A Real Options Approach to growth opportunities and resilience aftermath of the COVID-19 Pandemic

Abstract

Purpose - Facing the challenges posed by the Pandemic of COVID-19, this paper contributes to the resilience of businesses through the development of a Real Options Approach (ROA) that provides alternatives and opportunities for a Decision Process (DP) under situations when future events and outcomes are unknown and not capable of being known from current information.

Method - This paper involves a stochastic modelling process in generating a set of absolute option values, utilising available data and scenarios from the COVID- 19 pandemic event. The modelling and simulations using ROA suggest how strategic portfolios resolve the growing problem during the endemic to all but in the most isolated societies.

Findings - We find the emergent correlation between circuit breakers and lockdowns, which have brought about a 'distorted gravity' effect (inverse growth of global businesses and trades). However, 'time-to-build' real options (i.e., deferral, expand, switch, and compound exchange) start to function in the adaptive-transformative capabilities for growth opportunities of both government and corporate sectors. Significantly, some sectors grow faster than others while the compound exchange remains primarily challenging. Clearly, the government and corporate sectors are entangled, inevitably, the decoherence allows for the former to change uncertainty in the latter; therefore, government sector options change option values in the corporate sector.

Originality/values - The ROA by empirically focusing on both government and corporate sectors demonstrates under conditions of uncertainty how options in decision making generate opportunities that hitherto have not been recognised and exercised upon by research in the immediate context of the COVID-19 Pandemic. Importantly, the ROA provides an insightful concatenation (capability – behaviour approach) that drives resilience.

Keywords Pandemic, Real options, Dynamic capabilities, Growth opportunity, Resilience

Paper type Research paper

Introduction and motivation

Business and social environments are in a state of considerable flux where "uncertainty is the only certainty, there is, and knowing how to live with insecurity is the only security." (John Allen Paulos, cited in Harikae *et al*., 2020 p.1). The COVID-19 Pandemic has confronted human societies with far-reaching challenges and has persistently inspired scholars, governments, practitioners, and others by drawing on their remarkable adaptive capacities toward the complexity of contemporary decision problems. Research has taken persistent challenges from how human adaptations improve the capacity for creating, forging, preserving, and modifying connections between variant organisational activities, thus, increasing organisational populations through our knowledge of how they evolve (Augier and Teece, 2009; Li and Van den Steen, 2021; Peysakhovich and Rand, 2016; Van den Steen, 2019). Research has adopted the stochastic process in seeking explanations, modelling uncertainty, and inspiring solutions for economic organisation (Burggraef *et al*. 2018; Dixit and Pindyck, 1994; Kogut and Kulatilaka, 2001; Trigeorgis, 1996). However, despite our extant knowledge, how that organisation survives, revitalises, importantly, fitting in unprecedented times remains under-researched. Concerning rapidly changing and unpredictable environments, we lack a coherent model for dealing with uncertainty, specifically, with COVID-19. The Pandemic is believed to be consistently and widely present in many societies, in effect, it has become endemic, given the evolving and transformed Alphavirus, Delta virus, and new Omicron, their critical contagion effects. The crucial question raised is: How can organisations deal with uncertainty, exploring business growth opportunities, towards resilience aftermath of the COVID -19 Pandemic?

Towards the challenge, recent research advancement shows that scholars have linked real options thinking to organisations dealing with the uncertainty of the Pandemic (Chakhovich and Marttila, 2020; Craighead, Ketchen, and Darby, 2020; Harikae et al., 2020). We take a step

further to develop the Real Options Approach (ROA) and demonstrate how ROA can be employed as a set of thinking tools by decision-makers for their decision processes that concern the COVID-19 pandemic consequences. We define the term 'options' as that opposed to alternative or possibility in understanding problem-solution boundaries for decision-makers. We define 'real' as developing and testing relevant alternatives hypotheses, thus, creating opportunities for business growth and organisational resilience. Within a more general conception, Trigeorgis and Reuer (2017, p. 43) explain the term as "amounts to describing what makes them "options," and then what makes them "real"." Within the essential objectives of this paper, we provide the ROA that allows for decision-makers to reveal and subsequently exploit the unknowledge or information gaps that remain hidden until subsequently discovered through making connections and reconfiguring activity sets. We theorise that in the challenging environment organisational resilience implies dynamic capabilities such as adaptive and transformative capacity, and how businesses sense the change and transform routines into specialised assets (Augier and Teece, 2009; Teece, 2011; Schoemaker *et al.*, 2018). We define that resilience should apply to small perturbations (ie. a technical system change) as well as severe disruptions (i.e., the COVID-19 Pandemic), and has the capacity to absorb shocks and disturbance (Gallopin, 2006; Kohn, 2007), for which ROA offers a return to an extant growth trajectory under rapidly changing conditions. More importantly, towards resilience, we show how ROA enables organisations to build dynamic capabilities (Eisenhardt and Martin, 2000; Pentland *et al.*, 2012; Teece and Leih, 2016; Schoemaker *et al.*, 2018), while resilient organisations, in effect, demonstrate abilities to shape, reshape, configure and reconfigure, resources and capability routines (Helfat and Peteraf, 2003; Teece, 2007, 2011), towards the environment that is consistently changing.

The above defined study objectives suggest that we make two major contributions to the extant literature. First, we advance the "time-to-build" real options and contribute to the

literature on organisations' dynamic capability. In the extant literature, real options are used to support investment calculation methods (Verbeeten, 2006), and analyse the profitability of strategic investments (Tavles *et al*., 2007; McGrath and Nerkar, 2004). Research has suggested that real options allow businesses to build their assets flexibly, considering strategic alternatives when uncertainty is present and changing the investment (Mun, 2006). Scholars have shown how financial market tools can be used to value real options in the corporate sector (Johnston *et al*., 2008) and the ability of company managers to delegate investment decisions and how selected performance measures are affected by the real options available (Baldenius *et al.,* 2016). We show how ROA builds up the characteristics of dynamic capabilities that are primarily concerned with the functions in discovery and creation of connections to fulfil expectation values, rather than having failed to perceive them. We explore the relationships that have option value may have remained 'hidden in plain sight' and remain to be created or discovered while critically, options evolve with emerging uncertainty whereby the decision process (DP) correlates with both uncertainty and growth opportunities. In doing so, our second contribution lies in the pivotal point that we bring forward, that is how ROA implies for the formation of strategy, and how decision-makers exploit the theoretical insights to generate a coherent model for dealing with the uncertainty of economic organisations towards resilience aftermath of the COVID-19 Pandemic. In the extant literature, within supply chains (Flynn, Koufteros, and Lu, 2016), real options thinking has been applied to information technology initiatives (Tiwana, Wang, Keil, and Ahluwalia, 2007), and other supply chain projects (Hult, Craighead, and Ketchen, 2010). Real options conceptual frameworks have also been used for studies of firm resources and capabilities (Dierickx and Cool, 1989; Kylä̈heiko *et al*., 2002) and networks of reserves and flexibility (Loasby, 2002; Potts, 2000), modelling lags theoretical developments in complex environments. Within our objectives, we demonstrate how and why "deferral" and "abundant" options can be also disadvantages whilst, on the other hand, why

compound switch is advantageous. This is a step advanced move in research, building on real options modelling (e.g., Dixit and Pindyck, 1994; Kogut and Kulatilaka, 2001; Trigeorgis, 1996; Trigeorgis and Reuer, 2017).

The structural content of the paper shows that, first, we draw on available databases and current debates. It is widely known the Pandemic has had a considerable impact on wider reaches of societies, and the impact has become endemic in a post-pandemic environment. Governments continue to respond using a range of measures that include full lockdowns, circuit breakers (mini lockdowns of a specified time-period) to stem the reproduction rate of the virus, which have also created a 'distorted gravity' effect for global businesses. Secondly, in response to the challenges, we use ROA to explore how organisations sense the environments when the solution set is uncountable, yet sense can be made by linking ROA to the DP. We draw out the 'time-to-build' real options in a sequential framework to provide a set of scenarios as emerging responses to economic and business challenges. For example, the UK Government Plan A and Plan B results have been desirable while vaccine programs (Biontech-Pfizer and Oxford-AstraZeneca) gradually strengthen the first (Plan A, lockdown). Thirdly, we continue to develop research methods by which we demonstrate how we address a gap in prior literature that has barely begun to address. Importantly, we integrate real options valuation methods with dynamic capabilities' thinking to explain resilience.

Literature review and critical issues

Lockdown and "distorted gravity"

The COVID-19 epidemiology describes how rapid the virus percolates within and across societies. Given the evolving and transformed Alpha virus, Delta virus, and current Omicron, the contagion effect is the virus can be contracted through both direct and indirect effects such

as with infected people (direct) and through surfaces in the immediate environment (indirect) from objects used on the infected person and medical equipment (Gov. UK, 2020; WHO, 2020). Virus cases and fatalities continue to rise across countries, regions, and continents, including countries with less international travel and global business activity (WHO, 2021). Consequently, COVID-19 is more than a pandemic; it is syndemic- the term coined by Merrill in the mid-1990s (see, Merrill, 2009). The syndemic defines COVID-19 as a synergistic epidemic, having more than two concurrent sequential disease clusters (UK NHS 2020; WHO, 2020) based on the human population and other biological interactions. The COVID-19 pandemic containment to date has relied on measures to reduce the virus transmission rate. Full lockdowns and various circuit breakers such as targeted local lockdowns for specific periods are frequently adopted to curb the spread of the virus, especially in social settings where the virus remains virulent (WHO, 2020; Gov.UK, 2020). 'Lockdowns' informed the consequent pandemic impact that quickly revealed 'distorted gravity' due to the increasing pandemic effect, the increasing level of circuit breakers (lockdowns). Gravity models in economic theory (e.g., Bergstrand, 1985; Chaney, 2018) recognise the benefits of globalisation such that a gravitational pull accelerates economic activity through increasing socioeconomic interdependencies across ever-expanding geographical regions, generating further trade and enhanced production.

