform a panel fixed effect logistic regression using industry and time fixed effects. We include in the regression our baseline models' variables of uncertainty (i.e. EPU, sterling option-implied volatility and BUI).

Our results, reported in Table 4, show that the Brexit dimensions of uncertainty adopted in our baseline model (with the exception of sterling option-implied volatility, which also accounts for USD uncertainty) have a strikingly positive effect on the likelihood of a buyout in the USA. This indicates that Brexit uncertainty had an important and UK-specific negative effect on PE activity, supporting the validity of our prior results and potentially pointing to cross-country spillover effects arising from Brexit.

Additional results. In Appendix F in the online supporting information, we present some additional results. First, we re-estimate the baseline

regression during the 'Brexit period' (2016–2019) and find that uncertainty has a significantly negative impact on PE buyout activity (Section F.1). Second, we follow the merger waves literature to account for the counter-cyclicality of target firms' valuations. We show that the key result about the negative effect of uncertainty is robust.

The transmission channels of uncertainty to the PE market

We investigate the three postulated transmission channels of uncertainty characterized in H3–H5 and developed earlier. First, we consider predictions from theory, predicting that uncertainty will increase the real option (general partner incentive) to delay investment (cf. Gulen and Ion, 2016; Quigg, 1993). Bloom *et al.* (2018), analysing the impact of Brexit on business investment, found a significant decrease in business investment in the UK since the Brexit referendum. Likewise, other authors such as Serwicka and Tamberi (2018), or McGrattan and Waddle (2020), found evidence of a significant shift of foreign direct investment (FDI) from the UK to other countries in the EU. Second, we test the potential effect of a greater interim risk channel, known to significantly depress equity valuations (see Bhagwat, Dam and Harford, 2016) in the interim period between announcement and completion of an acquisition. Finally, we test the existence of a greater moral hazard incentive, created by the high period of uncertainty and leading limited partners to have lower control and ability to assess the performance of general partners. According to this argument, when uncertainty is elevated if limited partners' (principals') control over general partner (agent) actions are impaired, this could create greater empire-building incentives.

Testing the real options transmission channel

As we noted earlier, the value of the option is conditional on three main factors: (i) the degree of investment irreversibility; (ii) the cost of postponing the investment (buyout); and (iii) the extent to which uncertainty affects the investment target (PE portfolio target). We explore these factors in more detail below.

Investment irreversibility. To assess the validity of the real options theory applied to the context of UK buyouts, we use three different proxies of investment irreversibility to assess whether the effect of uncertainty on leveraged buyouts is stronger for irreversible investments. All measures of investment irreversibility are measured at the target level of a given buyout.

The first proxy of investment irreversibility is the PE target industry capital intensity ratio – computed as the industry mean net property, plant and equipment (PPE) over total assets. The underlying assumption is that investment in firms with greater amounts of fixed assets (PPE) would be harder to reverse. Therefore, we create a dummy variable taking the value of one if a buyout target in a given year has a greater capital intensity ratio than the industry median.

Our second proxy of investment irreversibility is based on given investment sunk costs. In a similar spirit to Kessides (1990) and Farinas and Ruano (2005), we argue that the greater is the rent and lease of firm tangible assets, the faster is its fixed capital depreciation (i.e. the shorter is the lifecycle of its assets) and the greater is the available secondary market for firm assets, the lower would be the sunk costs associated with an acquisition. Lower sunk costs should reduce the value of the option to delay a given buyout. Therefore, following Gulen and Ion (2016) and Bonaime, Gulen and Ion (2018), we compute the average industry level of: rent and lease expenditure; depreciation expense; and yearly sales of PPE (all scaled by lagged PPE). We then create a dummy variable to characterize an industry as having low investment sunk costs if all three measures are contemporaneously above the industry median in a given year.

We then follow Shleifer and Vishny (1992) and Almeida and Campello (2007) by suggesting that highly cyclical industries receive a considerably higher discount on asset liquidation values in periods of crisis. Therefore, in periods of high uncertainty, highly cyclical industries are significantly riskier than less cyclical ones, as firms in the same industry would be similarly affected by a given uncertainty shock. To identify cyclical industries, as is standard practice in the relevant literature (cf. Sharpe, 1994), we use SIC industry codes identifying cyclical industries as those industries characterized by a greater amount of durable goods.

