BEHAVIOURAL METHODS FOR MACROECONOMICS: Modelling Investment[1]

Michelle Baddeley
Professor in Economics
UTS Business School
University of Technology Sydney
Email: michelle.baddeley@uts.edu.au

<a> **ABSTRACT**

Macroeconomics has been relatively slow to embed insights from behavioural economics, partly because of the challenges associated with building an aggregate macroeconomic model from microeconomic foundations. Aggregation is especially problematic for behavioural macroeconomics because of the complexities which characterise behavioural economics more generally, including numerous and complex barriers to rational decision-making in the context of risk and uncertainty. Commonly, analytically rigorous macroeconomic models are forced to rely on simplified behavioural assumptions which are inconsistent with key insights from behavioural economics. In the context of these challenges, this chapter analyses some of the pitfalls associated with aggregation in macroeconomic models generally and in behavioural macroeconomic investment models in particular, and explores implications for building behavioural macroeconomic models founded on more realistic assumptions about how people think, decide and interact.

Keywords: behavioural macroeconomics, the aggregation problem, uncertainty, heuristics and bias, fixed asset investment

<a> **INTRODUCTION**

Behavioural macroeconomics is growing as a sub-discipline of behavioural economics, yet its progress is slowed by the methodological limitations faced by macroeconomics generally.

[1]With thanks to Tobias Rötheli for his comments and advice on an early draft.

From an empirical perspective, these methodological limitations are not of direct interest to policy-makers and, thus, this chapter embeds a different behavioural approach to macroeconomics, as explicated in Tobias Rötheli's contribution to this edited volume: 'The Business Cycle and Cycles of Behavioral Economics' – which builds on macroeconometric insights developed from Cowles Commission to develop an empirically-informed, tractable and policy-oriented behavioural model of the macroeconomy. In contrast, this chapter presents a theoretical analysis of fixed asset investment and its behavioural drivers in the context of macroeconomic trends. The different approaches presented in these two chapters are complementary to each other in representing different perspectives on aggregation and uncertainty.

To a limited extent, some insights from behavioural economics have been incorporated into macroeconomic models, for example via analyses of learning, limited attention and mimetic contagion (Gabaix 2020; Acemoglu 1993; Topol 1991). These models can be understood in terms of "softer" forms of rationality than that associated with traditional macroeconomic models. Nonetheless, these embellishments to the mainstream models are still limited in their approach to modelling decision-making in the context of risk and uncertainty.

In terms of aggregation and uncertainty, behaviour at the level of an individual is relatively easy to model. But, at the aggregate macroeconomic level, risk and uncertainty limit the construction of plausible models – especially as one of the key insights from behavioural economics is that decision-makers will behave in different ways in different circumstances. Even the same decision-maker may make different choices in depending on the context of their choices, how their choices are framed and the time horizon over which the consequences of their decisions will unfold. All these factors complicate the construction of intuitively plausible and analytically tractable models of macroeconomic outcomes, given that these outcomes are determined by large numbers of diverse and interacting individuals.

The solution adopted in the predominant macroeconomic paradigms, including rational expectations approaches as exemplified by dynamic stochastic general equilibrium (DSGE) models, is to design microeconomic foundations which are scaleable by embedding simplifying assumptions all individuals being identical (at least on average) and operating rationally, independently and selfishly. Although DSGE models have been adapted to incorporate heterogenous agents and the interdependencies between them, the basic idea is to take simple

microeconomic relationships and describe the macroeconomy, essentially as if it operates in the same way in which an individual agent would operate.

From a behavioural perspective, this approach is problematic. Shifting time and risk preferences; heuristics, bias and risk misperceptions; individual differences; learning; social influences, feedback effects and other interdependencies – all mean that coherent behavioural macroeconomic models cannot be captured just by aggregating individuals as if all individuals are the same. These problems are particularly profound for macroeconomic models of business investment and production because the behaviours driving investment and production for small and medium sized enterprises (SMEs) are very different from those characterising large businesses. Also, whilst the simplified DSGE models have a neat logical structure, they do not rest easily with our intuitions about human behaviour, especially in the context of risk and uncertainty.

All these complexities mean that the macroeconomic whole cannot be described as the sum of its behavioural microeconomic parts. Therefore, in building strong foundations for a behavioural macroeconomic theory that overcomes some of the limitations associated with rational expectations models, an important set of insights revolve around how decision-makers adapt to risk and uncertainty, a key focus in behavioural economic analysis. In terms of broad macroeconomic implications, the behavioural anomalies which defy aggregation will be magnified in the macroeconomy, generating substantial deviations between *ex ante* and *ex post* consumption, investment and rates of profit – with significant implications for productivity growth and macroeconomic performance.

