Ambiguity, managerial ability, and growth options

Tarik Driouchi ,[1] Mingyu Chen,[2] Zhuo Lyu,[1] David J. Bennett[3,4] and Raymond H.Y. So[1]

[1]King's College London, University of London, London, WC2B 4BG, UK, [2]Lancaster University, Lancaster, LA1 4YX, UK, [3]Chalmers University of Technology, Gothenburg, SE, 412 96, Sweden, and 4Aston University, Birmingham, B4 7ET, UK

ABSTRACT

This paper studies the role of ambiguity and managerial ability in firm growth options from the perspective of behavioural theory. We argue that managerial ability increases both the identification and exploitation of growth options opportunities, but ambiguity reduces strategic growth options value as a result of information incompleteness and non-Bayesian behaviour. Using a dataset of all US-listed firms, we test the joint effects of ambiguity and managerial ability on growth options value after controlling for standard determinants and endogeneity. The results indicate that ambiguity has a negative effect on growth options value, while ability has a positive effect. We also find that the negative association between ambiguity and growth options is less pronounced with higher managerial ability. These findings underscore the importance of firm heterogeneity in the identification, exercise, and management of strategic and innovative real options opportunities. The paper's contribution also provides relevant management insights into the behavioural antecedents of real options at the firm level as well as confirmation that managerial and behavioural characteristics are important determinants of growth options value.

Keywords: behavioural theory, real options, ambiguity, managerial ability

Introduction

Previous research on real options theory has highlighted the importance of growth options (GO) in resource allocation, innovation, and strategic investment decisions (McGrath, 1997; Smit and Trigeorgis, 2004). Concerned with expansion beyond assets-in-place and future value creation, real growth options provide firms with the strategic flexibility, optionality, and managerial discretion to not only exploit opportunities for growth, but to also undertake new projects and adopt a long-term incremental approach to corporate strategy (Kogut and Kulatilaka, 2004; Ahammad et al., 2017). As call options on (future) strategic assets, growth options arise from R&D, market entry, radical innovation, foreign expansion and other value-creating economic prospects (Trigeorgis, 1996; Driouchi and Bennett, 2012). Growth options firms are also characterised by higher idiosyncratic volatility, R&D intensity, cumulative sales growth, market power, and organisational flexibility (Trigeorgis and Lambertides, 2014; Makrominas, 2017).

Empirical evidence on the determinants of (real) growth options has shown that firm-specific characteristics and heterogeneity are more important drivers of GO value than industry and country effects (Tong and Reuer, 2006; Chintakananda et al., 2008). Examples of firm-specific factors investigated in extant research include: size (Koussis and Makrominas, 2015), leverage (Trigeorgis and Lambertides, 2014), incentives (Alessandri et al., 2012), organisational slack (Reuer and Tong, 2007), multinationality and investment modes (Belderbos et al., 2019), cash position (Trigeorgis and Lambertides, 2014), and return skewness (Bali et al., 2019). However, absent from the real options literature are studies on the behavioural antecedents of corporate growth options, and how managerial characteristics contribute to real growth options value. While research in economics, management, and entrepreneurship has highlighted the fundamental role of human capital, know-how, and prior technical experience in driving firm growth especially in the context of new technology-based

firms (Colombo and Grilli, 2005), the real options literature is yet to incorporate aspects of managerial ability and skills into the growth options value equation for publicly listed-companies. Another fundamental precept of real options logic is that volatility, a proxy for Bayesian uncertainty, has a positive effect on option value. Though this linkage has been documented empirically (with various moderating effects) in extant research (Belderbos et al., 2020; Kraft et al., 2018), we are yet to know how uncertainty beyond risk - i.e., ambiguity or non-Bayesian uncertainty[1] - and its behavioural/cognitive implications affect firm real growth options. We also do not know how management quality and managerial ability influence the identification and exploitation of growth options opportunities (as call options on future strategic assets) in the presence of ambiguity. Competence-based and entrepreneurial finance research has been able to successfully disentangle wealth and financing effects from capability effects in explaining firm growth in environments of technological uncertainty (Colombo and Grilli, 2005; Colombo and Grilli, 2010). However, when it comes to real options theory the empirical literature is relatively silent on the managerial drivers of real growth options, and how ambiguity and ability - and their interplay - jointly affect growth options value beyond firm-specific financial characteristics. These outstanding issues are relevant to empirical research concerned with real options theory and heterogeneity because managerial and behavioural attributes are key to the visualisation and exercise of growth options opportunities.

To address the above gaps in real options research, our paper examines how ambiguity and managerial ability contribute to growth options value from the perspective of behavioural theory. We define ambiguity throughout this study as the uncertainty and vagueness about a firm's future prospects and investors/managers' propensity to deviate from Bayesian behaviour because of a lack of information clarity regarding the future realisations of market returns/volatility and the inability to rule out the number of distributions associated with valuation heuristics (Einhorn and Hogarth, 1985; Mosakowski, 1997). Using a dataset of all

US-listed firms over the period 1983-2013, we investigate the joint effects of ambiguity and managerial ability on corporate growth options after controlling for GO determinants. Decision-theoretic literature on ambiguity and real options posits that, due to Knightian uncertainty and non-Bayesian behaviour, the effect of ambiguity on option value can be negative (Nishimura and Ozaki, 2004; Gao et al. 2018) and firm or investor heterogeneity influences the identification of shadow options opportunities, the timing of option exercise and, therefore, real option value (Miao and Wang, 2011; Delaney, 2020). Empirical validations of these real options theory dynamics at the firm level are, however, scarce. The same holds for the interplay between ambiguity and firm heterogeneity, specifically the interaction effect of managerial ability on the ambiguity-GO linkage. While competence-based research has shown that human capital and managerial skills are key drivers of firm growth, real options research is yet to assess the contribution of managerial ability to growth options value. In another set of insightful papers and applying the knowledge- and resource-based views to the context of firm innovative assets, Hussinger and Pacher (2015, 2019) show in their dataset of 382 manufacturing companies that the association between information ambiguity - proxied by analyst forecast dispersion - and firm value is negative, and suggest that patents may partly mitigate this association.[2] We add to extant research and complement the findings of Hussinger and Pacher (2019) by: i) examining the strategic growth options component of firm value, which is also fundamental to its innovative assets and knowledge reserves, ii) investigating the effect of firm-specific ambiguity on strategic flexibility and growth options value through a behavioural real options lens, and iii) examining the joint role of ambiguity and managerial ability - and their interaction - in the growth options value equation in a dataset of all US-listed firms. Studying the interplay between firm-specific ambiguity and ability is important because it helps to shed light on how, and the extent to which, learning, know-how, and management quality can mitigate the cognitive decision-making biases affecting firms in environments of

high uncertainty. We further complement Hussinger and Pacher (2015, 2019) by obtaining ambiguity information directly from financial statements and firm-specific market data (as well as from 10-Ks), capturing investors and managers' own ambiguity perceptions about the firm's economic prospects. We additionally confirm the evidence by Colombo and Grilli (2005, 2010) and others (on linkages between human capital and firm growth) that management quality differentials across firms are important in explaining differences in GO value. We do so using two-stage least squares (2SLS) panel regressions which account for endogeneity and omitted variables bias. Our study also generates avenues for further research on how more fine-grained information about firms' management teams can potentially be relevant in the context of corporate real options.

Consistent with Cao et al. (2008) and Trigeorgis and Lambertides (2014), we use market-implied growth options (MGO) and the ratio of firm capital expenditures to fixed assets (CAPFIX) as two of our main growth options proxies. For additional validation, we test the composite (principal component-based) indicator of Lyle (2019) as our third growth options proxy (PCGO hereafter). We rely on firm-specific ambiguity (AMB) and managerial ability (MA) as our key explanatory variables. In terms of ambiguity information we use two proxies from the corporate finance literature, namely the Choquet-based ambiguity score (AMB^{CU}) with non-additive probabilities of Driouchi et al. (2020) and the textual ambiguity score (AMB^{TEXT}) from 10-K forms by Friberg and Seiler (2017). The former (our main AMB proxy) captures investors' ambiguity perceptions about the firm's economic prospects, while the latter is more reflective of managerial ambiguity about such prospects. For our MA variables, we rely on the DEA-based indicator of Demerjian et al. (2012, 2013) and in further analysis employ the strategy (STRAT) and innovation (INNOV) scores by Bentley et al. (2013) and Kogan et al. (2017). We find that after controlling for standard factors, growth options value is negatively associated with ambiguity but increases with managerial ability, and the negative

effect of ambiguity on GO is mitigated by the interaction between AMB and MA. Our results are robust to endogeneity concerns and alternative specifications of growth options, ambiguity, and management quality.[3] Collectively, the findings from our study add to extant research on real options flexibility by offering further evidence on how firm heterogeneity affects the value of corporate growth options. We provide new evidence that both ambiguity and managerial ability are determinants of real growth options, and more importantly the interplay between firm-specific ambiguity and ability also contributes to growth options value. Specifically, while ambiguity is detrimental to growth options, more able managers can enhance firm GO value and mitigate the negative effect of ambiguity biases on corporate growth options. Our findings are in line with decision theory predictions on the adverse effect of ambiguity on option value and the role of firm-specific characteristics in real options management (identification, exploration, and exploitation). They are also consistent with theories of learning under ambiguity (Delaney, 2020; Baillon et al., 2018a), competence-based research (Colombo and Grilli, 2005; Grilli and Murtinu, 2018) on the role of human capital in explaining firm growth and expansion, and the recent findings by Hussinger and Pacher (2019) on how human capital may also partly mitigate the negative association between (dispersion-based) information ambiguity and firm value. Taking a real options-based view, we add to the extant evidence by highlighting how management quality (i.e., ability MA, discretion STRAT, and innovation INNOV) moderates the negative relation between firm-specific ambiguity and real growth options in all US-listed firms.

Our paper makes two contributions to the relevant literature. First, we extend behavioural real options research concerned with heterogeneity to the case of firm-specific ambiguity and managerial ability. Second, we contribute to management research on ambiguity and its decision-making implications by validating the adverse role of idiosyncratic ambiguity in performance outcomes (see e.g., Mosakowski, 1997; King and Zeithaml, 2001), and

unveiling the moderating effect of ability and know-how on the ambiguity-growth options relation. We also use and propose measures of ambiguity that are extracted directly from financial statements and firm-specific market data in our analysis of the determinants of growth options. These measures reflect managers and investors' ambiguity perceptions about the firm's economic prospects (i.e., outlook and value). The remainder of the paper proceeds as follows. Section 2 summarises our theory and hypotheses. Section 3 describes the data and research methods. Section 4 presents findings and robustness tests. Section 5 provides conclusions and identifies avenues for further research.

Theory and hypotheses

The distinction between risk and uncertainty as theorized by Knight (1921) and Keynes (1921) has led to a plethora of empirical studies on the role of ambiguity in economic choice since Ellsberg (1961) (Abdellaoui et al., 2011; Li et al., 2018; Abdellaoui et al., 2020). Viewed as uncertainty beyond risk or the lack of information clarity about future prospects, ambiguity has been found to explain cognition and individual behaviour in a number of experimental and natural settings (Baillon et al., 2018b; Baillon and L'Haridon, 2016). Empirical research in behavioural economics and management have related ambiguity matters to market participation (Antoniou et al., 2015), resource allocation and financing (Agliardi et al., 2016), cash holdings and capital structure (Friberg and Seiler, 2017; Ertugrul et al., 2017), initial public offerings (Park and Patel, 2015; Arnold et al., 2010), banking performance (Boyarchenko, 2012; Driouchi et al., 2020), leadership effectiveness (Cicero et al., 2010), mergers and acquisitions (Cording et al., 2008), and innovation activity (Carson et al., 2006; Hussinger and Pacher, 2019). Findings suggest that ambiguity has a detrimental impact on economic outcomes, increases exposures to risk, and exacerbates decision-making biases (e.g., pessimism, underinvestment, and inertia) (Trautmann and Schmidt, 2012; Sautua, 2017;

d'Albis et al., 2020). While the above evidence has successfully highlighted the adverse or moderating effects of ambiguity and ambiguity averseness on decision-making, willingness to commit or invest, and performance, we are not aware of any existing paper that has examined empirically the role of firm-specific ambiguity in growth options theory. Here, we study how ambiguity about firm value and future prospects contributes to corporate growth options (a proxy for firm strategic flexibility; see e.g., Herhausen et al., 2020) and analyse the moderating effect of managerial ability on the ambiguity-GO value association. We link firm heterogeneity to non-Bayesian uncertainty and ability in the context of corporate growth options. We view GO as real call options firms hold on their future strategic assets.