However, when the pandemic impact deepened, our figures show, India GDP growth was 7% and 5% in the second quarter of 2018 and 2019, respectively, but in 2020, GDP had fallen dramatically by 23.5. And UK is the second hardest-hit country with GDP down by 21%, France is the third hardest-hit country, with GDP falling by 18.9%, and the United States 9.1. While GDP contracted by an average of 11.8% in all other G20 economies, in the second quarter of 2020, India recorded the largest annual fall (23.5%). The widely felted effect included China; though it was the only G20 country recording growth the annual growth of

3.2% during 2020, the growth rate was still much lower than the country's average growth before the Pandemic (see, World Bank, 2018).
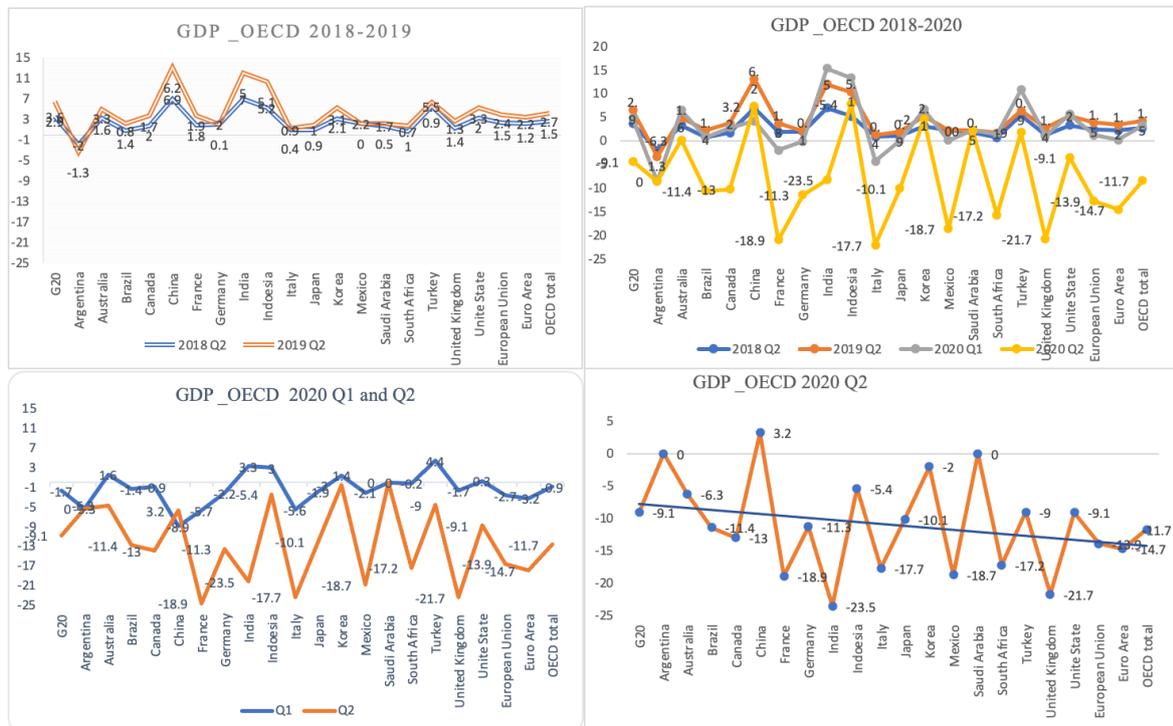
Figure 1a-1d. Distorted gravity: COVID-19 negative impact on GDP. Generated by the authors in using OECD release.

Diffusing business resilience

While many businesses demonstrated the Darwinian struggle to survive, others demonstrated evolutionary fitness and survival, with the pandemic situation creating opportunities that stimulated growth in some areas. For example, Liu, Wang, and Lee (2020) provide evidence-based information on the US crude oil market. Their results show that the COVID-19 Pandemic cannot exert a negative effect but has a statistically significant positive effect on crude oil and stock returns. In using the example of university programs: MBA and Public Health, we reveal that student admissions have remarkable features such as doubling growth rates, comparing 2021 student numbers with 2020. Further, during the time, many online businesses tripled their annual revenues (e.g., Amazon, Facebook or Meta, UK Royal Mail, and so forth). The

emerging trends suggest that in high-velocity environments, organisations can recognise the agility, adaptation, speed, and alternative use of resources that provide a transformational quality in achieving business effectiveness, different positions, and movement.

While the COVID-19 virus may present fewer options for the corporate sector since many companies had to shut down their operations, thus, eliminating the possibilities for keeping options alive. Other corporates had options, those selling essential products (i.e., supermarkets), services (i.e., banking and insurance), communication (mobile and online social networks), energy companies, and education. Thus, despite the Pandemic, many organisations have a range of growth opportunities. Social distancing and the focus on online activities increase the possibilities for corporate and government sectors to capitalise on advances in technology, creating opportunities for how new activity configurations, new technologies evolve. And many organisations have responded to the exogenous events, their behaviour and capability routines are disaggregated and reintegrated in fitting into the changing conditions. Their doing demonstrates the characteristics of dynamic capabilities, as we defined earlier.

The intriguing features, thus far, support our argument for resilience that is, many businesses can absorb the impact by undergoing 'resiliency' to be demonstrated by organisations' evolutionary fitness, adapting to the changes, to induce replication or reproductive success under changing environmental conditions. Wherein, dynamic capabilities deal with the paradox caused by the Pandemic such as the lockdown constraints, as well as opportunities. However, critical issues remain challenging. First, there is little evidence to suggest that dynamic capabilities can be sustainable over extended periods, in different contexts. In such situations, organisations should remain resilient, but some have become exhausted from continuous transformation (D'Aveni, Dagnino, Smith and Zajac, 2008). For instance, government options of 'lockdown' and circuit breakers reduced the value of many corporate options through lost production while increasing option values for corporates that could move their business online.

More widely, reduced production, lower profits, lower employment, reduced wages, and concomitant social problems and health disorders created widespread disruptions across large swathes of societies, though there were gains for several sectors. Critically, this leads to our second critical point. During the Pandemic, it appeared that government sectors had more options that were 'hardware' while the corporate sector had fewer options and were often trapped in the reactive 'software' or passive cycle. The point raised is decision making in both sectors subjects to substantial uncertainty and risk contingency. Thus, we contribute to opening the "black box" (Lewins, 2008; Zollo and Winter, 2002) of organisational capabilities.

Overview of the Real Options Approach (ROA)

We begin by considering the third source of uncertainty during the Pandemic in addition to the first, external (i.e., virus) and the second, internal (i.e.,s business undertainty). Chakhovich and Marttila (2020) identified the emergence of a plethora of conflicting research findings from variant research centres across several countries and the diversity among expert opinions. We consider the critical consequence, such as the paucity of information, and how governments worldwide introduced lockdowns and various circuit breakers. Although the above option helps with halting the spread of the virus, buying time to explore more scientifically grounded alternatives, such decisions under the condition of a lack of information also confront crucial risks and uncertainty, affecting business investment contingency, at least, for a certain period. From the real options perspective, Friedl (2002) suggested putting more weight on the decisions that occur during the sequence of investments rather than the initial decision. Carr (1988) stressed that real option dynamics are assumed to follow a well-defined process rather than using option techniques to predict future values of the underlying asset. This is because option pricing is indispensable, compounded if a decision change it changes options. Trigeorgis and Reuer (2017) describe real options as an inseparable package and are embedded in the same asset, allowing options to interact.

To continue with the preceding, we explain that such interaction creates advantages among options while it allows for investment flexibility such as deferring undertaking the project or to expand the project's scale by making an additional investment outlay. Whereas, although to permanently abandon a project is also an option, arguably, that abandonment without recovery will change the survival opportunity. For example, government sectors' Plan B by executing 'circuit breakers' (e.g., frequent small lockdown, or other restrictions) not only change its time-to-build options, but also cause corporate sectors either to switch or to abandon the investment. Although the compounded exchange can generate future option values, the current reality is the former by changing uncertainty in the latter, therefore, changing options incorporate opportunities such as revitalisation and growth. Thus, we bring Figure 2 by which to explain a set of options, including the options to *i)* defer, *ii)* expand, *iii)* switch, and *iv)* abandon (as compound exchange options).
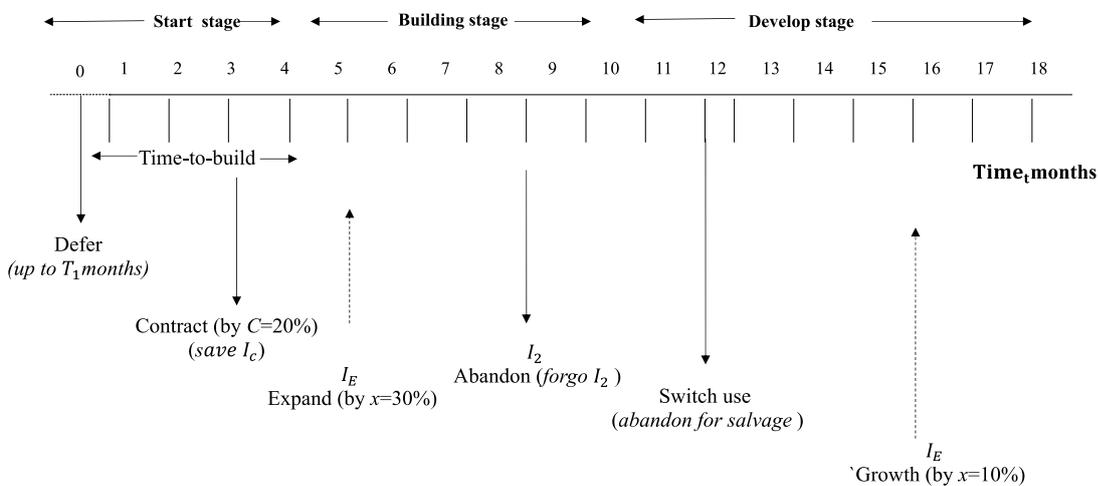

Fig. 2. Assumed government sector ROA of defer, expand, and switch

These four options were crucially concerned about the decision process during the unprecedented events of the COVID-19 Pandemic. First, with the lockdown decision in the timeline from 16th March 2020 to 8th March 2021 (IFG, 2021a), we explain this option together with the UK vaccine rollout programs during the time Dec 2020-Dec 2021 (Baraniuk, 2021;

IFG, 2021b), which are part of the government sector's real options portfolio. The above informed Project A: deferral, and Project B: expand. We evaluate the lockdown option by regarding it as a 'deferral' in a ROA to the decision process (DP). For instance, the initial single 'deferral' option by 'local lockdowns' or 'circuit breakers' halt the temporary spread of the virus, especially in social settings where it remains virulent (WHO, 2020; Gov.UK, 2020). The forms and means of control emerge endogenously (i.e., national institutions act collectively) to address the impact of the COVID-19 Pandemic. The benefits, more generally, are the underlying values at a particular point in time that have been seen as "saving lives", "saving the NHS" (National Health Service), and "protect the vulnerable".