Lastly, if the predictions from real options theory hold, and hence greater uncertainty creates

Table 5. Real options channel – economic policy uncertainty

	(1) Investment irreversibility	(2) Sunk costs	(3) Durable goods industry	(4) Industry concentration
Policy uncertainty (EPU)	−0.319 **	−0.281 **	−0.433 *	−0.539 ***
	(0.130)	(0.117)	(0.236)	(0.156)
Investment opportunity	−0.213 ***	−0.199 **	0.032	−0.228 **
	(0.080)	(0.084)	(0.125)	(0.090)
Industry shock	0.350 ***	0.775 ***	−0.038	1.801 ***
	(0.103)	(0.106)	(0.170)	(0.151)
TED spread	−1.202	−2.432 **	−1.700	−0.862
	(1.165)	(1.229)	(2.171)	(1.335)
Industry cumulative returns	−0.550 *	−0.759 **	−2.191 ***	-0.332
	(0.287)	(0.324)	(0.471)	(0.330)
Industry cumulative STD returns	0.696	5.061 ***	4.540 ***	−1.214
	(0.697)	(0.736)	(0.866)	(0.976)
Industry q	0.348 ***	0.421 ***	0.701 ***	0.655 ***
	(0.132)	(0.133)	(0.192)	(0.171)
Total assets	0.006 ***	0.003 *	−0.004	0.002
	(0.002)	(0.002)	(0.004)	(0.002)
ROA	0.010 ***	0.008 ***	0.001	0.006 ***
	(0.002)	(0.002)	(0.005)	(0.002)
Leverage	−0.000	−0.000	−0.000	−0.000 **
	(0.000)	(0.000)	(0.000)	(0.000)
Cash-to-asset	−2.078 ***	−1.454 ***	−2.429 ***	−1.871 ***
	(0.305)	(0.325)	(0.665)	(0.373)
Constant	−7.098 ***	−7.580 ***	−8.503 ***	−9.127 ***
	(0.445)	(0.424)	(0.773)	(0.668)
Observations	412,622	181,738	412,622	412,622

Notes: The table displays the results of a logistic regression of the likelihood of a buyout on economic policy uncertainty. All regressions are supplemented with several controls for industry and target-specific economic fundamentals. In column 1, the dependent variable assumes a value of 1 if at time t+1 target firms with a degree of investment irreversibility with above the industry median are the object of a buyout, and 0 otherwise. In column 2, the dependent variable assumes a value of 1 if at time t+1 a target firm pertaining to an industry with higher sunk costs is the object of a buyout, and 0 otherwise. In column 3, the dependent variable assumes a value of 1 if at time t+1 a firm from an industry classified in Sharpe (1994) as a durable good industry is the target of a buyout, and 0 otherwise. Eventually, in column 4, the dependent variable assumes a value of 1 if at time t+1 a target firm from an industry with a high degree of concentration is the object of a buyout, and 0 otherwise. All independent variables are continuous and measured instead at time t. Further in-depth information on the variables included in this table is reported in Section B.1 of the online supporting information. ***, **, * mark regression coefficients significant at the 1%, 5%, 10% level. Standard errors are reported in parentheses.

the incentive for the general partner to postpone investment, this incentive should be lower when postponement is more costly. In particular, as suggested by Grenadier (2002), delaying investment is considerably more expensive when the target firms operate in a highly competitive industry, where a delay could lead to competitors' appropriation of part of the benefits (profitability) yielded by the investment project. Based on this assumption, the incentive to delay the (completion of the) investment until uncertainty is resolved is considerably higher in concentrated industries (i.e. less competitive), where it is actually relatively inexpensive to delay. To assess industry concentration, we adopt the methodology used for the creation of the Herfindahl sales-based index of industry concentration. Therefore, we use a dummy variable taking the value of one if the median industry sales in a given year exceed all industries' sales median, and zero otherwise. Also, with respect to this proxy of industry concentration, the results appear robust and all point to a greater impact of uncertainty on PE investment within industries that are more concentrated rather than vice versa, as predicted by the real options theory.