Ambiguity and growth options

When firms are characterised by ambiguity and incomplete information, managers and shareholders do not know the exact distribution of future economic outcomes; they have several possible inferences about such outcomes and their likelihoods, and thus make decisions that are inconsistent with Bayesian theory (Baker et al., 2016; Foss and Weber, 2016). This affects strategic investment choices and resource allocation decisions, and also alters processes of opportunities identifications and exploitation within the firm (Coff and Laverty, 2007). Managers will have a higher propensity to make suboptimal allocation decisions under uncertainty as a result of their cognition, non-Bayesian behaviour and other ambiguity-related biases (Posen et al., 2018; Dicks and Fulghieri, 2020).[4] Moreover, and partly due to a lack of understanding of the links between resources and outcomes within the organisation (Coff, 1999; Coff and Laverty, 2007; Hales, 1999), heuristic and subjective decision-making will prevail over objective or more optimal/rational economic choices under such conditions (see also Hirshleifer et al., 2018). In terms of real options implications, subjective behaviour and ambiguity can lead to a poorer identification of growth opportunities, erroneous execution of loss-making shadow growth options, ill-timed option exercise (due to ambiguity aversion or

seeking), and costly or suboptimal integration and maintenance of real options resources (Ioulianou et al., 2017; Leiblein et al., 2017). This in turn results in firms mismanaging their commitment-flexibility trade-off and adopting less flexible strategies under uncertainty (Dalziel, 2009; Trojanowska and Kort, 2010; Posen et al., 2018). Differentiating between prospective and contemporaneous uncertainty as well as accounting for behavioural biases in options logic, Posen et al. (2018) show that - consistent with ambiguity theory - option value decreases with non-prospective uncertainty. Execution errors (under- and over-execution: failed exercise of in-the-money versus inability to terminate out-of-the-money options) are also more common if cognitive biases affect decision-making, and the size of the commitment-flexibility trade-off is wider with increasing uncertainty. From a market perspective, investors and shareholders are also more cautious and react aversely towards firms with highly uncertain growth prospects. They may require higher returns (i.e., ambiguity premium) from high ambiguity stocks because of the lack of information clarity about them (see e.g., Epstein and Schneider, 2008) and the higher propensity for default and corporate failure associated with them (Griffin and Lemmon, 2002). Hussinger and Pacher (2015) document that when it comes to firm innovative assets and R&D, information ambiguity has a negative effect on market value. Overall, ambiguity from managers and investors should be inversely related to corporate growth options. This leads to the first hypothesis about firm growth options:

H1: Ambiguity is negatively associated with growth options value.

Managerial ability and growth options

While ambiguity can be detrimental to growth options value, the role of managers in identifying and exploiting strategic opportunities is also important for future value creation and the realisation of a firm's growth potential. Management quality differentials and know-how have been shown to explain differences in growth and survival rates among NTBFs and start-ups (Cooper et al., 1994; Siegel et al., 1993; Colombo and Grilli, 2005). Managerial ability refers

to the knowledge, skills, and experience that a firm and its managers have (Kor, 2003; Holbrook et al., 2009). Through managerial skills and know-how, firms should have distinctive capabilities to capitalise on their strategic assets, manage tangible and intangible resources in a unique way, and perform tasks at a higher ability than other firms (Grant, 1996; Colombo and Grilli, 2005). Managerial ability should, thus, enable firms to both explore and manage their real options better than counterparts with lower ability (Trigeorgis, 1996; Buckland, 2009). Because of superior skillsets, better judgment and more effective monitoring, higher ability managers should be better able to visualise and identify shadow growth options opportunities, more optimally exercise/execute such opportunities, and maximise option payoffs more effectively over time relative to lower ability counterparts (see Ioulianou et al., 2017; Ioulianou et al., 2020; Leiblein et al., 2017). Indeed, recent evidence suggests that more able managers are associated with better firm performance (Finkelstein et al., 2009; Demerjian et al., 2012). This is more so when managerial discretion and monitoring quality are high within the organisation (Cheung et al., 2017). Other studies also document that skills and ability can lead to better economic outcomes such as higher NAV returns in close-end funds (Berk and Stanton, 2007), superior IPO/SEO performance (Chemmanur et al. 2009), more rapid firm growth (Colombo and Grilli, 2005; Colombo and Grilli, 2010), more accurate management earnings forecasts (Baik et al., 2011), lower tax avoidance (Koester et al., 2016), lower audit fees (Krishnan and Wang, 2015), better credit ratings (Bonsall et al., 2017), and hence higher financial flexibility at the firm and project levels. Moreover, and owing to their superior understanding of the firm's business and operating environments, higher ability managers can better align decision-making with corporate strategy, and effectively design and execute their real growth options (Andreou et al., 2017; Leiblein et al., 2017). Managerial ability can furthermore help firms achieve lower costs of capital and more positive dynamic options-NPVs, increasing strategic flexibility and inspiring further credibility among creditors and other

stakeholders (Chemmanur and Paeglis, 2005). Finally, higher ability decision-makers are more likely to achieve cost efficiency when managing strategic resources and infrastructure (Dziwornu, 2017). This leads to the second hypothesis:

H2: Managerial ability is positively associated with growth options value.

Ambiguity and growth options: The role of managerial ability

Contrary to real options theory on the positive effect of Bayesian uncertainty (i.e., volatility) on option value, the association formulated in H1 predicts that uncertainty beyond risk (i.e., ambiguity) adversely affects real growth options value. However, the strength of this relationship should also depend on firm heterogeneity and management ability to both identify, maintain, and exploit real options opportunities under uncertainty (see e.g., Driouchi and Bennett, 2011; Ioulianou et al., 2017; Leiblein et al., 2017). As discussed and suggested above, higher ability managers are more knowledgeable about the business and industry, form better judgments and estimates about product demand, earnings and other economic dynamics (Demerjian et al., 2013), and are, on average, more aggressive (Bentley et al., 2013). They also have a better appreciation of the firm's risk-reward trade-off, can predict market/industry trends better than lower ability counterparts, and are generally more efficient decision-makers (Demerjian et al. 2012). Higher ability managers should, therefore, be able to handle ambiguity and incomplete information better than peers with lower ability. Accordingly, firms with higher managerial ability should be less prone to the ambiguity-specific biases and errors affecting the identification, exploration, and exploitation of growth options opportunities when faced with uncertainty. In terms of exercise policies under ambiguity, the gap between optimal and subjective exercise of growth options should be narrower with higher ability. Similarly, the adverse effect of biases on option identification and execution should also be less pronounced with higher ability. Due to more aggressive/dynamic policies, higher ability managers are also likely to over-execute options in favour of projects than conversely because of under-precision

and confirmation biases (Posen et al., 2018). In their option-based behavioural theory of the firm, Posen et al. (2018) illustrate how the costs of over-execution when adopting more aggressive policies are lower than under-execution costs stemming from over-precision and low aggressiveness. This implies that the adverse effects of ambiguity on real option value and the commitment-flexibility trade-off can be lessened with higher ability. The same holds when accounting for dynamic learning under uncertainty (Epstein and Schneider, 2007; Delaney, 2020). For example, Hussinger and Pacher (2019) show that human capital (i.e., patent value as often proxied by patents citations) partly mitigates the negative effect of information ambiguity on market value. In sum, managerial ability should provide firms with the skills/tools to adjust to and learn from uncertainty, and deal with ambiguity less subjectively - and at times more proactively - than counterparts with lower ability. This leads to the third hypothesis:

> *H3*: The association between ambiguity and growth options value is less negative with higher managerial ability.

Data and methods

Data

Our sample consists of all U.S.-listed firms over the period 1983–2013.[5] We cover all firms since 1983 when NASDAQ data is readily available and market liquidity is high. Firms operating in financial and utility industries (with 4-digit SIC codes between 4900 and 4999, and between 6000 and 6999) are excluded. Fundamental data are collected from Compustat and market data are obtained from CRSP. We infer ambiguity information from financial statements and using market data following the ambiguity-based contingent-claims approach by Driouchi et al. (2020). For our other explanatory (and robustness) variables, we rely on datasets made available by researchers, including the ability score of Demerjian et al. (2012),

the textual managerial ambiguity measure from Friberg and Seiler (2017), and the innovation index by Kogan et al. (2017). Heterogeneity in data availability across explanatory variables explains the differences in the number of observations used to perform our analyses.

Dependent variable

We use market-implied growth options (MGO), the ratio of capital expenditures to fixed assets (CAPFIX) (see also Lambertides and Trigeorgis, 2014), and Lyle's (2019) composite growth options indicator (PCGO) of a firm being "option-like" as our main GO proxies. This also helps to differentiate between exercised versus yet to be exercised corporate growth options. In line with Kester (1984) and Cao et al. (2008), MGO captures the value of future growth opportunities as a percentage of total firm value:

$$MGO_{i,t} = PVGO_{i,t}/V_{i,t} = (V_{i,t} - \frac{CF_{i,t}}{WACC_{i,t}})/V_{i,t} \quad (1)$$

where $V_{i,t}$ is firm i's market value at time t; $PVGO_{i,t}$ is the present value of growth opportunities; $CF_{i,t}$ is the operating cash flow and $WACC_{i,t}$ is the weighted average cost of capital. Following Trigeorgis and Lambertides (2014), the market model is assumed setting beta to 1 for each company to compute the cost of equity used in the WACC. The market premium is calculated as the average premium of the S&P 500 index monthly return over the US government 1-month Treasury bill over the recent 60 months. The cost of debt is set to 4 percent lower than the cost of equity (see Trigeorgis and Lambertides, 2014). The effective tax rate is calculated as total income taxes divided by pre-tax income.

Similar to Cao et al. (2008), CAPFIX is measured as year-end capital expenditures deflated by year-end Property, Plant and Equipment (PPE). CAPFIX has been used as a GO proxy in prior research, as it reflects past commitment to capacity expansion and indicates near-term exercise of growth options (Anderson and Garcia-Feijoo, 2006; de Andres et al., 2017).[6]

Following Lyle (2019), we generate a PCGO proxy for being option-like based on the number of growth options the firm has. Specifically, we use each of the market value-to-book value of assets, Tobin's q, the debt-to-equity ratio, the ratio of capital expenditures-to-fixed assets, and the market-to-book ratio as growth options indicators (see Cao et al., 2008). We then use the first principal component (PCGO) of these five indicators as our third proxy for growth options value.

Independent variables

Ambiguity. Our first and main ambiguity measure is the ambiguity score (AMB^{CU}) with non-additive probabilities by Driouchi et al. (2020). Extending the Black-Scholes-Merton fundamental equation to multiple-priors and Choquet ambiguity, Driouchi et al. (2020) provide formulae to value contingent-claims under non-Bayesian uncertainty, and show how ambiguity information affects the dynamics of option prices and systemic risk in the US market. We apply the more general Choquet framework to the context of firm liabilities, viewing capital structure as a set of contingent-claims equity-holders/debt-holders have on the firm's assets (exploiting the analogy between call options and firm's equity), and elicit ambiguity information using financial statements and firm-specific market data. Analogous to Merton (1977), we view equity as an option that shareholders hold on the firm's assets but adjust value drivers for ambiguity by accounting for model uncertainty in the growth rate (drift) and variance (diffusion) of firm value returns (see e.g., So and Driouchi (2018) for how ambiguity affects the Brownian motion driving underlying asset and option values):

$$E = Ve^{-\delta' T}N(d'_1) - Be^{-r' T}N(d'_2) \quad (\forall\, c \in\ ]0,1[) \tag{2}$$

where:

$$d'_1 = \frac{ln(V/B)+(r' - \delta' + \frac{1}{2}(s\sigma)^2)T}{s\sigma\sqrt{T}},\ d'_2 = d'_1 - s\sigma\sqrt{T}$$

$$r' = r + m\frac{[r-(\mu+m\sigma)]}{s^2\sigma}, \delta' = \delta - \frac{(m+s^2\sigma-s\sigma)[(\mu+m\sigma)-r]}{s^2\sigma}$$

with:

$$m = 2c - 1 \text{ and } s = \sqrt{4c(1-c)}$$

E is the market value of equity, B is the face value of debt, V is firm value, σ is the standard deviation of firm value changes, and T is the time-to-debt maturity. Eq. (2) differs from the ambiguity-free Merton (1977) model in that ambiguity-adjusted factors δ' and r' (instead of risk-free rate r and objective dividend yield δ when $m = 0$ and $s = 1$), and subjective exercise probabilities *N(d')* are used in the valuation. *m* and *s* are misspecification parameters due to ambiguity score *c* and non-Bayesian behaviour. By backward solving the ambiguity score c (AMB^{CU} hereafter) from eq. (2), we infer the level of ambiguity implied by market-observed equity values (hence also capturing investors' ambiguity about the firm's prospects):

$$AMB^{CU} = E^{-1}(V, B, T, r, \delta, \mu, \sigma) \quad (3)$$

We also employ the text-based measure of ambiguity (AMB^{TEXT}) from US 10-K forms following Friberg and Seiler (2017) as an alternative proxy. The uncertainty words by Loughran and McDonald (2011) are sub-classified into specific risk, ambiguity, and uncertainty terms by Friberg and Seiler (2017). The occurrence of ambiguity words in firms' 10-Ks defines their ambiguity index. This index also reflects managerial pessimism and ambiguity aversion. To account for potential endogeneity and unobserved dynamics that may affect both GO and AMB in the empirical analysis,[7] we instrument our ambiguity proxies using skewness, firm-specific volatility, leverage (default risk proxied by Altman's Z-score), and the interaction of skewness and leverage in the 2SLS MGO (CAPFIX and PCGO) regressions. While an extensive study of the determinants of ambiguity is out of the scope of this paper and is worth pursuing in future research (given the need for additional fine-grained information about firms' management

teams and other executive characteristics), we use intuitive instruments to predict AMB based on some of the economic dynamics in (2)-(3) and other non-Bayesian uncertainty theory insights.