The deferral (Project A) therefore has an attempt to minimise the detrimental effects on the future economy. The decision process in our proposed sequential ROA (Figure 2, with references of Trigeorgis, 1996; Trigeorgis and Reuer, 2017), with initial considerations, becomes an addition to the government sector acquired a $t =$12-months (deferral) option. Thus, it also enabled further call and put options ($T_1 = 1$). Then the option to expand (Project B) can be a strategic dimension as it can make additional follow-up investments by building excess production capacity that would enable it to produce at a faster rate. The further opportunities, therefore, will be, for example, vaccine rollout and contractual programs (expand) and its associated (i.e., production infrastructure). If market conditions deteriorate, the government sector can choose to forgo any future planned investments (I_2).

In moving to option three (Project C) and option four (Project D), we explain the effects on corporate sectors' options on this account. Importantly, we develop ROA for organisations to reduce uncertainty and adaptation over time to evolutionary changes of the environments. This is revealed by Project C: compound switch by corporate sector. With respect to the above, from a very positive perspective, we evaluate government deferral option, and its impact on business, the corporate sector. So that, the ROA in a switching option from those planned business

strategies or investments to an alternative use (specified salvage value). Switching options may account for the situation that as COVID-19 unfolded, pharmaceutical companies used existing drugs such as Hydroxychloroquine or Remdesivir to treat virus symptoms (Craighead *et al.*, 2020), therefore expanding the production of key medical supplies. We also consider the HE sector's example while many universities switched from physical space to online teaching, Virtual or Ultra rooms, online libraries, blackboards (web-based platform), synchronous and asynchronous teaching and learning. These reflect the concepts of compound exchange in real options. And we titled these in kind as Project C, switching options.

However, with respect to Project D: compound abundant option by services of the corporate sector, we reveal some critical issues and consequently, negative impact. The COVID -19 pandemic caused unprecedented events and a crisis of some businesses. Critically, this would be disadvantageous, if organisations abandon their options and investment as indicated in Figure 2. Inevitably, costs incurred to maintain supply chains (restaurant and hotel bookings etc), energy bills, maintenance of unused university campus buildings/facilities such as shops, recreation centres, restaurants changed into home dining modes, aircrafts grounded, and airport facilities abandoned or considerably under-utilised. In contrast to the above, the abandonment from a positive perspective can be related to preparation and time-to-build for alternative investments such as concerning government sector' option, develop an arsenal of real options for navigating the associated opportunities, in the light of our proposed ROA.
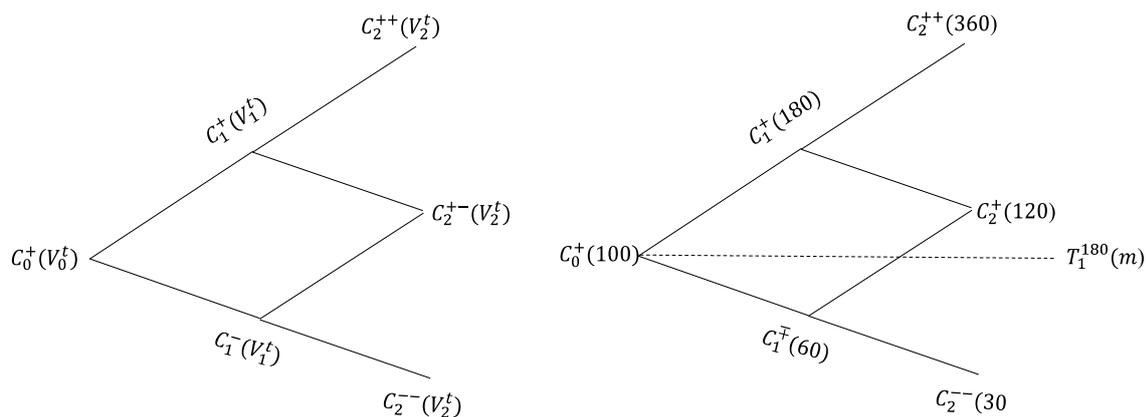
Figure 3 Compound Options for Assumed Opportunities

Thus, as depicted by Figure 3, we use the binomial framework of Cox, Ross, and Rubinstein (CRR, 1979), where we provided conceptual values for our estimate in coming up sections. The CRR's framework has been widely used to value compound/sequential real options (e.g., Kogut & Kulatilaka, 2001; Copeland & Tufano, 2004). To support the above, not different from other research, we have also made greater use of two Brownian motions. In our model evaluations of ROA, we demonstrate how they are correlated and thus influence the movements for both assets. To provide some expected values through the compound options, we also consider Carr's (1988, 1995) as combined elements of compound options, both expand and defer. The essential points derived from our ROA are the time-to-build (Figure 2) options, suggesting that deferral and abandon are an inseparable package with a set of underlying assets, and the options are embedded in the same asset. Our ROA suggests even if the source of the uncertainty is a lack of information, this option may be still more valuable than abandonment. Otherwise, the ability to suspend investment before spending the total investment expenditures reduces the irreversibility of the whole investment project.

Our arguments find support from prior work. For instance, Friedl (2002) believes that more reversible investment decisions may be undone, and therefore investment will take place sooner; however, if conditions change, the firm can react to the new situation by changing the

cash flow pattern. Although the invested capital cannot be recovered, a firm can reduce the planned investment expenditures by stopping an unfavourable project, thus the firm avoids the remaining investment outlays. Friedl (2002) and Margrabe (1978) suggest that the decision to suspend or abandon a project is often very unpopular, and management seems to avoid such decisions. If management has the option to suspend, management should invest in a higher number of projects and monitor the value drivers of each project more carefully during the life of their projects. We demonstrate how and why some projects (ROA) are more feasible than others. In what follows, we bring up the ROA modelling evaluations of the four projects and methodological approaches.

Modelling methods and simulation processes

Our methods generally involved a stochastic modelling process in generating a set of option values, utilising available data and scenarios from the COVID- 19 pandemic event. The modelling and simulations in using ROA suggest how strategic portfolios resolve the growing problem during the endemic to all but in the most isolated societies. We followed a standard Wiener process (i.e., a real-valued continuous-time stochastic process named in honour of American mathematician Norbert Wiener), building on Trigeorgis (1996), Trigeorgis and Reuer (2017). Our ROA also considers recent studies (Chakhovich and Marttila, 2020; Craighead, Ketchen, and Darby, 2020; Harikae *et al*., 2020). To explore the opportunity to invest in a project using Margrabe's (1978) call option on the value of the project future cash flows (P) with the exercise price equal to the required investment (K). For instance, Margrabe describes the evolution of the underlying asset (i.e., P and K) returns by the following stochastic differential equations: We employ simulation modelling and empirical investigations while considering current debates and relevant data sets. We, therefore, bring up a tentative

understanding, and importantly, offer potential solutions by exerting a proxy that has not hitherto been recognised by research in the immediate aftermath of the COVID-19 Pandemic.

The option to defer

To accommodate the government sector option, we start with the explanation and evaluation the deferral (Project A) option. This has an attempt to minimise the detrimental effects on the future economy while option to defer (an American call option) exercises on the necessary investment outlay (potential values). It is assumed the Project A value, *V*, can be obtained by using a stochastic process to identify a hidden option, or create an opportunity for the project life or related businesses, through its outlays, which can be written by Eq. 1:

$$\frac{dV}{V} = \alpha\, dt + \sigma\, dz \;\ldots\ldots \quad (1)$$

where *V* is the present value of the deferral project, α is the instantaneous expected return on the project, σ is the instantaneous standard deviation of the project value, and *dz* is an increment of a standard Wiener process.

To date, the UK government has a 12-months project granting lockdown (IFG, 2021a). The exclusive right to defer (ie. defer normal patterns of business) by the undertaken lockdown project, also means that the business sector has 12 months to defer (i.e. contract new stores or deliver investment projects). The deferral option in evaluation, therefore, becomes determined by the positive amount of the option in the deferability provided by the lockdown project value. From Eq. 2 below, the project value change, *dV,* is assumed to follow the standard diffusion Wiener process given by

$$\frac{dV}{V} = (\alpha - \delta)dt + \sigma dz \;\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where α, σ, dz, and dz are as defined earlier, and δ is the rate of return shortfall between the equilibrium total expected return required of an equivalent-risk asset (i.e., traded financial asset, or any proportional cash-flow, or dividend-like pay-out).