In Tables 5, 6 and 7, we show the results of our baseline model regressions including the aforementioned proxies of industry capital intensity, sunk costs and cyclicality. All the results point to a uniformly strong effect of uncertainty (with the

Table 6. Real option channel – sterling option-implied volatility

	(1) Investment irreversibility	(2) Sunk costs	(3) Durable goods industry	(4) Industry concentration
Sterling option-implied volatility	−0.045^{-}	−0.198 *	−0.258	−0.423 ***
	(0.097)	(0.104)	(0.178)	(0.123)
Investment opportunity	−0.171 **	−0.192 **	0.060	−0.211 **
	(0.081)	(0.087)	(0.124)	(0.087)
Industry shock	0.355 ***	0.785 ***	−0.028	1.896 ***
	(0.105)	(0.110)	(0.174)	(0.161)
TED spread	−0.388	−2.193 *	−1.251	−0.431
	(1.149)	(1.294)	(2.301)	(1.435)
Industry cumulative returns	−0.463	−0.795 **	−2.306 ***	−0.450
	(0.311)	(0.358)	(0.539)	(0.368)
Industry cumulative STD returns	0.822	5.318 ***	4.877 ***	−0.650
	(0.690)	(0.757)	(0.928)	(0.963)
Industry q	0.341 **	0.373 ***	0.669 ***	0.527 ***
	(0.135)	(0.143)	(0.206)	(0.188)
Total assets	0.006 ***	0.003 *	−0.004	0.002
	(0.002)	(0.002)	(0.004)	(0.002)
ROA	0.010 ***	0.008 ***	0.001	0.006 **
	(0.002)	(0.002)	(0.005)	(0.002)
Leverage	−0.000 *	−0.000	−0.000	−0.000 ***
	(0.000)	(0.000)	(0.000)	(0.000)
Cash-to-asset	−2.079 ***	−1.452 ***	−2.433 ***	−1.873 ***
	(0.305)	(0.325)	(0.666)	(0.373)
Constant	−7.777 ***	−8.016 ***	−9.246 ***	−10.019 ***
	(0.338)	(0.382)	(0.590)	(0.586)
Observations	412,622	181,738	412,622	412,622

Notes: The table displays the results of a logistic regression of the likelihood of a buyout on BoE sterling option-implied volatility. All regressions are supplemented with several controls for industry and target-specific economic fundamentals. In column 1, the dependent variable assumes a value of 1 if at time t+1 target firms with a degree of investment irreversibility with above the industry median are the object of a buyout, and 0 otherwise. In column 2, the dependent variable assumes a value of 1 if at time t+1 a target firm pertaining to an industry with higher sunk costs is the object of a buyout, and 0 otherwise. In column 3, the dependent variable assumes a value of 1 if at time t+1 a firm from an industry classified in Sharpe (1994) as a durable good industry is the target of a buyout, and 0 otherwise. Eventually, in column 4, the dependent variable assumes a value of 1 if at time t+1 a target firm from an industry with a high degree of concentration is the object of a buyout, and 0 otherwise. All independent variables are continuous and measured instead at time t. Further in-depth information on the variables included in this table is reported in Section B.1 of the online supporting information. ***, **, *, $^{-}$ mark regression coefficients significant at the 1%, 5%, 10%, 15% level. Standard errors are reported in parentheses.

exception of sterling option-implied volatility) on PE activity for buyouts characterized by high levels of investment irreversibility and analogous measures – in accordance with H3. This appears to be the case, with respect to both PE investment in the entire period of analysis and during the Brexit period, with statistical significance generally being higher for regressions estimated using the BUI. On the contrary, we document a much weaker real options channel with respect to the transmission of sterling uncertainty.