Managerial ability. Our main management quality indicator is the managerial ability score (MA) by Demerjian et al. (2012), which has been used in empirical research recently (Demerjian et al. 2013; Baik et al., 2020). This indicator relies on data envelopment analysis (DEA) to estimate firm efficiency within industries by optimising sales over firm-specific inputs, including net property, plant, and equipment; net operating leases; net R&D; purchased goodwill; other intangible assets; cost of inventory; and selling, general, and administrative expenses. Firm efficiency is regressed, using a Tobit model, on size, market share, free cash flow, age, business segment concentration, foreign currency adjustments, and year indicators within the relevant Fama and French (1997) 48 industry classifications. Residuals from the Tobit model reflect the firm's general level of managerial ability.

We also use the business strategy index of Bentley et al. (2013) and the innovation score by Kogan et al. (2017) as alternative indicators for robustness. The strategy measure (STRAT) in Bentley et al. (2013), which also relates to managerial discretion, is constructed by six factors following Miles and Snow (1978) and comprises R&D-to-sales ratio, number of employees-to-sales ratio, change in total revenue, marketing expenditures-to-sales ratio, fluctuations in employees numbers, as well as capital intensity. Innovation score INNOV measures innovation activity as in Kogan et al. (2017). It is given by the total monetary value of innovation produced by a given firm deflated by its total assets. Following Kogan et al. (2017), innovation value is calculated by summing up all values of patents granted to the firm. It also serves as an indirect proxy for management quality and human capital potential.

Control variables

In line with Trigeorgis and Lambertides (2014) and their growth options theory, we use several control variables for GO (see also Trigeorgis, 1996; Grullon et al. 2012). Skewness of the returns (SKEW) is estimated from the monthly stock returns over the previous three years; idiosyncratic risk (IVOL) is obtained as the residuals from the regression of firm equity returns on the S&P500 index returns using the market model; organisation flexibility is measured by selling, general, and administrative expenses divided by sales (SGA); financial leverage (LEV) is estimated as book value of total liabilities divided by firm market value; research and development intensity (R&D) is obtained as the average R&D percentage sales (R&D-to-sales) over the previous three years; cash flow coverage (CFC) is calculated as the ratio of cash and cash equivalents firms generate and maintain to the total borrowing costs; cumulative sales growth (SG) is calculated as the percentage change in revenues for the past three years; market power is measured as the square root of the Herfindahl-Hirschman Index (HHI) if Tobin's q is above the industry average,[8] otherwise as 0. For consistency with prior research, we treat missing variables in the same manner as Trigeorgis and Lambertides (2014).

Methods

We use 2SLS panel regressions to study the effects of ambiguity and managerial ability on GO. Firm and year fixed effects are included to capture time variation accounting for unobserved heterogeneity at the firm level and capturing effects of economy-wide variations or other unobserved factors. For robustness, we also include two-digit SIC industry fixed effects in the model and find that such dummies are automatically dropped as the firm fixed effect already captures any time-invariant effect. The multivariate regression model is specified as follows:

$$GO = f\,(AMB;\ MA;\ AMB * MA;\ SKEW;\ IVOL;\ SGA;\ LEV;\ R\&D;\ CFC;\ SG;\ HHI) \quad (4)$$

where all variables are as defined before. As mentioned, ambiguity information is instrumented using SKEW, LEV, IVOL and LEV*SKEW in the MGO (i.e., yet to be exercised GO) regressions, and SKEW, default risk DR (proxied by Z-score), IVOL and LEV*SKEW in the CAPFIX and PCGO multivariate specifications. First-stage results are described in footnote 10. Following Trigeorgis and Lambertides (2014) and their market-implied growth options specification, we also include an interaction term between skewness and leverage as a control variable. Due to potential serial correlation and the construction of the Lyle's (2019) GO proxy, LEV, IVOL and HHI are not used as control variables in the PCGO regressions. In line with Lyle (2019) and Trigeorgis and Lambertides (2014), we perform our analysis winsorizing the top and bottom 1% of observations for continuous variables. Variable definitions and measurements are presented in Appendix 1.

Findings and discussion

Descriptive statistics and correlations

Table 1 Panel A provides descriptive statistics for our dataset. The statistics show that the mean and median MGOs are around 0.751 and 0.757. We report mean (median) CAPFIX of 0.239 (0.199), consistent with Cao et al. (2008). PCGO shows mean and median values of -0.038 and -0.361. AMB^{CU} has a mean (median) around 0.513 (0.504), while AMB^{TEXT} presents a raw mean (median) of 82.063 (63). For comparability, AMB^{TEXT} is rescaled for the remainder of the analysis. The mean (median) MA score of -0.007 (-0.019) is consistent with Demerjian et al. (2012), while the distributions of STRAT and INNOV are in line with Bentley et al. (2013) and Kogan et al. (2017). Table 1 Panel B presents the correlation matrix for the variables. Variance inflation factors (VIFs) are below conservative thresholds (Kennedy, 1992).

Panel regression findings

The two-stage regressions findings analysing growth options value as measured by MGO, CAPFIX and PCGO are reported in Table 2 Panels A, B and C. In each panel, Model (1) reports the effect of control variables on growth options without our main explanatory factors. Models (2)-(3) present the incremental effect of ambiguity (proxied by AMB^{CU} and AMB^{TEXT}) beyond the controls. Models (4)-(6) report results with managerial ability (MA) first alone (including standard GO determinants), and respectively controlling for AMB^{CU} and AMB^{TEXT}. Models (7)-(8) report the effects of interactions between ambiguity and ability along with ambiguity beyond the GO factors.[9] We also investigate the effects of interaction terms (AMB^{CU} * High MA) and (AMB^{TEXT} * High MA) on GO value jointly with ambiguity and ability in full Models (9)-(10). To mitigate potential multicollinearity concerns in Models (9)-(10) and for consistency, we use a dummy variable for ability in regressions specifications with interactions terms. t-statistics are presented in parentheses below each standardised coefficient and are two-tailed, based on robust standard errors adjusted for heteroscedasticity. Adjusted R^2s and the number of observations are reported at the bottom of each column. Differences in observations across models (in Tables 2-3) are due to data availability and the choice of instruments in the 2SLS MGO, CAPFIX, and PCGO regressions specifications. In contrast to CAPFIX and PCGO, MGO captures yet to be exercised growth options information primarily.

The significance of the control variables in Model 1 (Table 2: Panels A-C) is generally consistent with prior research (Trigeorgis and Lambertides, 2014; Del Viva et al., 2017). Cumulative sales growth (SG), organisation flexibility (SGA), market power (HHI) show positive and significant effects on growth options (MGO and CAPFIX), while financial leverage (LEV) and skewness (SKEW) display negative associations. This suggests that growth options depend on firms' systematic efforts to identify future growth opportunities, improve their flexible infrastructure and market power to support innovation, as well as their

financial and managerial flexibility to meet obligations and adjust to change. PCGO is also showing consistent and intuitive dynamics vis-à-vis the control variables used. Differences in signs across a few variables can be explained by the fact that PCGO likely contains information about both exercised and yet to be exercised growth options opportunities (relative to MGO and CAPFIX).[10]

Ambiguity and growth options

Table 2 (Panels A-C) presents results on linkages among growth options (GO), ambiguity (AMB), and managerial ability (MA). Models (2)-(10) validate the significant negative association between ambiguity and growth options, as predicted in Hypothesis 1, across all multivariate specifications ($p < .05$). Models (2)-(3) in Panel A highlight the negative significant effects of AMB^{CU} and AMB^{TEXT} on MGO after controlling for standard determinants. An increase in AMB^{CU} (AMB^{TEXT}) by one standard deviation is associated with a decrease in MGO by 0.268 (0.257). The negative effects of AMB^{CU} and AMB^{TEXT} on MGO are maintained after including MA information in Models (5) and (6), and after adding the interaction between ambiguity and managerial ability to the regressions (see Models (7)-(10)). Similar patterns are observed in Panel B when CAPFIX (exercised GO) is used as an alternative dependent. Corresponding Models (2)-(3) indicate that higher firm-specific ambiguity is associated with lower growth options value ($p < .01$). A one standard deviation increase in AMB^{CU} (AMB^{TEXT}) is followed by a decrease in CAPFIX by 0.114 (0.087). This impact is economically significant in comparison to the mean CAPFIX of 0.239. The direct negative effect of ambiguity on CAPFIX is maintained after including ability and the interactions between AMB and high MA in the regressions. Similar dynamics are obtained in Panel C when Lyle's (2019) PCGO is used as a growth options proxy. Increases in AMB^{CU} (AMB^{TEXT}) are associated with clear decreases in the composite PCGO score in Models (2)-(3). These economically significant effects are consistently negative across Models (4)-(10) ($p < .01$).

Hypothesis 1 is, therefore, also validated when CAPFIX and PCGO are employed as real growth options proxies.

These findings are consistent with behavioural decision theory on the role of ambiguity in real options value (Nishimura and Ozaki, 2007; Trojanowska and Kort, 2010). When faced with ambiguity, managers and investors are not sure about the likelihood of the states of the world. Consequently, investment and allocation decisions are subject to behavioural biases and partial ignorance, resulting in suboptimal real options identification, ill-timed option exercise and missed strategic growth opportunities. Overall, our analysis empirically validates that ambiguity is negatively related to GO value and corporate growth options.

Managerial ability and growth options

Hypothesis 2 predicts a positive direct effect of ability on growth options. Panels A-C in Table 2 (Models 4-6) provide consistent support for this hypothesis: managerial ability is positively associated with GO value ($p < .05$). Model (4) in Panel A shows a significant positive effect (0.019 standardised coefficient) of MA on MGO. The direct positive effect of MA on MGO is maintained in Models (5)-(6) after accounting for ambiguity information (and other controls), with significantly positive MA coefficients of 0.025 and 0.023, respectively. As mentioned, we also include an interaction term between ambiguity and high ability in full Models (9) and (10) and the positive effect of MA on MGO is generally maintained. Table 2 Panel B reports similar CAPFIX findings. The positive association between MA and CAPFIX is confirmed after controlling for other GO determinants in Models (4)-(6) ($p < .01$), with standardised coefficients between 0.088 and 0.126. These effects hold after further accounting for ambiguity (AMB^{CU} and AMB^{TEXT}), and including the interaction between ambiguity and managerial ability in the regressions ($p < .05$). Panel C shows consistent findings for the PCGO proxy across all relevant models ($p < .01$). This provides further support for Hypothesis 2 and validates the direct positive effect of managerial ability on growth options value.

Ambiguity and growth options: The role of managerial ability

Table 2 also reports the extent to which the negative effect of ambiguity on GO value can be mitigated or alleviated by managerial ability. As proposed in Hypothesis 3, a one standard deviation increase in the interaction between ambiguity and ability should bring a less negative effect on growth options value (compared with a one standard deviation increase in ambiguity alone). This is confirmed in Models 7-10. In Model (7) Panel A, the coefficient of the interaction term (AMB^{CU} * high MA) is significant positive after controlling for AMB^{CU} and other effects ($p < .01$), suggesting that managerial ability moderates the negative effect of AMB^{CU} on MGO. The standardised coefficient for the interaction term (AMB^{TEXT} * high MA) in Panel A is also significantly positive (0.059) in Model (8) ($p < .01$). This effect is less pronounced in absolute terms than the direct negative effect of AMB^{TEXT}, as MGO's value decreases by 0.248 after an increase of one standard deviation in AMB^{TEXT}. Full Models (9)-(10) with interactions between ambiguity and the managerial ability dummy variable (AMB * High MA) display comparable patterns. Model (9) in Panel A shows a significant positive coefficient for the interaction term (AMB^{CU} * High MA) ($p < .01$), confirming that the negative effect of ambiguity on MGO is lowered with higher ability. Model (10) displays a positive insignificant coefficient for interaction term (AMB^{TEXT} * High MA), which still validates that the negative effect of ambiguity on MGO can be mitigated by higher MA. The above provides support for Hypothesis 3.

The moderating effect of managerial ability on the AMB-GO relation is robust in Panel B when CAPFIX is used as a growth options proxy. The coefficients for the interaction terms are significant and positive across all relevant models (Models (7)-(10)) ($p < .01$). Standardised coefficients for Models (7) and (9) are between 0.139 and 0.151, while Models (8) and (10) display coefficients of 0.099 and 0.070 respectively. These effects are economically significant and confirm that higher managerial ability can help alleviate the negative effect of firm-specific

ambiguity on corporate growth options. The same holds for Panel C when PCGO is used as an alternative proxy for growth options. Standardised coefficients for all the interaction terms in Models (7)-(10) are positive and significant ($p < .01$). Overall, Table 2 (Panels A-C: Models 7-10) provides strong and consistent support for Hypothesis 3 on the mitigating role of managerial ability in the negative AMB-GO linkage.