Theoretically, the value of lockdown option (Project A) will substitute the appropriate values for the payoffs to the deferral for the business growth opportunities (or equity claims), E^+ and E, in the risk-neutral valuation relationship,

$$E^+ = \max(V^+ - I_0, 0)$$

$$E^- = \max(V^- - I_0, 0)\dots\dots\dots\dots \quad (3)$$

Then, we have below values (accommodating with Figure 3) when the project starting value as V (i.e. £ 180 million) for a time $t = 12$ months (4 quarters), risk-free (or risk neutral) rate r (per quarter) = 0.4, the call price $I = 104$. The value with the option to defer (implicit in the lockdown) has asymmetrically altered the structure of the payoffs. Then the estimated option value would suggest that instead of paying for the cost of investment (£ million) immediately, the optimal defer (until the gross value of the project is roughly twice of the investment cost) would be advantageous because the deferral drives value growth in both government project and benefits of the corporate sector, given the reason we provided (Sn2, p. 10, and p.16). This leads to our first Hypothesises:

H1: When the equilibrium of Defer premium = Expanded non present value (NPV) - Passive NPV based is a positive value, the deferral will be a significant option, and hence it is optimal to defer.

Proof 1: Project A, Phase 1 consists of attempts to stem the transmission of the virus using lockdowns and circuit breakers, which provide the option to delay while gathering information and undertaking vaccine discovery. Then A favourable outcome from Phase 1 would be significantly reduced virus transmission rates coupled with successful vaccine discovery. And

in response to a favourable Phase 1 outcome, Phase 2 could see the gradual relaxation of lockdown measures and the scaling up of the vaccination program for option two: growth opportunities.

The option to expand

Now we are thinking of expanding option given government sector, Project B. During the lockdown from 16th March 2020 to 8th March 2021, the UK vaccine rollout programs also started from Dec 2020 to Dec 2021 (IFG, 2021b). The decision process (Figure 2, with references of Trigeorgis, 1996; Trigeorgis and Reuer, 2017) moved to the addition to the government sector acquired a t =12-months (deferral) option that had enabled some call and put options ($T_1 = 1$) such as to commence Project A enabled Project B building, the expanding investment for Project B. From the view of a European growth option, the present value of Project B cash inflows is, V_T, at time T with exercise price I. Suppose Project A value would increase with further Project B investment such as the investments in Oxford-AstraZeneca, or investments in Serum Institute India for production licencing, Figure 2).

The above expansion option theoretically shows that the option price for simulation is determined by the standard European call, C, option with Geske's (1979) framework:

$$C_0 = e^{-rT_2}\left[V_T M\left(k,h;\rho\right) - K_1 M\left(k - \sigma\sqrt{K_1}, h - \sigma\sqrt{K_1};\rho\right)\right] - K_2 e^{-rT_1} N\left(k - \sigma\sqrt{T_1}\right) \ldots\ldots (4)$$

And

$$h = \frac{\ln\left(\dfrac{v_T}{K_1}\right) + 0.5\sigma^2 T^1}{\sigma\sqrt{T_1}},$$
$$\ldots\ldots\ldots\ldots (5)$$
$$k = \frac{\ln\left(\dfrac{v_T}{v_c}\right) + 0.5\sigma^2 T_2}{\sigma\sqrt{T_2}},$$

Where

V_T = present value

V_C critical value above which the first call option will be exercised

K_1 = investment outlay (or I)

K_2 = investment outlay for the downstream

σ = volatility of the rate of change of the downstream

r = riskless rate of return.

$N(\bullet)$ = univariate normal distribution function,

$M(k, h: \rho)$ = bivariate cumulative normal distribution function $\rho = \left(T_1 / T_2\right)^{\frac{1}{2}}$.

If market conditions deteriorate, the government sector (see, Fig. 2) can choose to forgo any future planned investments (I_2). At this stage the government sector may also choose to reduce the scale by $c\%$, such as production scales and facilities of cost (I_c). The value of the investment opportunity, including the value of the option to expand, E, then becomes now it is possible for government sectors to review their decision-making process based on FNVP, which is ($_AC_0 +$ $_BC_0$)-$_AC_B$. The value of the option to expand based on the growth value, thus, suggesting that to expand with defer option, together the two projects strengthen the decision choice of the government sector. The original investment opportunity then becomes the initial-scale project plus a call option on the future opportunity (i.e., the corporate growth option of Myer, 1977). This leads to the second Hypothesis,

H2: Phase 2 With the gradual relaxation of lockdown measures implemented, time to expand option, Project B, will drive compound growth of both Project A and Project B.

Proof 2: Project B, Phase 2 is dependent on the outcome of Phase 1. Although social distancing measures would still be in place on public transport, restaurants, shops, bars, and sporting venue, but business, albeit at reduced capacity, would be restored thus providing time to build options in Phase 2. If otherwise, an unfavourable outcome such as high transmission

rates and unsustainable demand on hospital capacity would prolong phase 1 and lead to further restrictions. If this second phase is favourable, in that virus transmission is reduced to relatively low levels and hospital admissions continue to remain low, businesses may have the option to increase the scale of operation and enter a third phase, at the meantime, government sector Project B investment in vaccine program becomes more profitable.

Compound sequential options (switch and abandon)

The model as depicted by Figure 2 is also applicable for the corporate sector, as we discussed earlier (in Sn2). The corporate sector has a series of options in the subsequent context, where multiple option paths exist, the value of the underlying asset for options, therefore, might be greater. Now we evaluate the ROA as a switching option from those planned business strategies or investments to an alternative use (specified salvage value). We use Carr (1988, 1995) combining both elements of compound and options (to expand and defer) to analyse European compound (or sequential) exchange options. The call option is $C(S(V, I, \tau), E, \tau')$, giving the right upon paying an exercise price E within time to maturity τ', to acquire a subsequent simple (call) option, $S(V, I, t)$, to exchange (give up) an underlying ("delivery") risky asset, I, to receive another ("optioned") risky asset, V, within time t.

Assume V, is stochastic, E is a fixed proportion ($q\%$) of the delivery asset, i.e., $E = qI$ that the underlying risky assets V and I have no dividend-like pay-outs, and they follow a standard diffusion process as in Equation 6 and Equation 7

$$\frac{dV}{V} = \alpha \, dt + \sigma \, dz \ldots\ldots\ldots\ldots (6)$$

$$\frac{dI}{I} = \alpha' \, dt + \sigma' \, dz' \ldots\ldots\ldots\ldots (7)$$

In a risk-neutral (no-arbitrage) equilibrium, C must then satisfy the fundamental partial differential equation

$$(0.5\sigma^2 V^2 C_{VV} + \rho\sigma\sigma' VI C_{VI} + 0.5\sigma'^2 I^2 C_{II}) - C_{\tau'} = 0, \ldots\ldots (8)$$

s. t.

$$C(S, qI, 0) = \max(S - qI, 0).$$

But the value of the simple switch option, S, must also satisfy the same fundamental partial differential equation

$$(0.5\sigma^2 V^2 S_{VV} + \rho\sigma\sigma' V I S_{VI} + 0.5\sigma'^2 I^2 S_{II}) - S_{\tau} = 0, \ldots\ldots (9)$$

s. t.

$$S(V, I, 0) = \max(V - I, 0).$$

The solution to the latter partial differential equation was already derived by Margrabe (1978):

$$S(V, I, \tau) = V N(d_1) - I N(d_2), \ldots\ldots\ldots (10)$$

where

$$d_1 \frac{\ln(\chi) + 0.5 s^2 \tau}{s\sqrt{\tau}}, \ldots\ldots\ldots\ldots (11)$$

and

$$d_2 = d_1 - s\sqrt{\tau},$$

$$\ldots\ldots\ldots\ldots (12)$$

$$\chi \equiv V / I,$$

and

$$s^2 = \sigma^2 + \sigma'^2 - 2\rho\sigma\sigma'. \ldots\ldots\ldots (13)$$

Again, using the delivery asset as a numeraire (along with $E = qI$), we can reduce the dimensionality of the problem to a single stochastic variable, $\chi \equiv V / I$, that enable to solve Eq. 8 and Eq. 9 to obtain the value of the compound exchange option:

$$C(S(V,I,\tau)qI,\tau') = [V\, B(d_1^*,d_1,\rho) - I\, B(d_2^*,d_2,\rho)] - (qI)N(d_2^*), \ldots\ldots (14)$$

Where

$$d_1 \frac{\ln(\chi) + 0.5s^2\tau}{s\sqrt{\tau}}, \ldots\ldots\ldots\ldots\ldots (15)$$

$$d_2 = d_1 - s\sqrt{\tau}, \ldots\ldots\ldots\ldots\ldots (16)$$

$$d_{11}^* \frac{\ln(\chi / \chi^*) + 0.5s^2\tau'}{s\sqrt{\tau'}}, \ldots\ldots\ldots\ldots (17)$$

$$d_{22}^* = d_{11}^* - s\sqrt{\tau'},$$

$$\ldots\ldots\ldots\ldots . (18)$$
$$\chi = V / I$$

and

$$s^2 = \sigma^2 + \sigma'^2 - 2\rho\sigma\sigma', \ldots\ldots\ldots\ldots .. (19)$$

$N(\bullet)$ is the (univariate) cumulative standard distribution function, $B(a,b,\rho)$ is the bivariate cumulative normal distribution function with upper and lower integral limits a and b, respectively. The correlation coefficient ρ (where $\rho = \sqrt{\tau'/\tau}$), and χ^* is the critical value of $\chi \equiv V / I$, above which the compound exchange option should be exercised. (χ^* can be obtained by solving the indifference condition $S(\chi^*) = qI$, or after dividing (Eq. 10) by I, from $\chi^* N \equiv (d_1(\chi^*) - N(d_2(\chi^*)) = q$. Where V_T = present value of the cash inflows in year 2, $I =$ investment outlay in year 2, $\sigma =$ volatility of the rate of change of the cash inflows, $r =$ riskless rate of interests. The above leads to the third Hypothesis

H3a: With respect to government sector 'deferral' and 'expand' options, the corporate sector, Project C, by switching operation pattens will drive alternative investment, from which growth will emerge.