In addressing these gaps, this chapter explores some of the challenges in building behavioural macroeconomic models. Specifically, insights from behavioural economics can be embedded within macroeconomic analyses of investment – a key building block of macroeconomic theory because of its role in production, employment, expenditure generation and growth – founded on realistic behavioural assumptions about decision-making. Embedding strong and more realistic behavioural foundations will address some of the limitations of the rational expectations models associated with the mainstream micro-founded aggregative approach.

<a> BEHAVIOURAL MACROECONOMICS AND THE AGGREGATION PROBLEM

In mainstream macroeconomic analysis, the aggregation problem pertains to the limitations associated with building large, multi-factor macroeconomic models using smaller, simpler models from microeconomic theory (Klein 1946, Peston 1959, Fisher 1987). Building macroeconomic models based on microfoundations requires a series of restrictive assumptions associated with microeconomic theories of optimising behaviour with respect to households' and businesses' decisions about consumption, labour-leisure trade-offs, investment and production. These assumptions are founded on very specific behavioural assumptions associated with rational choice and homogenous, representative agents. There is no doubt that, whatever its flaws may be, this is a pragmatic approach because, if all decision-makers in an economy are assumed to be the same, then the macroeconomic model can be mapped directly onto simple microeconomic foundations and the task of building a macroeconomic model becomes much easier.

This micro-founded approach is associated most strongly with dynamic stochastic general equilibrium (DSGE) models. Variants of DSGE models do allow some relaxation of the restrictive assumptions but the key principles include the rational expectations hypothesis (REH) – which simplifies the challenge of capturing complex behaviours by assuming that rational agents are fully-informed, forward-looking, independent and self-interested maximisers (Muth 1961). According to the REH, rational agents learn instantaneously from any mistakes they make so that they do not repeat their mistakes. These restrictive behavioural assumptions about rationality work together with the representative agent hypothesis – that each group of economic agents (whether households/workers or firms/employers) can be represented by one highly-stylised, homogenous type – thus abstracting from individual differences. This enables all agents of each type to be captured within the model as if they are all the same. Thus, there is no fundamental difference between the macroeconomic aggregate of individuals' decisions and the microeconoimc behaviours of strictly rational individuals. The difference between microeconomics and macroeconomics is reduced to a problem of scale not substance.

Aggregation problems have been explored in the heterodox literature, specifically in the context of aggregate production functions (Felipe and Fisher 2008, Felipe and McCombie 2013) and there are additional problems for behavioural macroeconomic models given the complexities of economic behaviour which are the essential focus of behavioural economics.

Rules which fit in a perfect world in which there is no uncertainty, in which expectations are fulfilled and in which the rate of profit is unambiguous do not fit so well in the real world in which distortions such as uncertainty, disappointed expectations and ambiguities in the rate of profit lead to significant differences between the *ex post* and *ex ante* rate of profit (Harcourt 1965). In these circumstances, there will be no simple rule of thumbs to enable adjustment because rates of profit are greatly influenced by irrelevant factors, even under ideal conditions (Harcourt 1965, p. 80). Accounting rates of profits do not capture relative profitability and the relationships between them are too complicated to devise rough rules of thumb to enable approximations based on adjustments for life of machines, patterns of rising and falling quasi-rents (temporary profits), rates of growth and depreciation methods used. Nor is it possible to generalise about rates of profits in different countries and/or different industries. These microeconomic problems are magnified at an aggregate scale. Specifically, accountants' measures of profit at a microeconomic level will not accurately represent profits at a macroeconomic scale in four main cases: when distorted by quasi-rents from individual machines in the capital stock; when distorted by anomalies in the depreciation rate across businesses; when there is growth in the capital stock; and when the assets included in the capital stock are shifting (Harcourt 1965).

Similarly, constraints on expectations formation under conditions of fundamental uncertainty have also been explored in the heterodox post Keynesian literature (for example see Crotty 1992, Fontana and Gerrard 2004 Gerrard 1994; Howitt 1979/1997; Meeks 1991, 2003; Baddeley 2014, 2017). Whilst some of these heterodox literatures have touched on behavioural factors, bringing these insights together into a coherent behavioural economic framework remains as an overarching challenge for behavioural macroeconomic theory and analysis. An important starting point, connecting these heterodox literatures, are the behavioural analyses of decision-making under risk and uncertainty – as explored below.

<a> BEHAVIOURAL APPROACHES TO RISK, UNCERTAINTY AND EXPECTATIONS

Inspite of the aggregation problems outlined above, behavioural economics has the potential to provide a stronger foundation for behavioural macroeconomics than traditional macroeconomics because it has developed out of a focus on choices and decisions when the future is uncertain and information is complex and unclear. Many of the fundamental insights