Table 1. Summary statistics

Panel A: Descriptive statistics

	MGO	CAPFIX	PCGO	AMB^{CU}	AMB^{TEXT}	MA	STRAT	INNOV	SKEW	IVOL	SGA	LEV	R&D	CFC	SG	HHI
Mean	0.751	0.239	-0.038	0.513	4.021	-0.007	16.714	0.103	0.344	0.035	0.304	0.402	0.039	10.163	0.574	0.044
S.D.	0.508	0.158	1.072	0.047	0.986	0.106	4.345	0.181	1.099	0.024	0.321	0.225	0.096	55.542	1.589	0.110
Min	-0.934	0.021	-1.133	0.338	1.099	-0.303	6.000	0.000	-3.491	0.008	0.026	0.031	0.000	-139.994	-0.625	0.000
Median	0.757	0.199	-0.361	0.504	4.159	-0.019	16.000	0.034	0.303	0.028	0.227	0.377	0.000	0.854	0.202	0.000
Max	2.491	0.792	5.435	0.713	5.684	0.681	30.000	1.103	4.111	0.138	2.366	0.920	0.681	402.437	12.281	0.522

Panel B: Correlation matrix

	MGO	CAPFIX	PCGO	AMB^{CU}	AMB^{TEXT}	MA	STRAT	INNOV	SKEW	IVOL	SGA	LEV	R&D	CFC	SG	HHI
MGO	1.000															
CAPFIX	0.183	1.000														
PCGO	0.188	0.397	1.000													
AMB^{CU}	-0.051	-0.060	-0.071	1.000												
AMB^{TEXT}	-0.014	0.076	0.101	0.109	1.000											
MA	0.007	0.253	0.206	-0.038	-0.037	1.000										
STRAT	0.223	0.230	0.215	-0.020	0.108	0.066	1.000									
INNOV	0.147	0.195	0.427	-0.073	0.112	0.114	0.126	1.000								
SKEW	0.063	0.002	0.067	0.027	-0.002	-0.017	0.051	0.007	1.000							
IVOL	0.258	0.119	0.009	0.075	-0.077	-0.048	0.203	0.121	0.203	1.000						
SGA	0.381	0.255	0.368	-0.029	0.126	0.099	0.404	0.264	0.079	0.271	1.000					
LEV	-0.078	-0.309	-0.586	0.163	-0.054	-0.191	-0.163	-0.323	-0.018	0.175	-0.258	1.000				
R&D	0.030	0.025	0.044	-0.002	0.010	0.013	0.028	0.075	0.018	0.025	0.110	-0.025	1.000			
CFC	-0.009	0.100	0.079	-0.026	0.062	0.065	0.022	0.094	-0.004	-0.024	0.066	-0.169	0.005	1.000		
SG	0.171	0.267	0.216	-0.028	0.056	0.035	0.278	0.110	0.022	0.116	0.191	-0.127	0.002	0.006	1.000	
HHI	0.076	0.097	0.378	-0.056	-0.066	0.064	0.105	0.077	0.012	-0.042	0.041	-0.287	-0.001	0.006	0.081	1.000

Notes: Panel A reports descriptive statistics for variables used in the main regression models. Panel B provides the correlation matrix. MGO = market-implied growth options; CAPFIX = capital expenditures-to-fixed assets; PCGO = first principal component of Tobin's Q, market value-to-book value of assets, the debt-to-equity ratio, the ratio of capital expenditures-to-fixed assets, and the market-to-book ratio; AMB^{CU} = Choquet ambiguity score; AMB^{TEXT} = textual ambiguity score; MA = managerial ability score; STRAT = strategy index; INNOV = innovation score; SKEW = firm return skewness; IVOL = firm-specific volatility; SGA = selling, general, and administrative ratio; LEV = financial leverage; R&D = research and development intensity; CFC = cash flow coverage; SG = cumulative sales growth; HHI = market power.

Table 2. Panel regressions explaining growth options

Panel A: Growth options proxied by MGO										
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AMB^{CU}		-0.528***			-0.518***		-0.510***		-0.513***	
		(-13.337)			(-13.283)		(-13.476)		(-13.722)	
AMB^{TEXT}			-0.506**			-0.477**		-0.488**		-0.584***
			(-2.510)			(-2.396)		(-2.427)		(-3.024)
MA				0.019***	0.025***	0.023**			0.020**	0.020*
				(3.320)	(3.331)	(2.215)			(2.550)	(1.741)
Interaction (AMB^{CU} * High MA)							0.073***		0.020***	
							(11.002)		(3.184)	
Interaction (AMB^{TEXT} * High MA)								0.059***		0.009
								(4.575)		(0.704)
SKEW	-0.020***	-0.014	-0.009	-0.018**	-0.013	-0.007	-0.013	-0.007	-0.011	-0.008
	(-2.610)	(-1.458)	(-0.745)	(-2.390)	(-1.328)	(-0.615)	(-1.372)	(-0.604)	(-1.138)	(-0.671)
IVOL	0.048***	0.062***	0.054***	0.046***	0.063***	0.053***	0.065***	0.053***	0.063***	0.057***
	(8.276)	(7.937)	(4.172)	(7.919)	(8.047)	(4.125)	(8.341)	(4.107)	(8.119)	(4.394)
SGA	0.221***	0.260***	0.285***	0.252***	0.289***	0.301***	0.297***	0.308***	0.289***	0.300***
	(22.726)	(17.794)	(12.063)	(24.084)	(18.493)	(12.547)	(19.161)	(12.496)	(18.251)	(11.942)
LEV	-0.001	0.036***	0.021	-0.001	0.036***	0.019	0.043***	0.025*	0.037***	0.022*
	(-0.141)	(3.988)	(1.599)	(-0.120)	(4.049)	(1.486)	(4.770)	(1.789)	(4.073)	(1.659)
R&D	0.094***	0.132***	0.120***	0.091***	0.128***	0.131***	0.129***	0.130***	0.133***	0.138***
	(8.749)	(8.315)	(5.049)	(8.207)	(7.849)	(5.505)	(7.966)	(5.468)	(8.106)	(5.742)
CFC	-0.015***	-0.021***	-0.006	-0.016***	-0.022***	-0.006	-0.022***	-0.006	-0.021***	-0.006
	(-3.783)	(-3.848)	(-0.789)	(-3.895)	(-3.985)	(-0.878)	(-4.010)	(-0.929)	(-3.845)	(-0.849)
SG	0.018***	0.027***	0.054***	0.015***	0.025***	0.050***	0.023***	0.046***	0.024***	0.053***
	(3.997)	(3.438)	(3.275)	(3.112)	(3.164)	(2.968)	(2.912)	(2.869)	(3.076)	(3.176)
HHI	0.035***	0.042***	0.026***	0.035***	0.042***	0.026***	0.040***	0.026***	0.041***	0.026***
	(7.234)	(6.587)	(2.875)	(7.231)	(6.606)	(2.826)	(6.477)	(2.862)	(6.577)	(2.770)
SKEW* LEV	0.017**	0.011	0.003	0.016**	0.009	0.001	0.009	0.001	0.008	0.002
	(2.248)	(1.067)	(0.259)	(2.067)	(0.924)	(0.121)	(0.939)	(0.096)	(0.771)	(0.188)
Adj. R-squared	0.418	0.403	0.425	0.418	0.403	0.426	0.403	0.427	0.404	0.427
Observations	50,641	39,077	18,505	50,276	38,882	18,415	38,789	18,415	38,789	18,415
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Growth options proxied by CAPFIX										
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AMB^{CU}		-0.723***			-0.693***		-0.714***		-0.687***	
		(-13.159)			(-13.058)		(-13.575)		(-13.194)	
AMB^{TEXT}			-0.550***			-0.461***		-0.727***		-0.472***
			(-3.395)			(-2.933)		(-4.300)		(-2.959)
MA				0.124***	0.126***	0.088***			0.022**	0.037**
				(23.270)	(15.341)	(10.318)			(2.137)	(2.422)
Interaction (AMB^{CU} * High MA)							0.151***		0.139***	
							(19.231)		(14.328)	
Interaction (AMB^{TEXT} * High MA)								0.099***		0.070***
								(8.956)		(4.605)
SKEW	-0.019***	-0.022**	-0.019*	-0.015**	-0.018*	-0.014	-0.021*	-0.017*	-0.020*	-0.014
	(-2.660)	(-2.055)	(-1.909)	(-2.167)	(-1.723)	(-1.421)	(-1.942)	(-1.697)	(-1.929)	(-1.449)
IVOL	-0.053***	-0.034***	-0.022*	-0.051***	-0.030***	-0.025**	-0.026***	-0.013	-0.027***	-0.024**
	(-9.860)	(-3.901)	(-1.958)	(-9.384)	(-3.532)	(-2.218)	(-3.085)	(-1.132)	(-3.234)	(-2.187)
SGA	0.100***	0.063***	0.096***	0.139***	0.101***	0.100***	0.105***	0.111***	0.107***	0.104***
	(10.909)	(3.906)	(5.409)	(14.125)	(5.949)	(5.620)	(6.150)	(5.673)	(6.383)	(5.785)
LEV	-0.222***	-0.154***	-0.178***	-0.206***	-0.141***	-0.168***	-0.134***	-0.159***	-0.135***	-0.165***
	(-36.287)	(-15.310)	(-17.122)	(-33.653)	(-14.336)	(-16.588)	(-13.193)	(-13.902)	(-13.617)	(-15.789)
R&D	-0.116***	-0.060***	-0.079***	-0.127***	-0.071***	-0.078***	-0.069***	-0.070***	-0.070***	-0.078***
	(-11.486)	(-3.402)	(-4.330)	(-12.185)	(-4.014)	(-4.309)	(-3.861)	(-3.668)	(-3.983)	(-4.311)
CFC	0.005	0.004	0.019***	0.006	0.004	0.019***	0.004	0.019***	0.004	0.019***
	(1.302)	(0.587)	(3.427)	(1.591)	(0.611)	(3.484)	(0.644)	(3.311)	(0.697)	(3.392)
SG	0.103***	0.106***	0.132***	0.094***	0.098***	0.126***	0.097***	0.135***	0.097***	0.125***
	(23.565)	(12.355)	(12.443)	(21.404)	(11.615)	(12.000)	(11.421)	(12.331)	(11.599)	(12.014)
HHI	0.033***	0.028***	0.026***	0.031***	0.027***	0.025***	0.026***	0.025***	0.026***	0.025***
	(7.294)	(3.999)	(3.336)	(6.946)	(3.930)	(3.306)	(3.787)	(3.148)	(3.826)	(3.316)
SKEW* LEV	-0.005	0.004	-0.004	-0.008	-0.000	-0.009	0.002	-0.006	0.002	-0.009
	(-0.642)	(0.386)	(-0.420)	(-1.115)	(-0.012)	(-0.889)	(0.209)	(-0.580)	(0.151)	(-0.855)
Adj. R-squared	0.493	0.499	0.535	0.500	0.504	0.539	0.505	0.538	0.506	0.540
Observations	49,999	38,585	20,939	49,646	38,402	20,847	38,402	20,847	38,402	20,847
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel C: Growth options proxied by PCGO										
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AMB^{CU}		-0.586***			-0.554***		-0.594***		-0.554***	
		(-13.458)			(-13.263)		(-14.343)		(-13.575)	
AMB^{TEXT}			-0.514***			-0.362***		-0.702***		-0.456***
			(-3.829)			(-2.805)		(-5.116)		(-3.450)
MA				0.132***	0.124***	0.117***			0.052***	0.066***
				(27.185)	(17.699)	(14.741)			(5.719)	(4.654)
Interaction (AMB^{CU} * High MA)							0.121***		0.096***	
							(18.878)		(12.033)	
Interaction (AMB^{TEXT} * High MA)								0.101***		0.061***
								(11.830)		(4.884)
SKEW	0.040***	0.040***	0.037***	0.040***	0.040***	0.037***	0.040***	0.037***	0.040***	0.037***
	(12.705)	(8.936)	(8.444)	(12.857)	(9.206)	(8.839)	(8.924)	(8.029)	(9.182)	(8.636)
SGA	0.095***	0.068***	0.042**	0.097***	0.052***	0.048***	0.052***	0.055***	0.057***	0.052***
	(11.260)	(4.837)	(2.522)	(10.830)	(3.585)	(2.946)	(3.483)	(3.045)	(3.896)	(3.134)
R&D	-0.026***	0.005	0.017	-0.040***	0.001	-0.007	0.003	0.005	0.002	-0.003
	(-2.815)	(0.317)	(0.997)	(-4.232)	(0.090)	(-0.410)	(0.218)	(0.274)	(0.163)	(-0.194)
CFC	0.008**	0.012**	0.019***	0.008**	0.011**	0.018***	0.011**	0.019***	0.011**	0.018***
	(2.189)	(2.279)	(3.660)	(2.356)	(2.217)	(3.536)	(2.103)	(3.394)	(2.220)	(3.475)
SG	0.101***	0.102***	0.127***	0.095***	0.094***	0.120***	0.094***	0.130***	0.093***	0.121***
	(25.252)	(13.701)	(13.590)	(23.638)	(12.961)	(13.097)	(12.560)	(13.578)	(12.807)	(13.227)
MS	-0.020**	-0.040***	-0.069***	-0.028***	-0.048***	-0.073***	-0.041***	-0.068***	-0.044***	-0.071***
	(-2.462)	(-3.381)	(-4.716)	(-3.601)	(-4.259)	(-5.199)	(-3.523)	(-4.492)	(-3.887)	(-4.941)
Adj. R-squared	0.573	0.591	0.606	0.579	0.597	0.612	0.596	0.610	0.598	0.613
Observations	49,984	38,576	20,939	49,631	38,393	20,847	38,393	20,847	38,393	20,847
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Panels A, B and C respectively present the results of 2SLS panel data regressions explaining firm's growth options value as measured by market-implied growth options (MGO), capital expenditures-to-fixed assets (CAPFIX), and the first principal component (PCGO) of Tobin's Q, market value-to-book value of assets, the debt-to-equity ratio, the ratio of capital expenditures-to-fixed assets, and the market-to-book ratio. MA = managerial ability score; SKEW = firm return skewness; IVOL = firm-specific volatility; SGA = selling, general, and administrative ratio; LEV = financial leverage; R&D = research and development intensity; CFC = cash flow coverage; SG = cumulative sales growth; HHI = market power; MS = market share. Endogenous variables AMB^{CU} and AMB^{TEXT} are instrumented using prior skewness, firm-specific volatility, leverage and the interaction of skewness and leverage for MGO, and prior skewness, idiosyncratic volatility, default risk (proxied by z-score), and interaction of skewness and leverage for CAPFIX and PCGO in the first stage, with the predicted values of AMB^{CU} and AMB^{TEXT} then used in the second-stage regressions. For ease of exposition and brevity, the results of the first-stage are not reported. t-statistics are presented in parentheses and are two-tailed, based on robust standard errors adjusted for heteroscedasticity. Firm and year fixed effects are included. *, ** and *** indicate that the coefficient is significant at the 10%, 5% and 1% level, respectively.