Industry-level transmission of Brexit uncertainty. Next, we examine industry-level transmission of Brexit uncertainty. As pointed out in Bloom *et al.* (2019), 'The vote for Brexit was a largely unexpected event and we observe that it has had a heterogeneous impact on firms according to their pre-referendum exposure to Europe' (Bloom *et al.*, 2019: 2). In light of these findings, we argue that the incentive to delay investment when Brexit uncertainty arises is greater for industries that are more exposed to Brexit uncertainty (i.e. more exposed to the external trade sector, as in Bloom *et al.*, 2019, 2020). Of course, measuring exposure to uncertainty can be non-trivial. Hassan *et al.* (2020), using tools from computational linguistics, measured firm-level exposure to Brexit by analysing the recurrence of discussions

Table 7. Real option channel – Brexit uncertainty index

	(1) Investment irreversibility	(2) Sunk costs	(3) Durable goods industry	(4) Industry concentration
Brexit uncertainty (BUI)	−0.216***	−0.089***	−0.097	−0.144***
	(0.036)	(0.033)	(0.064)	(0.037)
Investment opportunity	−0.114***	−0.046	0.132	−0.150***
	(0.043)	(0.045)	(0.081)	(0.051)
Industry shock	0.380***	0.769***	−0.016	1.820***
	(0.101)	(0.099)	(0.170)	(0.145)
TED spread				
Industry cumulative returns	−0.242	−0.522	−1.968***	0.036
	(0.289)	(0.318)	(0.517)	(0.337)
Industry cumulative STD returns	−0.318	4.733***	4.129***	−1.843*
	(0.764)	(0.710)	(0.904)	(1.076)
Industry q	0.440***	0.538***	0.739***	0.755***
	(0.128)	(0.116)	(0.180)	(0.160)
Total assets	0.006***	0.003**	−0.004	0.002
	(0.002)	(0.002)	(0.004)	(0.002)
ROA	0.010***	0.007***	0.001	0.006**
	(0.002)	(0.002)	(0.005)	(0.002)
Leverage	−0.000	−0.000	−0.000	−0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
Cash-to-asset	−2.071***	−1.446***	−2.427***	−1.864***
	(0.302)	(0.325)	(0.665)	(0.372)
Constant	−7.608***	−8.545***	−9.417***	−10.037***
	(0.256)	(0.235)	(0.354)	(0.487)
Observations	412,622	181,738	412,622	412,622

Notes: The table displays the results of a logistic regression of the likelihood of a buyout on the BUI. All regressions are supplemented with several controls for industry and target-specific economic fundamentals. In column 1, the dependent variable assumes a value of 1 if at time t+1 target firms with a degree of investment irreversibility with above the industry median are the object of a buyout, and 0 otherwise. In column 2, the dependent variable assumes a value of 1 if at time t+1 a target firm pertaining to an industry with higher sunk costs is the object of a buyout, and 0 otherwise. In column 3, the dependent variable assumes a value of 1 if at time t+1 a firm from an industry classified in Sharpe (1994) as a durable good industry is the target of a buyout, and 0 otherwise. Eventually, in column 4, the dependent variable assumes a value of 1 if at time t+1 a target firm from an industry with a high degree of concentration is the object of a buyout, and 0 otherwise. All independent variables are continuous and measured instead at time t. Further in-depth information on the variables included in this table is reported in Section B.1 of the online supporting information.
***, **, * mark regression coefficients significant at the 1%, 5%, 10% level. Standard errors are reported in parentheses.

of benefits (and costs) associated with Brexit in listed firms' quarterly earning conference calls proceedings. They find a much stronger transmission of Brexit-related uncertainty (e.g. leading to outcomes such as loss of investment, employment, productivity, etc.) to firms that are highly exposed to Brexit. We measure external exposure using data on industry-level import and export from the UK Office for National Statistics (ONS). In particular, we compute for each industry and year the difference between the industry median of import (IM), export (X) and total exposure (IM+X) and the national median in a given year t. We then assess the impact of Brexit-related uncertainty on the probably of a buyout in an industry with high exposure to Brexit (i.e. exposure to the external sector).