Proof 3a: The time-to-build (Figure 2) options suggest that deferral and switch are an inseparable package with a set of underlying assets embedded in the same asset. Many real options are sequential or compound – exercising uncovers not an underlying asset but another option, thus, experiencing expected growth opportunities. The option gives the holder the right to exercise through to the exercise date will be more realistic.

However, in following from the above projects (A, B, and C), now we have onus to explain the ROA alternative, too: positive and negative underlying asset values. In bringing options for variant business sectors, we evaluate some consequences in businesses that must terminate or to abandon some of their investment projects. For example, the government initial single option, 'local lockdowns' halt the temporary spread of the virus (WHO, 2020; Gov.UK, 2020). Air travel was temporally halted. Abandonments sometimes were perceived as allocating funds elsewhere to address more pressing needs. The COVID -19 pandemic caused unprecedented events and the crisis of some businesses.

For terminology in the correlation project, we note defer as 'D', and abandon as 'E', which are correlated and hence simulated project values for each asset are derived as follows:

$$\frac{dV_D}{V_D} = rdt + \sigma_D dZ_D \quad \text{…………………....... (20)}$$

and

$$\frac{dV_E}{VE} = rdt + \sigma_E dZ_E \quad \text{…………………......... (21)}$$

Here the two Brownian motions are correlated and thus influence the movements for both assets. To find the value of the sequential exchange (or compound switch and abandon) option,

we can also consider Carr's (1988) continuous time literature on return (increasement, W),

$W\big(V(P, K, {}_{,t_v})qk, tw.\big)$, using stochastic differential:

$$W\big(V(P, K, t_v), qK, t_w\big) = PB\big(a_1, d'_1; p\big) - Ke^{-rftv} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$B\big(a_2, d'_2; p\big) - qKe^{-rftv} N(a_2) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (23)$$

$$a_1 = \frac{In\left(\dfrac{P/Ke^{-rft_v}}{Q * e^{-rftw}}\right) + 0.5\sigma^2 t_w}{\sigma\sqrt{t_w}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots... \quad (24)$$

$$a_2 = a_1 - \sigma\sqrt{t_w} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots... \quad (25)$$

$$d'_1 = \frac{In\left(\dfrac{P}{Ke^{-rftv}}\right) + 0.5\sigma^2 t_v}{\sigma\sqrt{t_v}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots... \quad (26)$$

$$d'_2 = d'_1 - \sigma\sqrt{t_v} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots... \quad (27)$$

$$P = \sqrt{\frac{t_w}{t_v}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots... \quad (28)$$

subject to the following boundary condition: $V(P, Kt_v) \geq W\big(V(P, K, t_v), qK, t_w\big) \geq 0$ and terminal condition:

$$W\big(V(P, K, t_v), qK, 0\big) = \max\left[0, PN\big(d_1\Big(\frac{P}{K}, t_v - t_w\Big)\big) - Ke^{-rf(t_v - t_w)} N\big(d_2\Big(\frac{P}{K}, t_v - t_w\Big)\big) - qK\right] \ldots\ldots \quad (29)$$

The evaluation examines multiple options by using the scenario that considers sequential investments: the investment, I_1, is to expand, I_2, when I_1 is terminated, as the original plan is matured in 12 months and now expanded to 24 months, the second investment is to invest a new project I_3 that is correlated with I_2, by deferring. Consequently, the payoff may be expressed as the flexible net present value (FNPV) composed of the actual option premium C_A,

and the theoretical worth of option C_0. The business option or growth opportunities are available to a firm. Yet here is the assumption that the volatility is an unlevered estimate though that can be calculated, from the historical stock price volatility) and volatility on its publicly traded option prices. Where future prices are equal to the present value of the cash inflows, V_T, at time T with exercise price *I*. This drives the alternative of third Hypothesis:

H3b: With respect to government sector 'deferral' and 'expand' options, some businesses in the corporate sector, Project D, by switching operation pattens will lead to some abandonments of investment, which drive them to further uncertainty and declined growth.

Proof 3b: The FNPV arises from (-*V*)- (+*V*) = -*V*, which suggests some loss, and abandonment is not recommended. The abandonment investment in E within the time scale and value distribution is such that the economic viability requires the valuation of options on both assets while evaluating the correlation between the two assets. Our ROA suggests that if the source of the uncertainty is a lack of information, the option (of partial or switching investment than abandonment) may also be valuable. Due to the time delay and the costs (Project E, abandon) for future growth, the NPV will be negative for both (D and E). Instead, rather, the ability to suspend investment before spending the total investment expenditures will reduce the irreversibility of the whole investment project.

Analytical results of the sequential real options

We drew on data from our observations and had a set of values, which were also used accommodating with Figure 3 presented earlier. We considered the project of starting value *V* (£ 180 million) for a time *t* =12 months (4 quarters), risk-free (or risk neutral) rate *r* (per quarter) = 0.4, the call price *I* = 104 (see also Appendix 1). The value with the option to defer (implicit in the lockdown) had asymmetrically altered the structure of the payoffs. Then the estimated

option value suggested that instead of paying for the cost of investment immediately, the optimal defer is advantageous because the deferral drives value growth both in

$$E^+ = \max(V^+ - I_0, 0) = \max(180 - 112.32, 00 = 67.68)$$

$$E^- = \max(V^- - I_0, 0) = \max(60) - 112.32, 0) = 0$$

The above suggests by defer, $I_0 = 104$ growing at 8% to $I_1 = 112.32$, and

$$p = \frac{(1+r)S^+ - S^-}{S^+ - S^-} = 0.4.$$

$$E_0 = \frac{pE^+(1-p)E^- - S^-}{1+r} = \frac{0.4 \times 67.68 + 0.6 \times 0}{1+r} = 25.07$$

Thus, Defer premium = 25.07-(-4) = 29.07 (million).

Based on the above modelling, Project A to defer is significant and it is optimal to defer. H1 is supported because *Project A obtains the positive equilibrium of defer premium.*

With respect to Project B, we identified the project value for the excise £ (million) V= 368, and project investment is, $K_1 = 62$ and $K_2 = 350$ (e.g., investments in Oxford-AstraZeneca, or investments in Serum Institute India for production licencing). Where the government sector also chosen to forgo as planned investments (I_2). At this stage the government sector reduced the scale by $c\%$, such as production scales and facilities of cost (I_c), as indicated earlier (Figure2). For expansion, E, that is,

$$E = \max(V, 2V - I_1')$$
$$= V + \max(V - I_1', 0),$$

The value of the investment opportunity, including the value of the option to expand then became

$$E_0 = \frac{pE^+(1-p)E^-}{1+r} - I_0$$

Project B expansion had the following inputs: $_EV_0 = 368$, $K_1 = 62$, $K_2 = 350$, $T_1 = 12$ months, $T_2 = 24$ months, $r = 4\%$, $\sigma = 22\%$. Then the option value for Project A is $_AC_0 = 46.21$ and the option for Project B is $_BC_0 = 149$, where FNVP was $(_AC_0 + {}_BC_0)$-$_AC_B$. The value of the option to expand based on the growth value is equal to 33.8 million, or 34% of the project gross value, suggested that to expand with defer option strengthens the decision choice of the government sector (see, Table 1 below).

Thus, H1 finds further support, where H2 is also supported because Project B drives compound growth of both options. Consequently, H3a is supported, given the results in both Table 1 and Fig. 6.

Table 1 Time-to-build option in sequential A, B, and C projects

		V_t	I	C_0	C_A	FNPV	Decision
(Expand)	Project B	368	350	149	62	87	Recommend
(Defer)	Project A	270	281	64	47	17	Recommend
(Switch)	Project C	386	392	144	62	82	Recommend

(Where C refers to corporate sector project, in association with government sector project A, see, also Appendix A for details)

To continue with the evaluation, results from Table 2 once again, suggest H3a and H3b are support. The value three (Figure 3) of the business option or growth opportunities are available to a firm. The value assumptions are $r = 4\%$, $\sigma = 22\%$ and $T = 2$ years; the volatility is an unlevered estimate (or can be calculated from the historical stock price volatility) and volatility on its publicly traded option prices, where future prices are equal to the present value of the cash inflows, V_T, at time T with exercise price I. And the downstream investment in E suggests that the economic viability requires the valuation of options on both assets while evaluating the correlation between the two assets.

The estimate as reported in Table 2 showed that Project E, the FNPV is negative -43, and investment is not advised. The calculations also reflected the correlation coefficients as explained earlier between the two options (of Project D and E, as compound defer and abandon), where the NPV is negative.

The results lend further support to H3b, thus, the option of abandonment is not recommended. For the above Fig. 4a and 4b, provide coherent argument and further explanations.