Robustness checks: Alternative proxies and additional results

Our above findings on the role of managerial ability as a determinant of growth options are based on the ability indicator of Demerjian et al. (2012). In robustness tests, we also proxy management quality and ability by the strategy index (STRAT) in Bentley et al. (2013) and the innovation score (INNOV) by Kogan et al. (2017). High strategy index firms enact an environment that is more dynamic than other types of organisations, and require high ability and discretion to exploit new product and market opportunities as well as facilitate and coordinate diverse operations (Miles and Snow, 1978; Bentley et al., 2013). Corporate innovation outputs are also indicative of management quality (Holcomb et al., 2009; Kogan et al., 2017).

Table 3 (Panels A-C) confirms that our main results are robust to alternative ability and management quality proxies. Models (1)-(7) in Panels A-C indicate that: (1) ambiguity (AMB^{CU} and AMB^{TEXT}) is significantly negatively associated with MGO, CAPFIX, and PCGO after controlling for STRAT and growth options determinants, (2) STRAT is consistently and positively related to growth options value, and (3) the negative effect of ambiguity is generally moderated/mitigated through its interaction with STRAT. Models 8-14 in Panels A-C show that our results also hold when INNOV is used as an alternative management quality proxy.

In additional analysis and for further robustness (Appendices 2-4), we confirm that our findings on the negative ambiguity effect are unchanged to using multiple-priors-based ambiguity AMB^{MEU} (i.e., uncertainty in growth rate only in (2)) as an alternative ambiguity proxy (Appendix 2). In untabulated results, we find that our conclusions are unaffected if we replace our AMB proxies by the first principal component of AMB^{CU} and AMB^{TEXT}. We also show in Appendix 3 that the negative effect of AMB on GO is more pronounced in NBER recessions and that though the positive interaction effect is generally maintained, the direct effect of MA on growth options is weaker around economic recessions. We further validate our

conclusions in a dataset of all US-listed manufacturing firms, extending recent insights by Hussinger and Pacher (2019) to the entire universe of US manufacturing firms (Appendix 3). Finally, we rerun our analysis using multivariate OLS specifications and find that our main results generally hold (i.e., albeit slight weaker in a few PCGO specifications) for AMB^{CU} after accounting for firm and time fixed effects in the regressions (Appendix 4). Conclusions are qualitatively comparable for AMB^{TEXT} (unreported) but findings are insignificant (negative) for MGO-related regressions specifications, hence justifying the need to correct for endogeneity in the various models. Our main conclusions also hold in residual-based OLS GO specifications (unexplained portions of GO) on the effects of AMB, AMB and AMB*MA on growth options value.

Table 3. Panel regressions explaining growth options using alternative managerial ability proxies

Panel A: Growth options proxied by MGO

	Managerial Ability proxied by STRAT							Managerial Ability proxied by INNOV						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
AMB^{CU}		-0.112***		-0.116***		-0.116***			-0.446***		-0.450***		-0.445***	
		(-2.581)		(-2.623)		(-2.607)			(-8.031)		(-8.124)		(-8.030)	
AMB^{TEXT}			-0.677***		-0.700***		-0.725***			-0.433*		-0.578**		-0.467**
			(-3.269)		(-3.364)		(-3.333)			(-1.707)		(-2.202)		(-2.050)
STRAT	0.044***	0.045***	0.075***			0.024*	0.040**							
	(5.177)	(5.012)	(3.636)			(1.657)	(2.370)							
Interaction (AMB^{CU} * High STRAT)				0.035***		0.026*								
				(3.625)		(1.901)								
Interaction (AMB^{TEXT} * High STRAT)					0.085***		0.066***							
					(3.602)		(2.874)							
INNOV								0.026**	0.033***	0.027*			0.029**	0.038**
								(2.569)	(2.905)	(1.717)			(2.496)	(2.313)
Interaction (AMB^{CU} * High INNOV)											0.027***		0.023**	
											(2.726)		(2.280)	
Interaction (AMB^{TEXT} * High INNOV)												0.102***		0.090**
												(2.768)		(2.551)
Adj. R-squared	0.409	0.391	0.417	0.390	0.416	0.392	0.417	0.500	0.484	0.540	0.480	0.540	0.485	0.541
Observations	41,722	35,185	15,970	35,185	15,970	35,185	15,970	12,818	10,334	4,277	10,334	4,277	10,334	4,277
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Growth options proxied by CAPFIX

	Managerial Ability proxied by STRAT							Managerial Ability proxied by INNOV						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
AMB^{CU}		-0.350***		-0.471***		-0.356***			-0.669***		-0.696***		-0.681***	
		(-7.586)		(-9.510)		(-7.527)			(-8.909)		(-9.162)		(-9.020)	
AMB^{TEXT}			-1.041***		-1.064***		-1.054***			-0.762**		-1.201***		-1.052***
			(-5.659)		(-5.764)		(-5.726)			(-2.133)		(-2.817)		(-2.614)
STRAT	0.095***	0.094***	0.158***			0.024*	0.070***							
	(12.484)	(10.112)	(8.287)			(1.700)	(4.212)							
Interaction (AMB^{CU} * High STRAT)				0.107***		0.081***								
				(10.692)		(6.197)								
Interaction (AMB^{TEXT} * High STRAT)					0.134***		0.106***							
					(7.089)		(5.272)							
INNOV								0.039***	0.041***	0.070***			0.036***	0.054***
								(4.050)	(3.443)	(4.056)			(2.957)	(2.587)
Interaction (AMB^{CU} * High INNOV)											0.033***		0.027**	
											(2.861)		(2.296)	
Interaction (AMB^{TEXT} * High INNOV)												0.149***		0.125**
												(2.644)		(2.312)
Adj. R-squared	0.480	0.492	0.532	0.492	0.531	0.492	0.532	0.538	0.538	0.537	0.537	0.536	0.539	0.538
Observations	41,233	32,136	19,272	32,136	19,272	32,136	19,272	12,640	10,195	5,264	10,195	5,264	10,195	5,264
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel C: Growth Options proxied by PCGO

	Managerial Ability proxied by STRAT							Managerial Ability proxied by INNOV						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
AMB^{CU}		-0.157***		-0.164***		-0.160***			-0.446***		-0.514***		-0.435***	
		(-4.461)		(-4.556)		(-4.446)			(-6.737)		(-7.481)		(-6.642)	
AMB^{TEXT}			-0.969***		-0.974***		-0.963***			-0.124***		-0.183***		-0.166***
			(-6.608)		(-6.629)		(-6.576)			(-3.465)		(-4.875)		(-4.548)
STRAT	0.068***	0.068***	0.141***			0.030***	0.060***							
	(9.918)	(8.954)	(8.611)			(2.643)	(3.939)							
Interaction (AMB^{CU} * High STRAT)				0.057***		0.044***								
				(7.644)		(4.357)								
Interaction (AMB^{TEXT} * High STRAT)					0.119***		0.095***							
					(7.652)		(5.647)							
INNOV								0.309***	0.288***	0.261***			0.261***	0.238***
								(32.846)	(25.852)	(17.295)			(23.190)	(15.628)
Interaction (AMB^{CU} * High INNOV)											0.159***		0.110***	
											(15.684)		(11.193)	
Interaction (AMB^{TEXT} * High INNOV)												0.180***		0.140***
												(11.406)		(9.023)
Adj. R-squared	0.585	0.590	0.613	0.590	0.612	0.590	0.613	0.657	0.665	0.651	0.645	0.637	0.670	0.657
Observations	41,222	34,766	19,272	34,766	19,272	34,766	19,272	12,640	10,195	5,264	10,195	5,264	10,195	5,264
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Panels A, B and C respectively present the results of panel data regressions (2SLS) explaining firm's growth options value as measured by market-implied growth options (MGO), capital expenditures-to-fixed assets (CAPFIX), and the first principal component (PCGO) of Tobin's Q, market value-to-book value of assets, the debt-to-equity ratio, the ratio of capital expenditures-to-fixed assets, and the market-to-book ratio. STRAT = strategy index; INNOV = innovation score. Control variables in each panel are the same as those in Table 2. Endogenous variables AMB^{CU} and AMB^{TEXT} are instrumented using prior skewness, firm-specific volatility, leverage and the interaction of skewness and leverage for MGO, and prior skewness, idiosyncratic volatility, default risk (proxied by z-score) and the interaction of skewness and leverage for CAPFIX and PCGO in the first stage, with the predicted values of AMB^{CU} and AMB^{TEXT} then used in the second-stage regressions. For ease of exposition and brevity, the results of the first-stage are not reported. t-statistics are presented in parentheses and are two-tailed, based on robust standard errors adjusted for heteroscedasticity. Firm and year fixed effects are included. *, ** and *** indicate that the coefficient is significant at the 10%, 5% and 1% level, respectively.

Conclusions

This paper studies the growth options implications of ambiguity and managerial ability in a dataset of all US-listed firms. Validating behavioural theory and real options theory predictions on the role of ambiguity and heterogeneity in firm performance outcomes, we reveal a negative association between firm-specific ambiguity and corporate growth options, and highlight the moderating effect of managerial ability on the ambiguity-growth options linkage. We also confirm a direct positive relation between ability and growth options. While this relation has been documented in competence-based research, real options research is yet to connect firm-specific managerial characteristics to real growth options value. Our findings are robust to alternative specifications of ambiguity, managerial ability, and corporate growth options. We add to the literature by linking real options research on firm heterogeneity to the case of non-Bayesian behaviour and ambiguity, documenting a strong negative relation between the latter and growth options, and extending extant evidence on how management quality and know-how affect the management of real options opportunities under uncertainty in publicly listed-US firms.

Our new evidence provides relevant management insights into the behavioural antecedents of real options at the firm level and confirms that managerial and behavioural characteristics are important determinants of growth options. Our research also corroborates the adverse impact - hypothesised in prior studies - of ambiguity on economic outcomes, and underscores the significant interplay between management quality (i.e., heterogeneity) and non-Bayesian uncertainty in explaining firm competitive advantage. This suggests that in order to cope better with uncertainty, minimise the negative repercussions of decision-making biases, and more effectively balance the trade-off between commitment and flexibility, managers and their firms need to continually develop/update their knowledge reserves, skills, and know-how, and adjust their norms and routines through learning, decentralisation and the acquisition of

new knowledge. While real options logic offers flexibility to benefit from upside potential and mitigate downside risk via expansion, deferral, switching, scaling-down and abandonment, accounting for uncertainty beyond risk and how to deal with behaviour in the exploration and exploitation of options opportunities can help enable firms to better realise their flexibility potential and more effectively translate such potential into actual real options (value).

We have examined ambiguity herein in the context of firm strategic opportunities using a behavioural options lens. It would be relevant to extend the study of the consequences and antecedents of ambiguity to alternative theories of the firm, and investigate resource allocation decisions involving market entry, modes of operations, governance, and internationalisation. Investigating such dynamics using cross-border datasets is worth considering. Our paper also generates interesting avenues for further research into how more fine-grained information about firms' top management teams and executives' characteristics could potentially be relevant to the study of corporate real options, management quality determinants, and in examining the drivers of ambiguity and other cognitive biases within organisations. This is recommended for future research.