In Table 8, we find that sectors more heavily exposed to the external sector have a lower likelihood of buyout as a result of greater Brexit uncertainty, in line with H3. We repeat the test using the EPU and sterling uncertainty from 2016 onward, instead of the BUI, and our results remain robust and unaffected (see columns 2, 5 and 7). In confirmation of the above argument, we do not find evidence of a greater transmission of uncertainty to industries heavily exposed to the external sector before the Brexit referendum (see columns 3 and 6).

Table 8. Buyouts in industries highly exposed to Brexit

	2010–2019 Industry exposure to the EU	2016–2019 Industry exposure to the EU	2010–2015 Industry exposure to the EU	2010–2019 Industry exposure to the EU	2016–2019 Industry exposure to the EU	2010–2015 Industry exposure to the EU	2010–2019 Industry exposure to the EU
Policy uncertainty (EPU)	−0.262**	−0.248-	0.899				
	(0.120)	(1.179)	(0.850)				
Sterling option-implied volatility				−0.092	0.093	0.242-	
				(0.100)	(0.442)	(0.168)	
Brexit uncertainty (BUI)							−0.119*** (0.034)
Observations	408,036	163,050	261,615	408,036	163,050	261,615	408,036
Macroeconomic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table displays the results of a logistic regression of the likelihood of a buyout in a given industry on economic policy uncertainty (columns 1, 2 and 3), sterling option-implied volatility (column 4, 5 and 6) and Brexit uncertainty (column 7). The likelihood of an industry receiving PE investment is expressed as a function of the industry exposure to the external sector (IM+X). All regressions are supplemented with several controls for industry and target-specific economic fundamentals. In each year t, the dependent variable assumes a value of 1 if at time t+1 a firm belonging to an industry with external sector exposure higher than the median for all industries is the target of a buyout, and 0 otherwise. In columns 1, 4 and 7, we consider the likelihood of PE buyouts in industries highly exposed to the external sector over the whole period (pre- and post-Brexit referendum). In columns 2 and 5, we analyse the likelihood of PE buyouts in industries highly exposed to the external sector just in the year of the Brexit referendum and after. Instead, in columns 3 and 6, we re-perform the logistic model analysing the years before the referendum. Overall, this analysis enables us to compare the coefficients' sign and significance before and after the referendum, therefore, to assess potential differences in the transmission of uncertainty to the private equity industry. All independent variables are continuous and measured instead at time t. Further in-depth information on the variables included in this table is reported in Section B.1 of the online supporting information.
***, **, *, - mark regression coefficients significant at the 1%, 5%, 10%, 15% level. Standard errors are reported in parentheses.

Testing the interim risk channel

In Table 9, we test whether across our whole sample period and in the Brexit period, uncertainty transmitted to the buyout market through this channel. In an interim risk channel, uncertainty transmits to PE activity in the interim period, hence leading investors to postpone (or cancel) investment.[10] However, crucially, deals with a longer interim period are subject to much greater interim risk than deals with shorter interim periods.

Therefore, we measure the interim periods of all buyout deals considered in our analysis and assess the impact of policy uncertainty (in column 1), sterling option-implied volatility (in column 2) and Brexit uncertainty (in column 3) on the likelihood of a buyout of a target with a longer than the industry median interim period. We find that neither policy uncertainty nor sterling uncertainty significantly affect the likelihood of a buyout – based on the target interim period – hence, we find no evidence of an interim risk channel for the whole period of analysis (2010–2019). On the contrary, Brexit uncertainty significantly reduced the likelihood of buyout of a target with longer interim period than the industry median. This implies that during the years of elevated Brexit uncertainty, not only were buyouts more unlikely, and investment lost (as we found in Tables 2 and 3), but the interim risk channel played a role, in agreement with H4.

[10]Tests for this channel are exclusively performed on UK firms that at some point in the period of analysis were the target of a buyout. These are indeed the only ones that can have an interim period (and hence are exposed to this channel).

Testing the moral hazard channel

We build our empirical setting to investigate the empire-building incentive by focusing on the 'value-destruction' implications of this channel.