Table 2 Real options in sequential D and E projects

|	Vt	I_0	C_0	C_A	FNPV	Decision
Project D (Defer)	300	320	77	47	30	Recommend
Project E (Abandon)	200	150	19	62	-43	Reject

To continue, we combine both elements (compound exchange options) in the analysis, by (European) call options, $C(S(V, I, \tau), E, \tau')$, giving the right upon paying an exercise price E with time to maturity τ', to acquire a subsequent option, $S(V, I, t)$, to exchange (give up) an underlying ("delivery") risky asset, qI, to receive another ("option") risky asset, V, with time t (see Carr, 1988; Margrabe, 1978; Trigeorgis 1996: 215). There, V, is stochastic in the partial differential equation, E is a fixed proportion ($q\%$) of the delivery asset, i.e., $E = qI$ that the underlying risky asset V and I have no dividend-like pay-outs (see, Appendix B). And the gross project value (V_t) is assumed to follow the standard diffusion Wiener process.
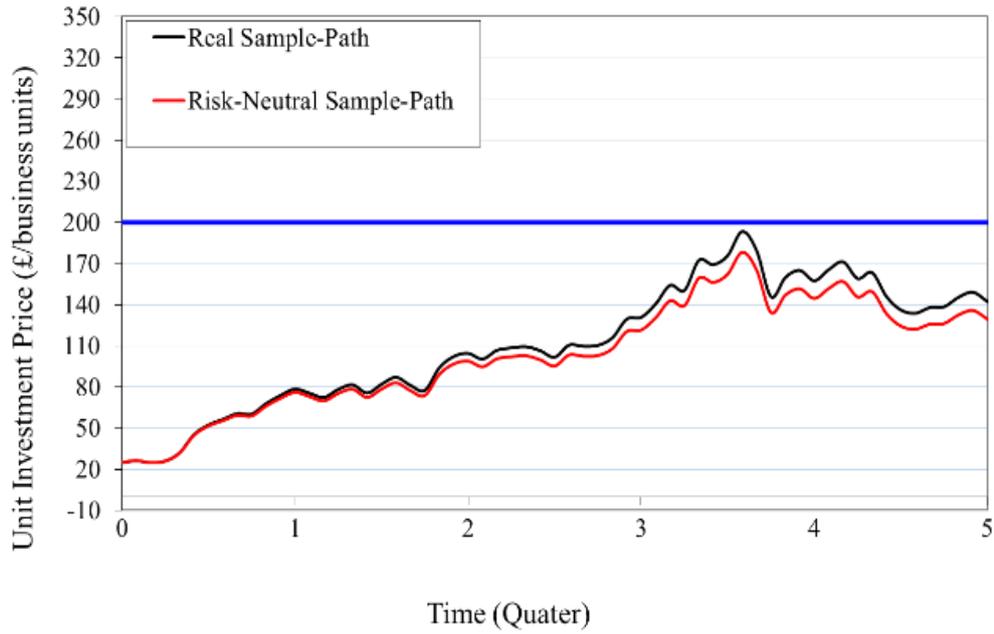
**Figure 4a.** Sample path simulations: Abandonment option at earlier stage
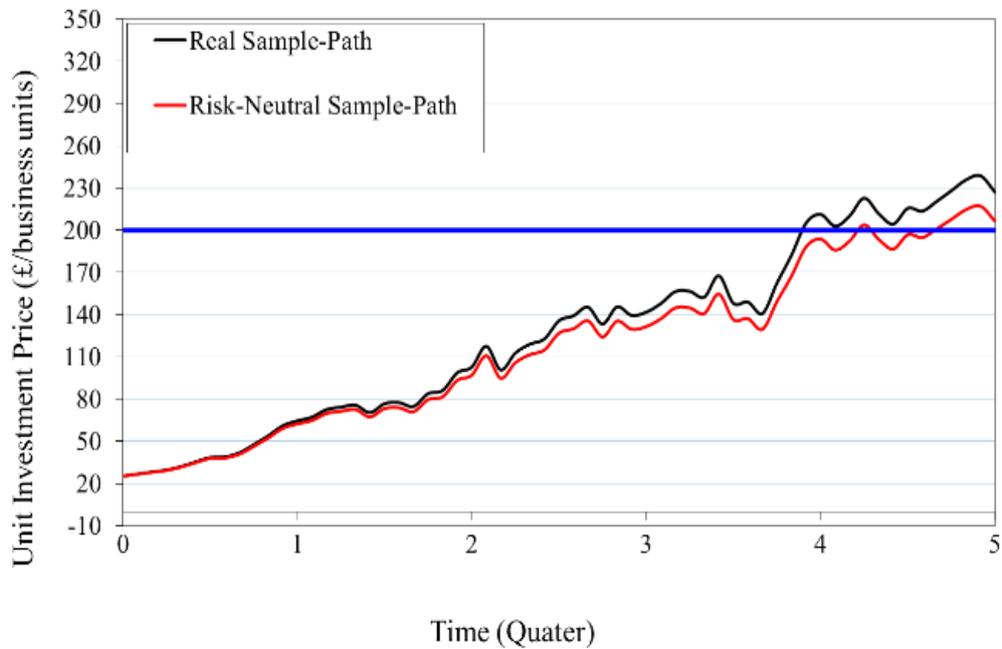
Figure 4b. Sample path simulations: Abandonment option in revival stage

The above lent further support to H3b. The results indicate two critical points. First, Figure 4 suggests, when considering the compound exchange option of deferring with abandonment, the value distributions in interactions, in effect, show where the abandon option decreases project values, reduces the value of the options. Although a business can hopefully compound the effects by the switch and other options, there is greater volatility for the corporate sector, and time is a critical issue while time-to-build suggests it will take, at least three quarters (9 months) to business to recover and revitalise the business.

Thus, it is required the measurement and analysis of the option value adopt the concept of options as interactions. For which further critical points raised are, first ROA needs valuing the two differentials (i.e., α*dt* and σ*dz*), as showed earlier in following the Wiener process. The correlation coefficient ρ, is $p = \sqrt{(\tau'/\tau)}$, the probability for compound (exchange), which can also be found in Selby and Hodges (1987) and Trigeorgis (1996), and hence the valuation can follow the actual bivariate (both time and price) process under a discrete-time process, and the martingale approach (e.g., multivariate diffusion). Because the values of the compound-options are correlated, the government sector by revising their future action can have effect contingent on uncertain future developments of businesses, setting constraints to some businesses to expand their opportunity's true value (where business per unit value of investment was assumed *v* =200 (thousand, as equilibrium price).

The results in Figure 5 show that project expansion has a predetermined exchange or expansion rate. More generally, both government and corporate sectors may have the choice to decide the exchange at a different scale and time that leads to positive interaction with the prior call option to exchange. As we have seen from the above calculations, the probability of the exchange, $\rho = \sqrt{\tau'/\tau}$), is more than 0.71 and the correlation coefficients between the two options of Project C, $N_2(a,b;p)$ is about 0.82. This suggests that both sectors (government and

corporate) have options to revise its future actions contingent on uncertain future developments for more productive options.
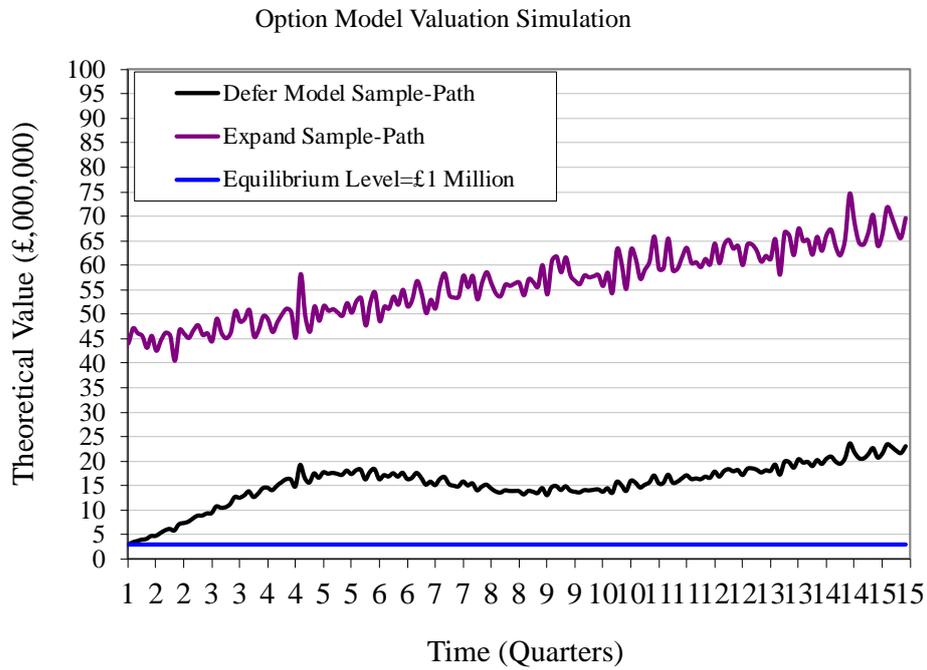
Figure 5. Sample path simulations: Defer vs compound expansion options
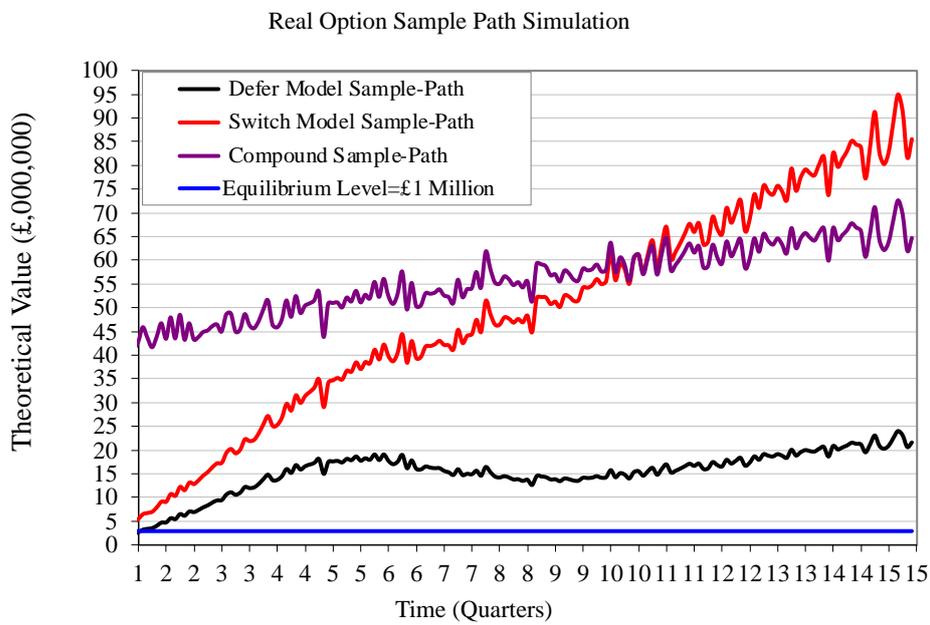

Figure 6. Sample path simulations: Comparing option values (defer, switch and compound)

Figure 6 presents results from sample paths simulation based on the estimated risk-neutral assumption using sample data values considered are in Appendix B. where Project A $P(t)$= 1 year defer, Project B $P(t)$ = expansion, Project compound $C(t)$= (defer and switch). The results suggest that both deferral and expansion of the government sector's options create positive value, where the compound with switch for corporate sector had remarkable increase growth opportunities. The results are constant with the results attained earlier (i.e. Table 1- Table 2), showing an overall positive increase. The results, in general, support three Hypotheses we raised.