Footnotes

1. We view ambiguity in this paper as uncertainty beyond probabilistic risk (i.e., deviations from Bayesianism). Ambiguity aversion (pessimism) can be defined as the tendency to overweight events with bad outcomes when faced with uncertainty, while ambiguity-seeking (optimism) is interpreted as one's propensity to overweight good, but less probable, outcomes displaying uncertainty-liking (i.e., non-Bayesian behaviour). In this study, we employ the terms "ambiguity", "non-Bayesian uncertainty" - as opposed to risk and Bayesian uncertainty - and "Knightian uncertainty" interchangeably.

2. Also relevant is Coiculescu et al. (2019) who link ambiguity information to innovation activity through patents citations and R&D.

3. We find the negative effect of ambiguity on GO to be more pronounced during NBER recessions. Our main results hold in the universe of US-listed manufacturing firms. We also confirm our results by using the strategy index of Bentley et al. (2013) and innovation score by Kogan et al. (2017) as alternative MA proxies. Our findings hold under the multiple-priors ambiguity specification.

4. The types of biases affecting decision-making include amongst others: conservatism, escalation of commitment, precision/estimation, confirmation and cognitive dissonance (see Coff and Laverty, 2007; Posen et al., 2018).

5. Our time window ends in 2013 to match the availability of ambiguity (AMB^{CU} and AMB^{TEXT}) data.

6. For robustness, we also employ the market-to-book ratio (MABA) as an another GO indicator (see also Ogden and Wu, 2013) and conclusions are comparable.

7. Hausman endogeneity tests indicated that the AMB measures are endogenous. This motivates our use of 2SLS regressions specifications. F-tests confirmed that the instruments used are not weakly identified.

8. As HHI contains Tobin'q related information, we instead use market share (MS) as a control variable in the PCGO regressions. Our 2SLS conclusions generally hold if IVOL is added to the regressions.

9. Our conclusions are unchanged to using raw managerial ability scores in these models.

10. In the first-stage regressions, we find that IVOL, LEV and DR are significantly positively related to AMB. The effect of SKEW is positive for AMB^{CU} and negative for AMB^{TEXT}, both insignificant when controlling for other instruments.

Appendix 1. Variable Definitions and Measurements

Appendix 1. Definition and measurement of variables

Variables	Definitions
Dependent Variables	
MGO	Market-implied growth options measured following Cao et al. (2008) and Trigeorgis and Lambertides (2014)
CAPFIX	Capital expenditure to fixed assets measured as the capital expenditures deflated by Property, Plant and Equipment (PPE)
PCGO	The first principal component of five proxies for growth options following Lyle (2019), including Tobin's Q, the market value-to-book value of assets, the debt-to-equity ratio, the ratio of capital expenditures-to-fixed assets, and the market-to-book ratio
Explanatory Variables	
AMB^{CU}	Choquet ambiguity score measured following Driouchi et al. (2020)
AMB^{TEXT}	Textual ambiguity score from Friberg and Seiler (2017)
MA	Managerial ability score by Demerjian et al. (2012)
*AMB * High MA*	Interaction between ambiguity and a dummy variable that takes the value of 1 when MA is higher than its median and zero otherwise.
Control Variables	
SKEW	Skewness estimated using the previous 3 months daily stock returns
IVOL	Firm-specific volatility estimated from the residuals of the regression of the previous 3 months daily stock's returns on the market index return (S&P500) using the market model
SGA	Selling, general, and administrative (SGA) ratio measured as SGA deflated by sales
LEV	Financial leverage measured as the book value of total liabilities divided by the firm's market value
R&D	R&D intensity measured as the average recent 3 years' research and development expenses over current year sales (this variable is set to zero if R&D data is missing)
CFC	Cash flow coverage measured as the amount of excess cash and equivalents maintained by the firm following Trigeorgis and Lambertides (2014)
SG	Cumulative sales growth measured as the percentage change in firm revenues over the recent 3-year period
HHI	Market power measured as the square root of Herfindahl-Hirschman Index (HHI) each year in each industry (according to their 2-digit SIC code) if a firm has an above-average Tobin's q and 0 otherwise
MS	Market share measured as the share of sales each year in each industry (according to their 2-digit SIC code)
*SKEW * LEV*	Interaction between skewness and financial leverage
Alternative Measures	
AMB^{MEU}	Ambiguity using the multiple-priors-based (MEU) specification focusing on uncertainty in drift only following Driouchi et al. (2020)
STRAT	Strategy index measured following Bentley et al. (2013)
INNOV	Innovation score from Kogan et al. (2017)

Appendix 2. Panel regressions explaining growth options using alternative ambiguity proxy AMB^{MEU}

	Growth Options proxied by MGO				Growth Options proxied by CAPFIX				Growth Options proxied by PCGO			
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
AMB^{MEU}	-0.152**	-0.147**	-0.208**	-0.130*	-0.549***	-0.525***	-0.872***	-0.627***	-0.272***	-0.248***	-0.362***	-0.252***
	(-2.173)	(-2.067)	(-2.293)	(-1.717)	(-7.086)	(-6.786)	(-7.532)	(-7.409)	(-4.239)	(-3.886)	(-4.733)	(-3.752)
MA		0.015**		0.003		0.110***		0.045***		0.127***		0.101***
		(2.365)		(0.303)		(15.277)		(4.174)		(21.095)		(11.510)
Interaction (AMB^{MEU} * High MA)			0.140***	0.074*			0.506***	0.360***			0.236***	0.143***
			(2.762)	(1.784)			(8.470)	(8.277)			(5.992)	(4.130)
SKEW	-0.019**	-0.018**	-0.017**	-0.015*	-0.031***	-0.027***	-0.032***	-0.021**	0.039***	0.039***	0.037***	0.039***
	(-2.271)	(-2.131)	(-2.063)	(-1.848)	(-3.254)	(-2.859)	(-3.055)	(-2.231)	(10.057)	(10.327)	(9.507)	(10.492)
SGA	0.053***	0.053***	0.054***	0.051***	0.094***	0.130***	0.197***	0.139***	0.094***	0.078***	0.097***	0.078***
	(6.721)	(6.672)	(6.619)	(6.585)	(6.540)	(8.667)	(9.631)	(9.164)	(7.735)	(6.084)	(6.373)	(6.132)
R&D	0.270***	0.300***	0.320***	0.302***	-0.070***	-0.080***	-0.065***	-0.063***	-0.012	-0.015	-0.012	-0.010
	(21.539)	(22.377)	(19.233)	(22.029)	(-4.510)	(-5.111)	(-3.650)	(-3.928)	(-0.922)	(-1.162)	(-0.872)	(-0.781)
CFC	-0.012	-0.011	0.002	-0.005	0.017***	0.017***	0.016***	0.014***	0.026***	0.025***	0.024***	0.023***
	(-1.423)	(-1.297)	(0.263)	(-0.724)	(3.304)	(3.211)	(2.703)	(2.686)	(5.916)	(5.649)	(5.452)	(5.288)
SG	0.124***	0.119***	0.122***	0.125***	0.136***	0.129***	0.121***	0.120***	0.132***	0.123***	0.120***	0.125***
	(9.167)	(8.563)	(8.635)	(8.828)	(16.641)	(15.710)	(14.228)	(15.648)	(18.977)	(17.719)	(18.856)	(19.689)
HHI	-0.013***	-0.013***	-0.015***	-0.014***	0.027***	0.027***	0.024***	0.026***				
	(-2.732)	(-2.923)	(-3.253)	(-3.067)	(4.472)	(4.458)	(3.524)	(4.480)				
LEV	0.038***	0.036***	0.033***	0.033***	-0.235***	-0.221***	-0.187***	-0.202***				
	(5.290)	(4.956)	(4.828)	(4.893)	(-24.979)	(-23.616)	(-20.495)	(-24.328)				
IVOL	0.039***	0.039***	0.038***	0.039***	-0.022**	-0.019**	-0.009	-0.021**				
	(7.296)	(7.347)	(7.200)	(7.341)	(-2.457)	(-2.172)	(-0.823)	(-2.521)				
SKEW* LEV	0.012	0.010	0.010	0.009	0.004	0.000	0.000	-0.004				
	(1.378)	(1.234)	(1.144)	(1.067)	(0.453)	(0.024)	(0.026)	(-0.475)				
MS									-0.032***	-0.042***	-0.034***	-0.041***
									(-3.173)	(-4.260)	(-3.463)	(-4.292)
Adj. R-squared	0.399	0.400	0.400	0.400	0.496	0.501	0.499	0.503	0.5876	0.5937	0.5897	0.5939
Observations	38,781	38,493	38,493	38,493	38,299	38,116	38,116	38,116	38,290	38,107	38,107	38,107
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Columns 1 to 4, 5 to 8, and 9 to 12 respectively present the results of panel data regressions analysing firm's growth options value as measured by market-implied growth options (MGO), capital expenditures-to-fixed assets (CAPFIX), and the first principal component (PCGO) of Tobin's Q, market value-to-book value of assets, the debt-to-equity ratio, the ratio of capital expenditures to fixed assets, and the market-to-book ratio. MA = managerial ability score; SKEW = firm return skewness; IVOL = firm-specific volatility; SGA = selling, general, and administrative ratio; LEV = financial leverage; R&D = research and development intensity; CFC = cash flow coverage; SG = cumulative sales growth; HHI = market power; MS = market share. AMB^{MEU} is instrumented using prior skewness, idiosyncratic volatility and the interaction of skewness and leverage in the first stage, with the predicted values of AMB^{MEU} then used in the second-stage regressions. For brevity, the results of the first-stage are not reported. t-statistics are presented in parentheses and are two-tailed, based on robust standard errors adjusted for heteroscedasticity. Firm and year fixed effects are included. *, ** and *** indicate that the coefficient is significant at the 10%, 5% and 1% level, respectively.

Appendix 3. Subsample analysis: Manufacturing industry and NBER recessions

Panel A: Growth options proxied by MGO

	Manufacturing Industry						NBER Recessions					
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
AMB^{CU}	-0.721***		-0.709***		-0.688***		-1.033***		-1.019***		-1.010***	
	(-11.017)		(-10.927)		(-11.284)		(-5.632)		(-5.515)		(-5.464)	
AMB^{TEXT}		-0.511**		-0.503**		-0.258*		-1.387*		-1.300*		-1.255*
		(-2.500)		(-2.447)		(-1.849)		(-1.837)		(-1.758)		(-1.832)
MA			0.039***	0.023*	0.024*	0.029**			-0.007	0.009	-0.027	-0.076
			(2.931)	(1.656)	(1.788)	(2.139)			(-0.329)	(0.188)	(-1.095)	(-0.998)
Interaction (AMB^{CU} * High MA)					0.058***						0.027	
					(5.730)						(1.547)	
Interaction (AMB^{TEXT} * High MA)						0.000						0.106*
						(0.004)						(1.808)
Adj. R-squared	0.362	0.413	0.362	0.413	0.363	0.413	0.314	0.374	0.314	0.374	0.314	0.374
Observations	20,741	11,931	20,715	11,912	20,715	11,912	5,401	3,812	5,377	3,795	5,377	3,795
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Growth Options proxied by CAPFIX

	Manufacturing Industry						NBER Recessions					
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
AMB^{CU}	-0.743***		-0.720***		-0.716***		-1.882***		-1.700***		-1.686***	
	(-9.496)		(-9.417)		(-9.789)		(-6.580)		(-6.018)		(-5.991)	
AMB^{TEXT}		-0.883***		-0.861***		-0.856***		-2.326*		-2.162*		-2.083**
		(-3.708)		(-3.658)		(-3.772)		(-1.912)		(-1.875)		(-1.990)
MA			0.130***	0.102***	0.105***	0.081***			0.068***	0.013	0.009	-0.141
			(10.473)	(7.333)	(8.279)	(5.436)			(3.130)	(0.211)	(0.351)	(-1.319)
Interaction (AMB^{CU} * High MA)					0.091***						0.081***	
					(9.644)						(4.450)	
Interaction (AMB^{TEXT} * High MA)						0.099***						0.193**
						(6.479)						(2.256)
Adj. R-squared	0.477	0.511	0.484	0.517	0.486	0.519	0.468	0.522	0.470	0.523	0.475	0.524
Observations	20,542	11,960	20,516	11,928	20,516	11,922	5,295	3,779	5,272	3,758	5,272	3,758
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel C: Growth Option Proxied by PCGO

	Manufacturing Industry						NBER Recessions					
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
AMB^{CU}	-0.565***		-0.512***		-0.518***		-1.529***		-1.406***		-1.353***	
	(-9.214)		(-8.752)		(-9.029)		(-7.480)		(-6.947)		(-6.679)	
AMB^{TEXT}		-0.390**		-0.328*		-0.373**		-1.903***		-1.737**		-1.864***
		(-2.239)		(-1.912)		(-2.115)		(-2.643)		(-2.496)		(-2.650)
MA			0.118***	0.139***	0.047***	0.084***			0.079***	0.087	0.043*	0.044
			(11.631)	(11.779)	(3.479)	(3.742)			(4.094)	(1.015)	(1.936)	(0.456)
Interaction (AMB^{CU} * High MA)					0.084***						0.051***	
					(8.466)						(3.029)	
Interaction (AMB^{TEXT} * High MA)						0.065***						0.203**
						(3.458)						(2.323)
Adj. R-squared	0.612	0.606	0.617	0.612	0.618	0.613	0.591	0.621	0.597	0.625	0.598	0.626
Observations	20,534	11,960	20,508	11,928	20,508	11,928	5,295	3,779	5,272	3,758	5,272	3,758
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Appendix 3. Continued

Notes: This table shows panel data regressions analysing firm's growth options value for the manufacturing industry subsample and during NBER recessions. The dependent variables in Panels A, B and C are respectively market-implied growth options (MGO), capital expenditure to fixed assets (CAPFIX), and the first principal component (PCGO) of Tobin's Q, market value-to-book value of assets, the debt-to-equity ratio, the ratio of capital expenditures-to-fixed assets, and the market-to-book ratio. Control variables are similar to those in Table 2. MA is the managerial ability score. Control variables in each panel are the same as those in Table 2. Endogenous variables AMB^{CU} and AMB^{TEXT} are instrumented by prior skewness, firm-specific volatility, leverage and the interaction of skewness and leverage for MGO, and prior skewness, idiosyncratic volatility, default risk (proxied by z-score) and the interaction of skewness and leverage for CAPFIX and PCGO in the first stage, with the predicted values of AMB^{CU} and AMB^{TEXT} then used in the second-stage regressions. For ease of exposition and brevity, the results of the first-stage are not reported. t-statistics are presented in parentheses and are two-tailed, based on robust standard errors adjusted for heteroscedasticity. Firm and year fixed effects are included. *, ** and *** indicate that the coefficient is significant at the 10%, 5% and 1% level, respectively.