Table 9. Interim risk channel

	(1) Interim risk	(2) Interim risk	(3) Interim risk
Policy uncertainty (EPU)	−0.107		
	(0.201)		
Sterling option-implied volatility		0.080	
		(0.161)	
Brexit uncertainty (BUI)			−0.100**
			(0.050)
Investment opportunity	0.003	0.028	0.041
	(0.078)	(0.077)	(0.059)
Industry shock	−0.167	−0.164	−0.122
	(0.186)	(0.184)	(0.168)
TED spread	−0.500	−0.437	
	(0.440)	(0.395)	
Industry cumulative returns	−0.217	−0.112	−0.088
	(0.471)	(0.474)	(0.490)
Industry cumulative STD returns	−3.493**	−3.406**	−4.068***
	(1.445)	(1.472)	(1.530)
Industry q	0.208	0.211	0.262
	(0.156)	(0.155)	(0.166)
Total assets	0.154***	0.154***	0.150***
	(0.023)	(0.023)	(0.022)
ROA	0.017*	0.017*	0.015*
	(0.009)	(0.009)	(0.009)
Leverage	0.011***	0.011***	0.011***
	(0.002)	(0.002)	(0.002)
Cash-to-asset	−0.168	−0.142	−0.346
	(0.572)	(0.566)	(0.592)
Constant	−3.366***	−3.613***	−3.502***
	(0.560)	(0.396)	(0.420)
Observations	6,888	6,888	6,888

Notes: The table displays the results of a logistic regression of the likelihood of a buyout of a target firm with interim period above the industry median on economic policy uncertainty (column 1), sterling option-implied volatility (column 2) and Brexit uncertainty (column 4). All regressions are supplemented with several controls for industry and target-specific economic fundamentals, which for space reasons are not presented. In each regression, the dependent variable assumes a value of 1 if at time t+1 a PE target firm has interim period greater than the industry median, and 0 otherwise. All independent variables are continuous and measured instead at time t. Tests for this regression are performed exclusively on firms which at some point in time have been the target of buyouts, as only those would have data on the buyout interim period. The considered period of analysis is 2010–2019. Further in-depth information on the variables included in this table is reported in Section B.1 of the online supporting information.
***, **, * mark regression coefficients significant at the 1%, 5%, 10% level. Standard errors are reported in parentheses.

We do so by assessing the change in our baseline model accounting variables (ROA, operating income, total assets and cash-to-assets) around the time of the buyout (between t−1 and t+1) in moments of high (Brexit) uncertainty and low (Brexit) uncertainty,[11] and we test the significance of the difference of the coefficients in the two time periods.

The results presented in Table 10 show that deals realized in periods of high policy uncertainty are characterized by a higher short-term growth in ROA and by lower operating income than those in periods of low policy uncertainty (see Panel A). We find no sign of moral hazard when comparing periods of high and low sterling option volatility (see Panel B). Hence, the evidence does not support H5. In periods of high Brexit uncertainty, we observe that only deals with a greater change in ROA are significant – all other variables being not significant (see Panel C). We find this evidence refutes the 'empire-building channel'. Periods of high uncertainty are in fact characterized by a loss of buyout

[11]We classify years of high uncertainty as such if in those years a given uncertainty measure has values above the median for the whole period of analysis. In contrast, years with low uncertainty have a value below the entire period median.