The results as further demonstrated in Figure 7a and 7 below, reveal the critical capability issues in the uncertain environment. The investment performance landscapes are associated with complex and flexible investment processes. And sequential options are an integral part of the strategic dimension of the ROA, especially in growth option scenarios. In undertaking the project, the government sector creates a time-to-build option through exploiting sequential interdependencies across time. For example, if the option is more enthusiastically received in the market than originally expected in its decision, thus, helping with producing an initial-scale project plus a growth option on a future opportunity consistent with the corporate growth function (Myers,1977).

Figures 7a and 7b suggest there are capacity limits, and that change in uncertain environments (V=velocity, U=uncertainty, C=complexity, A= ambiguity) as decision-makers acquire knowledge of crucial parameter values. The decisions in the COVID-19 crisis should not rely on beliefs and opinions only, of which only a small proportion is likely to be perceived. Consequently, working on 'sensing' market and broader environment changes as peoples' needs change, will be important, yet they are also the most difficult to assess. A gap exists in our knowledge, which remains hidden values within the managerial 'properties' of system states' unknowledge (or ignorance). Options thinking could be challenging when the source of

the uncertainty is conflicting evidence – then the risks of making decisions may be unacceptably high. Moreover, the evidence may continue to be inconsistent, even if more evidence is collected.
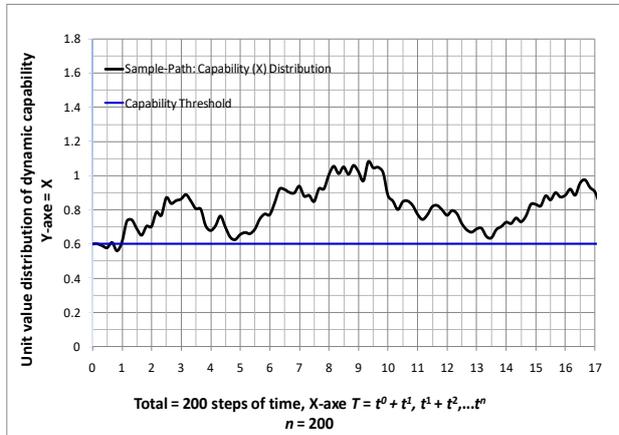
Figure 7A. Capability in states (stable, less velocity environment): Mean sample-path distribution against the capability threshold (x=0.60)
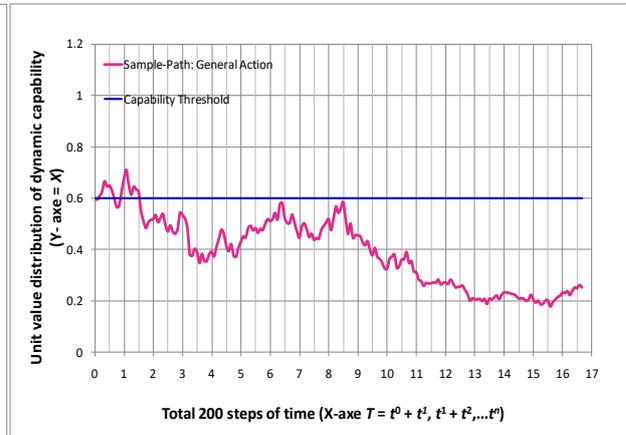
Figure 7b. capability decreases while complexity in states (VUCA) increases against the capability threshold (x=0.60)

Discussion

Contributions to dynamic capability building under the conditions of uncertainty

We have analysed how government actions changed the values of corporate sector assets, and consequently, changed the values of corporate options. We have also shown how the ROA can be used to structure decisions, both government and corporate, under conditions of uncertainty, but the ROA to decision making, as Trigeorgis and Reuer (2017) note, requires competencies in problem structuring, valuation and modelling, and planning for implementation. Scholars have argued that during the Pandemic, some actions appear to have been grounded in desperation rather than through the exercise of well-designed options, which may have limited the effectiveness of ROA as an investment tool during the current crisis. Research also suggests that helping managers figure out which options to create before the next Pandemic and to

determine when such options could be exercised as the next Pandemic unfolds, represents a clear opportunity for supply chain scholars to contribute to theory and practice. The uncertainty factor challenges the value of resources that will change during the process of their development.

The critical issue raised during the covid-19 Pandemic was uncertainty, due to a lack of information on the speed of diffusion and the speed of response in the early stages of the virus. Under the circumstance, if information suffices for opening lockdowns in the first place, more information can be gathered during the process on how the process can be continued. This is explained by Chakhovich and Marttila (2020) as a time-to-build option. Using a ROA, we modelled corporate actions as responses to decisions taken by governments to manage the COVID-19 crisis. In Dec 2019 few people could have anticipated the Pandemic. More likely it was an 'unknown-unknown'. So, attention turns to how society responds once it is recognised the virus' spread was more rapid and more widespread than what was known from the transmission of other viruses such as the flu virus. Further, it became clear in early 2020 that COVID-19 would have devastating health consequences that were incomparable with other known viruses. While governments around the world varied both in their response and their timing, in general, actions were rapid, deep, and far-reaching, with unprecedented consequences for the corporate sector. During the time, a set of issues raised concern 'opening the black-box of organisational capabilities.

We contribute to research by filling a gap while we demonstrate that managing volatile, uncertain, complex, and ambiguous environments (VUCA, as described by Schoemaker et al., 2018) requires dynamic capabilities, which are to be distinguished from ordinary capabilities (e.g., operating routines based on accumulated experiences). To accommodate our conjectures, we offer the ROA as a tool for structuring time-consuming resource/capability accumulation processes that simultaneously require the resolution of several problems. In our ROA, the

building phase provides decision-makers with the opportunity to expand, but not the obligation, as the options to suspend or abandon the project may become available if conditions change. If the investment is suspended, the firm can then decide whether to continue with the project's second stage, such as further investment and suspension and abandonment may come into play again. It is, therefore, suggested by Pindyck (1991) that after completion of the first stage, there is an ongoing decision process ahead of the second phase; hence time-to-build solutions provide a rule for optimal sequential investment that accounts for the time required to undertake the investment. The volatility factors are continuous stochastic processes with independent and stationary increments during the process. Hence managerial decisions involve risk contingency, and those contingent factors can lead to further ignorance and misinterpretations that influence decisions.

Our approach distinguishes between two sources of uncertainty: the value of the completed project (due to uncertainties over the path of underlying prices of the output) and uncertainty over the cost of completing the project. When the value of resource bundles is stochastic, accumulating resources bears the risk that their future value may be at a discount relative to the present, with the consequence that the firm may be unable to fully recover their investment. Further, decision complexity can increase with factors such as causal ambiguity and time-inconsistent behaviour. In the presence of causal ambiguity, decisions may be skewed towards past outcomes, producing strong path dependency, in that the past casts a shadow on the future. Options can be interpreted as conferring a value on bundles of resources and capabilities, where organisational leaders endlessly manipulate the bundles as perceptions of the productive opportunities that resources make a possible change (Penrose, 1959). Creating option value depends not just on the underlying activities but on patterns of coherence. Given the current endemic, time-inconsistent behaviour is illustrated by unexpected events such as the global pandemic crisis that may appear as recursive and stationary patterns. Continually manipulating

the resource base is a process of constantly augmenting skills and operating procedures. Every time the organisation is engaged in adapting, integrating, separating, or expanding the resource base represents a different knowledge structure (Potts, 2000; Loasby, 2001). But decision-makers are neither able to predict what the new pattern looks like exactly, nor where the stationary period starts or terminates, suggesting a non-stationary parameter.

From a ROA perspective, uncertainty adds to the number of possible actions available to governments in responding to the crisis, thus increasing their option values. In terms of the COVID crisis, rather than focusing on economic value, governments might seek to minimise the impact of the disease on individuals and specific groups in society, importantly the business sector, and society more broadly. This might require policy initiatives that reduce infections through carefully targeted investments in healthcare, better and more effective hospitalisation, investing in vaccination programs and so on that minimise the impact on the more vulnerable, minimise economic losses for businesses affected by the Pandemic and householders most affected by the economic downturn or the Pandemic more directly, such as the loss of a wage earner. Government policy initiatives directly affect the corporate sector because of the change in the economic value of corporate real options.

On this account, to deal with uncertainty is also to deal with ambiguity by implying a natural consequence of knowledge acquisition in open-ended systems, where connections between tentative forms of knowledge are options on the connections between further pieces of knowledge (Loasby, 2002). In an organisational setting, this might involve an assessment of opportunities (i.e., tentative new knowledge, technology), alternatives, or possibilities. This would suggest that governmental uncertainties change how the traditional option heuristics are to be interpreted, which has implications not only for governments but also for corporate sector option modelling, concerning the circumstances of time and place in a particular setting. This requires the dynamic capabilities that are over other types of capabilities, and such capabilities

in dealing with the dynamic environment concerns both speed and choice need to be strategically sense making. We therefore in next brought up the time-to-build real options.