Appendix 4. OLS regressions of AMB^{CU} on growth options

Panel A: Managerial ability proxied by MA

	Growth Options proxied by MGO					Growth Options proxied by CAPFIX					Growth Options proxied by PCGO				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
AMB^{CU}		-0.109**	-0.111**	-0.143***	-0.109**		-0.048***	-0.053***	-0.072***	-0.066***		-0.148*	-0.143*	-0.244***	-0.190**
		(-2.317)	(-2.364)	(-3.026)	(-2.303)		(-3.346)	(-3.713)	(-5.061)	(-4.659)		(-1.751)	(-1.715)	(-2.900)	(-2.264)
MA	0.091***		0.079***		0.078**	0.195***		0.178***		0.112***	1.329***		1.200***		0.960***
	(3.320)		(2.633)		(2.550)	(23.270)		(19.453)		(10.140)	(27.185)		(22.435)		(14.785)
Interaction (AMB^{CU} * High MA)				0.069***	-0.006				0.056***	0.037***				0.301***	0.132***
				(7.103)	(-0.588)				(19.777)	(10.744)				(18.051)	(6.526)
Adj. R-squared	0.418	0.402	0.399	0.400	0.400	0.500	0.493	0.499	0.500	0.501	0.578	0.588	0.593	0.591	0.594
Observations	50,276	39,077	38,789	38,789	38,789	49,646	38,585	38,402	38,402	38,402	49,631	38,576	38,393	38,393	38,393
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Managerial ability proxied by STRAT

	Growth Options proxied by MGO					Growth Options proxied by CAPFIX					Growth Options proxied by PCGO				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
AMB^{CU}		-0.109**	-0.087*	-0.098**	-0.084*		-0.048***	-0.058***	-0.071***	-0.063***		-0.148*	-0.092	-0.153*	-0.112
		(-2.317)	(-1.804)	(-2.018)	(-1.720)		(-3.346)	(-4.038)	(-4.888)	(-4.300)		(-1.751)	(-1.094)	(-1.797)	(-1.312)
STRAT	0.005***		0.005***		0.006***	0.004***		0.003***		0.003***	0.017***		0.016***		0.014***
	(5.177)		(4.922)		(4.301)	(12.484)		(10.914)		(7.518)	(9.918)		(8.959)		(6.259)
Interaction (AMB^{CU} * High STRAT)				0.030**	-0.009				0.030***	0.010**				0.142***	0.044
				(2.457)	(-0.566)				(8.197)	(2.166)				(6.613)	(1.642)
Adj. R-squared	0.409	0.402	0.391	0.390	0.391	0.480	0.493	0.492	0.491	0.492	0.585	0.588	0.590	0.590	0.590
Observations	41,722	39,077	35,185	35,185	35,185	41,233	38,585	34,775	34,775	34,775	41,222	38,576	34,766	34,766	34,766
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel C: Managerial ability proxied by INNOV

	Growth Options proxied by MGO					Growth Options proxied by CAPFIX					Growth Options proxied by PCGO				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
AMB^{CU}		-0.109**	-0.280**	-0.299**	-0.294**		-0.048***	-0.099**	-0.102**	-0.133***		-0.148*	-0.369	-0.763**	-0.494*
		(-2.317)	(-1.972)	(-2.107)	(-2.072)		(-3.346)	(-2.202)	(-2.269)	(-2.991)		(-1.751)	(-1.246)	(-2.498)	(-1.678)
INNOV	0.073**		0.101***		0.090***	0.036***		0.042***		0.036***	1.834***		1.763***		1.623***
	(2.569)		(3.340)		(2.941)	(4.050)		(4.407)		(3.860)	(32.846)		(28.782)		(26.025)
Interaction (AMB^{CU} * High INNOV)				0.063***	0.056***				0.011*	0.014**				0.663***	0.430***
				(3.226)	(2.811)				(1.771)	(2.269)				(15.800)	(10.386)
Adj~~usted~~ R-squared	0.500	0.402	0.481	0.481	0.481	0.538	0.493	0.533	0.532	0.533	0.657	0.588	0.667	0.645	0.671
Observations	12,818	39,077	10,334	10,334	10,334	12,641	38,585	10,196	10,196	10,196	12,640	38,576	10,195	10,195	10,195
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Columns 1 to 5, 6 to 10, and 11 to 15 respectively present the results of OLS regressions analysing firm's growth options as measured by MGO, CAPFIX and PCGO as our dependent variables. The ability variables in Panels A, B and C are respectively proxied by managerial ability score (MA), strategy index (STRAT) and innovation score (INNOV). AMB^{CU} is the Choquet ambiguity score. Control variables for dependents are the same as those in Table 2. t-statistics are presented in parentheses and are two-tailed, based on robust standard errors adjusted for heteroscedasticity. Firm and year fixed effects are included. *, ** and *** indicate that the coefficient is significant at the 10%, 5% and 1% level, respectively.

References

Abdellaoui, M., A. Baillon, L. Placido and P. P. Wakker (2011). 'The rich domain of uncertainty: Source functions and their experimental implementation', *American Economic Review*, **101**, pp. 695–723.

Abdellaoui, M., H. Bleichrodt, E. Kemel and O. L'Haridon (2020). 'Measuring beliefs under ambiguity', *Operations Research*, 1 July, https://doi.org/10.1287/opre.2020.1980.

Agliardi, E., R. Agliardi and W. Spanjers (2016). 'Corporate financing decisions under ambiguity: pecking order and liquidity policy implications', *Journal of Business Research*, **69**, pp. 6012–6020.

Ahammad, M. F., V. Leone, S. Y. Tarba, K. W. Glaister and A. Arslan (2017). 'Equity ownership in cross-border mergers and acquisitions by British firms: an analysis of real options and transaction cost factors', *British Journal of Management*, **28**, pp. 180–196.

d'Albis, H., Attanasi, G., and Thibault, E. (2020). 'An experimental test of the under-annuitization puzzle with smooth ambiguity and charitable giving', *Journal of Economic Behavior & Organization*, **180**, pp. 694–717.

Alessandri, T. M., T. W. Tong and J. J. Reuer (2012). 'Firm heterogeneity in growth option value: the role of managerial incentives', *Strategic Management Journal*, **33**, pp. 1557–1566.

Anderson, C. and L. Garcia-Feijoo (2006), 'Empirical evidence on capital investment, growth options, and security returns', *Journal of Finance*, **61**, pp. 171–94.

Andreou, P. C., I. Karasamani, C. Louca and D. Ehrlich (2017). 'The impact of managerial ability on crisis-period corporate investment', *Journal of Business Research*, **79**, pp. 107–122.

Antoniou, C., R. D. Harris, R. Zhang (2015). 'Ambiguity aversion and stock market participation: an empirical analysis', *Journal of Banking and Finance*, **58**, pp. 57–70.

Arnold, T., R. P. H. Fishe and D. North (2010). 'The effects of ambiguous information on initial and subsequent IPO returns', *Financial Management*, **39**, pp. 1497–1519.

Baik, B., D. B. Farber and S. Lee (2011). 'CEO ability and management earnings forecasts', *Contemporary Accounting Research*, **28**, pp. 1645-1668.

Baik, B., S. Choi and D. B. Farber (2020). 'Managerial Ability and Income Smoothing', *The Accounting Review*, **95**, pp. 1-22.

Baillon, A. and O. L'Haridon (2016). 'La decision en ambiguïté: Modèles et évaluations expérimentales', *L'Actualité Economique*, **92**, pp. 81–111.

Baillon, A., H. Bleichrodt, U. Keskin, O. L'Haridon and C. Li (2018a). 'The effect of learning on ambiguity attitudes', *Management Science*, **64**, pp. 2181–2198.

Baillon, A., Z. Huang, A. Selim and P. P. Wakker (2018b). 'Measuring ambiguity attitudes for all (natural) events', *Econometrica*, **86**, pp. 1839–1858.

Baker, S.D., B. Hollifield and E. Osambela (2016). 'Disagreement, speculation and aggregate investment', *Journal of Financial Economics*, **119**, pp. 210–225.

Bali, T. G., L. del Viva, N. Lambertides and L. Trigeorgis (2019). 'Growth options and related stock market anomalies: Profitability, distress, lotteryness, and volatility', *Journal of Financial and Quantitative Analysis*, **55**, https://doi.org/10.1017/S0022109019000619.

Belderbos, R., T. W. Tong and S. Wu (2018). 'Multinational investment and the value of growth options: Alignment of incremental strategy to environmental uncertainty', *Strategic Management Journal*, **40**, pp. 127–152.

Belderbos, R., T. W. Tong and S. Wu (2020). 'Portfolio configuration and foreign entry decisions: A juxtaposition of real options and risk diversification theories', *Strategic Management Journal*, **41**, https://doi.org/10.1002/smj.3151.

Bentley, K. A., T. C. Omer and N. Y. Sharp (2013). 'Business strategy, financial reporting irregularities, and audit effort', *Contemporary Accounting Research*, **30**, pp. 780–817.

Berk, J. and R. Stanton (2007). 'Managerial ability, compensation, and the closed-end fund puzzle', *Journal of Finance*, **57**, pp. 529–556.

Bonsall, S. B., IV, E. R. Holzman and B. P. Miller (2017). 'Managerial ability and credit risk assessment', *Management Science*, **63**, pp. 1425–49.

Boyarchenko, N. (2012). 'Ambiguity shifts and the 2007-2008 crisis', *Journal of Monetary Economics*, **59**, pp. 493–507.

Buckland, R. (2009). 'Private and public models for strategies in universities', *British Journal of Management*, **20**, pp. 524−536.

Cao, C., T. Simin and J. Zhao (2008). 'Can growth options explain the trend in idiosyncratic risk?', *Review of Financial Studies*, **21**, pp. 2599-2633.

Carson, S.J., A. Madhok and T. Wu (2006). 'Uncertainty, opportunism, and governance: the effects of volatility and ambiguity on formal and relational contracting', *Academy of Management Journal*, **49**, pp. 1058–1077.

Chemmanur, T. J. and I. Paeglis (2005). 'Management quality, certification, and initial public offerings', *Journal of Financial Economics*, **76**, pp. 331–368.

Chemmanur, T. J., S. He and G. Hu (2009). 'The role of institutional investors in seasoned equity offerings', *Journal of Financial Economics*, **94**, pp. 384–411.

Cheung, K. T. S., D. Naidu, F. Navissi and K. Ranjeeni (2017). 'Valuing talent: Do CEOs' ability and discretion unambiguously increase firm performance', *Journal of Corporate Finance*, **42**, pp. 15–35.

Cicero, L., A. Pierro and D. Van Knippenberg (2010). 'Leadership and uncertainty: How role ambiguity affects the relationship between leader group prototypicality and leadership effectiveness', *British Journal of Management*, **21**, pp. 411–421.

Coff, R. (1999). 'When competitive advantage doesn't lead to performance: the resource-based view and stakeholder bargaining power', *Organization Science*, **10**, pp. 119–133.

Coff, R. and K. Laverty (2007). 'Real options meet organizational theory: coping with path dependencies, agency costs and organizational form', *Advances in Strategic Management*, **24**, pp. 333–361.

Coiculescu, G., Izhakian, Y. and S. A. Ravid (2019). 'Innovation under ambiguity and risk', Baruch College Zicklin School of Business Research Paper. Research Paper 2019-08-07. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3428896.