Table 10. Moral hazard channel

	High	Low	High − low
Panel A: Economic policy uncertainty			
Delta ROA	0.016***	0.002	0.014**
	(0.005)	(0.005)	
Delta total assets	0.040	−0.036	0.004
	(0.026)	(0.046)	
Delta operating income	−0.009***	0.002	−0.011***
	(0.004)	(0.003)	
Delta cash-to-asset	0.049	−0.071	0.11
	(0.044)	(0.201)	
Constant	−2.257***	−2.061***	−0.196
	(0.051)	(0.053)	
Panel B: Sterling option-implied volatility			
Delta ROA	0.008	0.010**	−0.002
	(0.005)	(0.005)	
Delta total assets	0.022	0.006	0.016
	(0.037)	(0.033)	
Delta operating income	−0.008*	−0.008	0.000
	(0.003)	(0.004)	
Delta cash-to-asset	0.026	0.136	−0.011
	(0.043)	(0.159)	
Constant	−2.219***	−2.161***	0.058
	(0.061)	(0.061)	
Panel C: Brexit uncertainty index			
Delta ROA	0.016***	0.003	0.013**
	(0.005)	(0.005)	
Delta total assets	0.022	0.004	0.018
	(0.030)	(0.036)	
Delta operating income	−0.007*	−0.003	−0.004
	(0.004)	(0.005)	
Delta cash-to-asset	0.043	−0.060	0.103
	(0.041)	(0.280)	
Constant	−2.185***	−2.254***	0.069
	(0.045)	(0.062)	

Notes: The table displays the results of a logistic regression of the likelihood of year t displaying a level of economic policy uncertainty above (or below) the median (Panel A), sterling option-implied volatility above (or below) the median (Panel B) and Brexit uncertainty above (or below) the median (Panel C). All regressions use as independent variables target-level information on the change in return on assets, total assets, operating income and cash-to-assets in the 2 years around the buyout (i.e. in the period ranging from 1 year before to after the buyout). In column 1, the dependent variable takes the value 1 if in year t the level of uncertainty is above the median for the whole period. In column 2, the dependent variable takes the value 1 if in a given year, the level of uncertainty is above the median for the whole period. In column 3, we test the significance of the difference between the logistic regression coefficients. The considered period of analysis is 2010–2019. Further in-depth information on the variables included in this table is reported in Section B.1 of the online supporting information.

***, **, * mark regression coefficients significant at the 1%, 5%, 10% level. Standard errors are reported in parentheses.

deals, as explained above, rather than an increase – as the moral hazard channel would predict. Moreover, deals realized in periods of uncertainty do not seem to compromise shareholder value, as hypothesized by Duchin and Schmidt (2013).

Conclusions

In this paper we explore the role of uncertainty on PE activity in the UK by developing new hypotheses and employing a novel dataset of PE targets

and non-targets from 2010 to 2019. Our particular focus is to elicit the uncertainty stemming from the Brexit referendum and contrast it with other forms of uncertainty (e.g. macroeconomic, equity and currency). Uncertainty from Brexit is directly measured by employing the recent Bloom *et al.* (2019) BUI constructed from surveys to the CFOs of approximately 3,000 UK businesses. To complement this approach, we conduct a finer-grained analysis of the relevance of potential uncertainty transmission channels that might affect buyouts.

Strikingly, we provide evidence that uncertainty affects PE activity negatively, even when controlling for economic activity. Brexit-related uncertainty has a significant negative effect, which is distinctly different from other forms of uncertainty and consequently augments the other uncertainties PE companies are facing. Moreover, uncertainty not only reduces PE activity but also delays PE buyouts. In terms of transmission channels, we provide evidence that Brexit-related uncertainty operates via the real options channel and the interim channel but has no statistically measurable effect via the moral hazard channel. Notably, uncertainty particularly affects sectors where investments are relatively irreversible, sunk costs are high and goods durable. Overall, our empirical analysis finds strong empirical support for the negative effects of uncertainty on PE activity in the UK, as conjectured by Wright *et al.* (2016).

Of course, Brexit uncertainty is presently ongoing. Our results suggest that this *particular* uncertainty will continue to result in less PE activity and, as a corollary, reduced investment and economic activity in the UK. To avoid the continued amplification of negative long-run economic effects, we would urge UK policymakers to resolve such uncertainties as quickly as possible. This work and our conclusions are built on the foundations of some earlier work by Mike Wright and co-authors. We would like to note that Mike Wright's work was highly original, influential and vast, in both scope and scale. He was also a great friend to many. We very much hope that our work above, building on just a few of his many insights into private equity, can be seen as part of a fitting tribute.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table A1. Accounting variables yearly observations
Table A2. Asset distribution of estimation sample
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Table A8. PE waves and uncertainty