Contributions to the time-to-build options

We emphasised that in such pandemic circumstances, the means in solving the problems was co-alignment of strategies with environmental change. Where uncertainty in DP can occur at two levels: corporate and government. Then organisations embark on the search for various reasons and use different procedures for resolving the tension in responding to exogenous forces in the environment. Preserving or increasing capacity requires organisations to actively seek growth opportunities, either through finding new ways of exploiting the current stock of resources or from discovering new complementarities of resource bundles. This is so because knowledge of the behaviour of the system is never complete, and not incapable of being made complete and thus uncertainty is never fully resolved. Over time a succession of configurations unfolds as knowledge about activities and their interactions accumulate. Reconfiguring resources is concerned with making new connections and each configuration will be influenced by the starting configuration (Loasby, 2001). Organisations can be envisioned as moving through state space exercising options by rearranging connections and deepening commitment to successive configurations of resources and capabilities. This implies both adaptation and transformation, to extend real options via search, information gathering, and acquiring needed resources at a cost (i.e., explorative research on vaccines and their exploitation through production and vaccination programs).

We predict that ROA to responses can be both time-based advantage and strategic choice sense-makin. Our proposal of dynamic coherence hence addresses the concerns of time-based advantage, turning into such finite advantage sustainable through organisational coherence. To do so, compound options, may make the best sense in creating further opportunities for growth

through this remains the most challenging. Economic sustainability is, therefore, conditioned by the knowledge and the capabilities embedded in the intricacies and complexity of the cross-sectional linkages (Rivkin, 2000). They are what Penrose (1959, p. 31) describes as the subjective productive opportunities, "all of the productive possibilities that its entrepreneurs can see and take advantage of", the ability to "integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (Teece, Pisano & Shuen, 1997, p. 516). In our ROA, the response strategy captures the idea of how value can be created by timely reconfiguration of the resource base that are most valuable when they are oriented towards specific change or some new possibilities. Preservation capacity with ROA provides organisations with options on the future and provides the firm with resource path that constitutes a different set of options. We expect the ROA to generate dynamic resource capabilities through dynamic response; developing revision possibilities; and generating real options.

Thus, the time-to-build option is the discovery or creation of an opportunity. The time-to-build option can be subdivided into smaller steps, instead of executing all at once, giving more time to search and organise all the information. Crucially, with the time-to-build option, the source of the uncertainty is the abundance of information, that allows beginning the decision-making process with a relatively small scale of decision. Capabilities are therefore in synergistic and growth opportunities that are discovered, as well as, created. Our findings suggest that first, an option has value only if there is uncertainty, though defining the relevant source of the uncertainty is not trivial. Secondly, an operationally important element of design is the provision of discretion, to correspond to discrete points of 'go no-go' decisions. Thirdly, the concept of irreversibility is critical to the explanation of why inertia of organisational capabilities is the source of the value for real options. Irreversibility does not mean that firms cannot change, or that transformation is not possible (Kogut and Kulatilaka, 2001), it does

mean however that if a decision can be costlessly reversed, then uncertainty has no direct effect on the decision, and therefore, without uncertainty there is no option value (see Dixit & Pindyck, 1994). The ROA allows for a more effective response to unexpected disturbance interruption or opportunities in a changing technological competitive or general business environment that require compound options. Through this, we argue actors and organisation must reserve the advantage through deploying and reconfiguring choice structures (dynamic coherence), which is valuable to managers when the value of an even/decision moves unfold.

Conclusion and implications

Research on real options has offered a set of primary or elemental options, including deferral, expand, switch, abandonment, and sequential exchange compound options. Our ROA is applied to the post-pandemic situation at a time when the virus is likely to become 'endemic' in societies, where uncertainties will continue to exist, such as uncertainty about the duration of the endemic period, uncertainty over the timing of any breakouts that might occur, and the likelihood that future breakouts will trigger further pandemics, as exemplified by the recent discovery of the Omicron variant in November 2021 which has led to further restrictions and the introduction of more circuit breakers in the UK, Europe, and elsewhere. Organisations' capabilities in dealing with the complexity of the cross-sectional linkages relate to organisations' dynamic revision possibilities. Dynamic revision enables adaptation and makes available a flexible response that is captured by variables associated with organisational learning and cooperative behaviours. ROA can tackle the irreversibility by introducing a time asymmetry into the analysis by placing a time subscript on the value of resources (see Pindyck, 1991; Dixit and Pindyck, 1994). For example, when the value of resource bundles is stochastic, resource accumulation bears the risk that their future value may be at a discount relative to the present, with the consequence that the firm may be unable to fully recover its investment costs.

ROA allows for revision possibilities by facilitating adjustments or switching along various alternative paths as opportunities arise.

While real options modelling has become a valuable tool for corporate decision-makers, extending the approach to governments has barely begun, exceptionally few studies (e.g., Chakhovich and Marttila, 2020) have recognised the value of real options to assess the possible alternatives for governments and corporates, and analyse the outcomes of unpredictable events such as the COVID crisis. Limitations also exist in the modelling process. To strengthen research, the above reveals clearly, there are multiple uncertainties and the need to consider non-market uncertainties suggest that Black-Scholes modelling procedures and their variants will have limited value in a real options world that includes pandemics such as COVID-19 and the government policy initiatives designed to combat the spread. Also, correlations could be incorporated without increasing the computational burden. For example, abandonment of production or reduce its level could be negatively correlated with the firm market value, and positively correlate with the variable of cost. To overcome the limitations, it could be helpful if an explicit function of those two inputs is defined and implied. Bowman and Moskowitz (2001) point out that the formal use of real options requires any associated models to be adjusted to the situation of each organisation. The stochastic process of the project value is usually more complex (Harikae *et al.*, 2020), and the project value calculated from simulation may not be consistent with a Brownian motion (Smith, 2005).

From a corporate perspective, we demonstrate that ROA provides a robust set of heuristics that firms can deploy to exploit the uncertainties within markets and identify the economic value that could be created from having the flexibility to respond, such as the ability to defer decisions, the time-to-build, to switch between alternative courses of action or upscale and downscale investment commitments. We address the gaps in the current literature in terms of adopting the theories of real options in which, the real options paradigm is explained as an

alternative strategy by scholars in the strategic management literature but on the other hand, the real values remain hidden due to the lack of insight. Prior empirical work has mostly attempted to confirm a few regression coefficients or causal relationships through statistical analysis. These studies have been valuable, but the benefits for real options thinking is limited because they haven't explored what real options are, and how they create value, particularly by predicting into future in respect to entering future decisions that remain unknown in the current moment of decision. Our framework is aimed at providing a framework for structuring future uncertain choices rather than confirming past success in respect to any strategies adopted. The valuations demonstrate how ROA inform DP and the connection between opportunity recognition and uncertainty. The important question is whether organisational resource/capability endowments are useful not only for current applications, but also for the future, and such endowments might also be seen more generically as the knowledge of the organisation. Complex choice combinations can emerge from a series of system transitions where the capability is the adaptation that enables ex-ante selection, identifying 'higher-order choices', or 'themes' (Porter, 1996), and subsequent transitions constitute elaborations on these themes as events unfold ex-post (Gavetti and Levinthal, 2000; Ghemawat and Levinthal, 2002).

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Appendix 1

Parameter values of simulations Project A, B and C

(Defer)	Project A	(Expand)	Project B	(Switch)	Project C
d1=	1.73	d1=	1.89	d1=	0.74
N(d1)=	0.96	N(d1)=	0.97	N(d1)=	0.77
d2=	1.42	d2=	1.58	d2=	0.29
N(d2)=	0.92	N(d2)=	0.94	N(d2)=	0.61
k=	0.08	k=	0.10	s=	0.32
r=	0.05	r=	0.05	p=	-0.50
s=	0.22	s=	0.22	Sv=	0.22
t=	2.00	t=	2.00	sI=	0.15
Exp(-r_T)=	0.90	Exp(-r_T)	0.90	t=	2.00
				Exp(-r_T)	2.72

Appendix 2

Parameter values of simulations real options: Defer, Switch, Abandon

Project Abandon		Project Defer		Project Expand	
Exp(-r_T2)	0.85	Exp(-r_T2)	0.85	Exp(-r_T2)	0.85
$r=$	0.04	$r=$	0.04	$r=$	0.04
$s=$	0.22	$s=$	0.22	$s=$	0.22
$p=$	0.8	$p=$	0.8	$p=$	0.8
K1=	62	K1=	62	K1=	62
K2=	350	K2=	350	K2=	350
T (quarter)1	2	T (quarter)1	2	T (quarter)1	2
T(quarter)2	4	T(quarter)2	4	T(quarter)2	4
CVt=	200	DVt=	300	EVt=	580
CVc=	150	DVc=	320	EVc=	620
k	0.813	k	0.077	k	0.072
h	1.039	h	-0.046	h	-0.052
N2(k,*h;p*)	0.620	N2(k,*h;p*)	0.410	N2(k,*h;p*)	0.541
(k-sigma*SQRT(K1))	-0.919	(k-sigma*SQRT(K1))	-1.656	(k-sigma*SQRT(K1))	-1.660
(h-sigma*SQRT(K1))	-0.693	(h-sigma*SQRT(K1))	-1.778	(h-sigma*SQRT(K1))	-1.785
N2(A69),(A70; p))	0.078	N2(A69),(A70; p))	0.019	N2(A69),(A70; p))	0.023
k-sigmaSQRT(T$_1$)	-0.601	*k-sigmaSQRT(T$_1$)*	-1.338	*k-sigmaSQRT(T$_1$)*	-1.342
N1(A72)	0.274	N1(A72)	0.091	N1(A72)	0.090