Colombo, M.G. and L. Grilli (2005). 'Founders' human capital and the growth of new technology-based firms: A competence-based view', *Research Policy*, **34**, pp. 795–816.

Colombo, M.G. and L. Grilli (2010). 'On growth drivers of high-tech start-ups: Exploring the role of founders' human capital and venture capital', *Journal of Business Venturing*, **25**, pp. 610–626.

Cooper, A.C., F. J. Gimenon-Gascon, C.Y. Woo (1994). 'Initial human capital and financial capital as predictors of new venture performance', *Journal of Business Venturing*, **9**, pp. 371–396.

Cording, M., P. Christmann and D. R. King (2008). 'Reducing causal ambiguity in acquisition integration: intermediate goals as mediators of integration decisions and acquisition performance', *Academy of Management Journal*, **51**, pp. 744–767.

Dalziel, M. (2009). 'Foregoing the flexibility of real options: when and why firms commit to investment decisions', *British Journal of Management*, **20**, pp. 401–412.

De Andres, P., G. de la Fuente and P. Velasco (2017). 'Does it really matter how a firm diversifies? Assets-in-place diversification versus growth options diversification', *Journal of Corporate Finance*, **43**, pp. 316-339.

Delaney, L. (2020). 'Irreversible investment under ambiguity with incomplete information and learning', Department of Economics, City University of London. Working Paper.

Del Viva, L., E. Kasanen and L. Trigeorgis (2017). 'Real Options, Idiosyncratic Skewness, and Diversification', *Journal of Financial and Quantitative Analysis*, **52**, pp. 215– 41.

Demerjian, P., B. Lev and S. McVay (2012). 'Quantifying managerial ability: a new measure and validity tests', *Management Science*, **58**, pp. 1229-1248.

Demerjian, P., B. Lev, M. Lewis and S. McVay (2013). 'Managerial ability and earnings quality', *The Accounting Review*, **88**, pp. 463–498.

Dicks, D. L. and P. Fulghieri (2020). 'Uncertainty, investor sentiment, and innovation', *Review of Financial Studies*, June 16, https://doi.org/10.1093/rfs/hhaa065.

Driouchi, T. and D. J. Bennett (2011). 'Real options in multinational decision making: managerial awareness and risk implications', *Journal of World Business*, **46**, pp. 205–219.

Driouchi, T. and D. J. Bennett (2012). 'Real options in management and organisational strategy: a review of decision making and performance implications', *International Journal of Management Reviews*, **14**, pp. 39–62.

Driouchi, T., R. H. Y. So and L. Trigeorgis (2020). 'Investor ambiguity, systemic banking risk and economic activity: The case of too-big-to-fail', *Journal of Corporate Finance*, **62**, https://doi.org/10.1016/j.jcorpfin.2019.101549.

Dziwornu, R. K. (2017). 'Does managerial ability really drive cost efficiency? Evidence from Broiler Businesses', *Managerial and Decision Economics*, **38**, pp. 731–741.

Einhorn, H. J. and R. M. Hogarth (1985). 'Ambiguity and uncertainty in probabilistic inference, *Psychological Review*, **92**, pp. 433–461.

Ellsberg, D. (1961). 'Risk, ambiguity, and the savage axioms', *Quarterly Journal of Economics*, **75**, pp. 643-669.

Epstein, L. and M. Schneider (2007). 'Learning under ambiguity', *Review of Economic Studies*, **74**, pp. 1275-1303.

Epstein, L. and M. Schneider (2008). 'Ambiguity, information quality and asset prices', *Journal of Finance*, **63**, pp. 197–228.

Ertugrul, M., J. Lei, J. Qiu and C. Wan (2017). 'Annual report readability, tone ambiguity, and the cost of borrowing', *Journal of Financial and Quantitative Analysis*, **52**, pp. 811–36.

Fama, E. F. and K. R. French (1997). 'Industry costs of equity', *Journal of Financial Economics*, **43**, pp. 153–193.

Finkelstein, S., D. C. Hambrick and A. A. Cannella (2009). *Strategic Leadership: Theory and Research on Executives, Top Management Teams, and Boards*. New York: Oxford University Press.

Foss, N. and L. Weber (2016). 'Moving opportunism to the back seat: Bounded rationality, costly conflict, and hierarchical forms', *Academy of Management Review*, **41**, pp. 61-79.

Friberg, R. and T. Seiler (2017). 'Risk and ambiguity in 10-Ks: an examination of cash holdings and derivatives use', *Journal of Corporate Finance*, **45**, pp. 608-631.

Gao, Y., T. Driouchi and D. J. Bennett (2018). 'Ambiguity aversion in buyer-seller relationships: A contingent-claims and social network explanation', *International Journal of Production Economics*, **200**, pp. 50–67.

Grant, R.M. (1996). 'Toward a knowledge-based theory of the firm', *Strategic Management Journal*, **17**, pp. 109–122.

Griffin, J.M. and M.L. Lemmon (2002). 'Book-to-market equity, distress risk, and stock returns', *Journal of Finance*, **57**, pp. 2317–2336.

Grilli, L. and S. Murtinu (2018). 'Selective subsidies, entrepreneurial founders' human capital, and access to R&D alliances', *Research Policy*, **47**, pp. 1945–1963.

Grullon, G., E. Lyandres and A. Zhdanov (2012). 'Real options, volatility, and stock returns', *Journal of Finance*, **67**, pp. 1499–1537.

Hales, C. (1999). 'Why do managers do what they do? Reconciling evidence and theory in accounts of managerial work', *British Journal of Management*, **10**, pp. 335−350.

Herhausen, D., R. E. Morgan, D. Brozović and H. W. Volberda (2020). 'Re‐examining strategic flexibility: A meta‐analysis of its antecedents, consequences and contingencies', 25 June, *British Journal of Management*, https://doi.org/10.1111/1467-8551.12413.

Hirshleifer, D., M. Jian and H. Zhang (2018). 'Superstition and financial decision making', *Management Science*, **64**, pp. 235–252.

Holbrook, D., W. M. Cohen, D. A. Hounshell and S. Klepper (2000). 'The nature, sources, and consequences of firm differences in the early history of the semiconductor industry', *Strategic Management Journal*, **21**, pp. 1017–1041.

Holcomb, T. R., R. M. Holmes Jr and B. L. Connelly (2009). 'Making the most of what you have: managerial ability as a source of resource value creation', *Strategic Management Journal*, **30**, pp. 457–485.

Hussinger, K. and S. Pacher (2015). 'Information ambiguity and firm value', *Applied Economics Letters*, **22**, pp. 843-847.

Hussinger, K. and S. Pacher (2019). 'Information ambiguity, patents and the market value of innovative assets', *Research Policy*, **48**, pp. 665–675.

Ioulianou, S. P., L. Trigeorgis and T. Driouchi (2017). 'Multinationality and firm value: The role of real options awareness', *Journal of Corporate Finance*, **46**, pp. 77-96.

Ioulianou, S. P., M. J. Leiblein and L. Trigeorgis (2020). 'Multinationality, portfolio diversification, and asymmetric MNE performance: The moderating role of real options awareness', 20 August, *Journal of International Business Studies*, https://doi.org/10.1057/s41267-020-00357-3.

Kester, W. C. (1984). 'Today's options for tomorrow's growth,' *Harvard Business Review*, **62**, pp. 153-160.

Keynes, J. M. (1921). *A Treatise on Probability*. London: MacMillan.

King, A. W. and C. P. Zeithaml (2001). 'Competencies and firm performance: examining the causal ambiguity paradox', *Strategic Management Journal*, **22**, pp. 75–99.

Knight, F. H. (1921). *Risk, Uncertainty, and Profit*. Boston, MA: Houghton-Mifflin.

Koester, A., T. J. Shevlin and D. Wangerin (2016). 'The role of managerial ability in corporate tax avoidance', *Management Science*, **63**, pp. 3285–310.

Kogan, L., D. Papanikolaou, A. Seru and N. Stoffman (2017). 'Technological innovation, resource allocation, and growth', *Quarterly Journal of Economics*, **132**, pp. 665-712.

Kogut, B. and N. Kulatilka (2004). 'Real options pricing and organizations: The contingent risk of extended theoretical domains', *Academy of Management Review*, **29**, pp. 102-110.

Kor, Y. Y. (2003). 'Experience-based top management team competence and sustained growth', *Organization Science*, **14**, pp. 707–719.

Koussis, N. and M. Makrominas (2015). 'Growth options, option exercise and firms' systematic risk', *Review of Quantitative Finance and Accounting*, **44**, pp. 243–267.

Kraft, H., E. Schwartz and F. Weiss (2018). 'Growth options and firm valuation', *European Financial Management*, **24**, pp. 209–238.

Krishnan, G. and C. Wang (2015). 'The relation between managerial ability and audit fees and going concern opinions', *Auditing: A Journal of Practice and Theory*, **34**, pp. 139–60.

Leiblein, M. J., J. S. Chen and H. E. Posen (2017). 'Resource allocation in strategic factor markets: A realistic real options approach to generating competitive advantage', *Journal of Management*, **43**, pp. 2588–2608.

Li, Z., J. Müller, P. P. Wakker and T. V. Wang (2018). 'The rich domain of ambiguity explored', *Management Science*, **64**, pp. 3227–3240.

Loughran, T. and B. McDonald (2011). 'When is a liability not a liability? Textual analysis, dictionaries, and 10-Ks', *Journal of Finance*, **66**, pp. 35–65.

Lyle, M.R. (2019). 'Information quality, growth options, and average future stock returns', *The Accounting Review*, **94**, pp. 271–298.

Makrominas, M. (2017). 'Recognized intangibles and the present value of growth options', *Review of Quantitative Finance and Accounting*, **48**, pp. 311–329.

McGrath, R. G. (1997). 'A real options logic for initiating technology positioning investments', *Academy of Management Review*, **22**, pp. 974-996.

Merton, R.C. (1977), 'An analytic derivation of the cost of deposit insurance and loan guarantees', *Journal of Banking & Finance*, **1**, pp. 3-11.

Miao, J. and N. Wang (2011). 'Risk, uncertainty, and option exercise', *Journal of Economic Dynamics and Control*, **35**, pp. 442-461.

Miles, R. E. and C. C. Snow (1978). *Organizational Strategy, Structure, Process.* New York: McGraw-Hill.

Mosakowski, E. (1997). 'Strategy making under causal ambiguity: conceptual issues and empirical evidence', *Organization Science*, **8**, pp. 414–442.

Nishimura, K. and H. Ozaki (2004). 'Search and Knightian uncertainty', *Journal of Economic Theory*, **119**, pp. 299-333.

Nishimura, K. and H. Ozaki (2007). 'Irreversible investment and Knightian uncertainty', *Journal of Economic Theory*, **136**, pp. 668-694.

Ogden, J. P. and S. Wu (2013). 'Reassessing the effect of growth options on leverage', *Journal of Corporate Finance*, **23**, pp. 182-195.

Park, H. D. and P. C. Patel (2015). 'How does ambiguity influence IPO underpricing? The role of the signalling environment', *Journal of Management Studies*, **52**, pp. 796–818.

Posen, H. E., M. J. Leiblein, J. S. Chen (2018). 'Toward a behavioral theory of real options: Noisy signals, bias, and learning', *Strategic Management Journal*, **39**, pp. 1112–1138.

Sautua, S.I. (2017). 'Does uncertainty cause inertia in decision making? An experimental study of the role of regret aversion and indecisiveness', *Journal of Economic Behavior & Organization*, **136**, pp. 1–14.

Siegel, R., E. Siegel, I.C. Macmillan (1993). 'Characteristics distinguishing high growth ventures', *Journal of Business Venturing*, **8**, pp. 169–180.

Smit, H. T. J. and L. Trigeorgis (2004). *Strategic Investment: Real Options and Games*. Princeton: Princeton University Press.

So, R. H. Y. and T. Driouchi (2018). 'Improving volatility forecasts using market-elicited ambiguity aversion information', *Financial Review*, **53**, pp. 705–740.

Tong, T. W. and J. J. Reuer (2006). 'Firm and industry influences on the value of growth options', *Strategic Organization*, **4**, pp. 71–95.

Tong, T. W. and J. J. Reuer (2007). 'Real options in multinational corporations: organizational challenges and risk implications', *Journal of International Business Studies*, **38**, pp. 215–230.

Tong, T. W., T. M. Alessandri, J. J. Reuer and A. Chintakananda (2008). 'How much does country matter? An analysis of firms' growth options', *Journal of International Business Studies*, **39**, pp. 387–405.

Trautmann, ST. and U. Schmidt (2012). 'Pricing risk and ambiguity: The effect of perspective taking', *Quarterly Journal of Experimental Psychology*, **65**, pp. 195–205.

Trigeorgis, L. (1996). *Real Options*. Cambridge, MA: MIT Press.

Trigeorgis, L. and N. Lambertides (2014). 'The role of growth options in explaining stock returns', *Journal of Financial and Quantitative Analysis*, **49**, pp. 749-771.

Trojanowska, M. and P. M. Kort (2010). 'The worst case for real options', *Journal of Optimization Theory and Applications*, **146**, pp. 709–734.