from behavioural economics explore the constraints on decision-making under risk and uncertainty and the complexities generated by shifting risk and time preferences. These factors will dampen the key drivers of macroeconomic activity – including consumption and investment. Capturing the behavioural influences determining how households and businesses plan consumption and investment decisions, the consequences of which will unfold over long time horizons, is a key challenge for macroeconomic theory. Rational expectations models (for example as seen in the rational expectations models of consumption smoothing and investment decision-making) do not connect well with behavioural analyses and microeconomic experimental evidence about the limits on decision-makers' ability to plan for the future. Addressing these behavioural divergences from the assumptions embedded within rational expectations models is especially pressing in the context of macroeconomic theory. Whilst there is broad consensus from across the spectrum of macroeconomic theory that uncertainty impedes economic decision-making, debates have emerged around the relevance of different types of uncertainty, specifically Knightian risk versus Knightian uncertainty– a distinction contemporaneously identified by Knight, and Keynes (Keynes 1921, 1937; Knight 1921). The differences in the theories emerge in the ways in which risk and uncertainty are defined and modelled. In mainstream models, uncertainty is conceptualised as a quantifiable risk, that is Knightian risk – defined as a measurable, knowable form of uncertainty – for example knowable from frequency distributions capturing the incidence of similar events in the past. Complex economic decisions are often associated with Knightian *uncertainty* and, given the complexity of real-world macroeconomic influences, these are more likely to be affected Knightian uncertainty. For example, under Knightian uncertainty, future prospects around investments will be unquantifiable and unknowable. In terms of macroeconomic consequences, the dampening impacts of risk misperceptions and uncertainty may reflect economic and/or information constraints – such as those preventing business managers from forming reliable expectations of future sales and other economic variables. In a macroeconomic context, this theme is a key feature of Keynes's analyses of the psychological foundations of decision-making and its implications for the macroeconomy (1930, 1936, 1937). Uncertainty is triggers sluggishness in entrepreneurs' animal spirits, dampening their plans for the future – an insight originally explored by Keynes (1936) and also Katona (1946). Animal spirits, albeit in a re-imagined form, are now the centrepiece of many behavioural macroeconomic theories (de Grauwe 2011, 2012; Farmer and Guo 1994; Gabaix 2020; Howitt and McAfee 1992; Baddeley 2014, 2016, 2019).

Departures from an analysis of rational choice in the context of Knightian risk does not, however, necessarily imply that decisions are formed irrationally. Departures from the assumptions of perfectly rationality – in the sense of making complete use of available information and avoiding systematic mistakes – can more accurately be conceptualised in line with Herbert Simon's analysis of bounded rationality in the context of Knightian uncertainty, when optimising is not possible because of the bounds on optimising behaviour (Simon 1955). In other words, with Knightian uncertainty, decision-makers will be bounded by constraints on information and/or their cognitive processing capacity and so their decisions will diverge from what the far-sighted rational optimisers who inhabit rational expectations models would decide.

From the perspective of behavioural economics, the negative impacts from uncertainty will be magnified by behavioural constraints and biases – some of which have been brought into behavioural macroeconomic models. Keynes's analyses connect with Herbert Simon's distinction between different forms of rationality and their relevance depending on levels and types of uncertainty. Simon distinguishes substantive rationality – which can still operate well in a quantifiable world of Knightian risk; and procedural rationality – operating in a world of Knightian uncertainty (Simon, 1979, p. 67). The substantively rational decision-maker will behave as described within standard economic theory, and they will focus on achieving objectively quantifiable goals of utility or profit maximisation in the face of fixed, knowable constraints. For example in a macroeconomic context, if business decision-makers are substantively rational, then they will form quantifiable expectations of the future and will make decisions using constrained optimisation techniques. In other words, they will utilise complex mathematical rules embedding forward-looking expectations to estimate the discounted flows of expected future utility or profit from their fixed asset investment decisions. But Simon (1979, p. 68) responds to the mathematical approaches subsumed within the substantively rational approaches associated with traditional economics by arguing that economic decisions are often the product of a 'procedurally rational' process – that is a process which operates from a basis of bounded rationality rather than the strict rationality associated with optimal decision-making. In much of economic decision-making, optimising behaviour is not achievable because of limits to information and/or cognitive processing ability. In this sort of world, decisions will be based on a broad reasoning process rather than the achievement of given representative agent's goals (Simon, 1979, p.68).

<a> **HEURISTICS, ALGORITHMS AND BEHAVIOURAL BIAS**

Developing insights about heuristics in a world of uncertainty, a key focus in behavioural economics is on the ways in which economic decision-makers use simple rules of thumb – i.e. heuristics – to navigate complex decision-making challenges, information overload and choice overload (for example, see the seminal paper by Tversky and Kahneman 1974). More precisely in economics, two distinct 'styles' of decision-making are highlighted (Baddeley 2006). First, heuristical approaches: these allow that decision-makers use heuristics – simple rules of thumb – to guide them. For example, Gigerenzer and Brighton (2011) conceptualise heuristics as devices that save decision-makers time and energy in thinking through complex algorithmic calculations (Gigerenzer and Brighton 2011). Second, algorithmic approaches: these assume that any decision-maker, with access to the same information set, will form identical expectations centred about some objective probability distribution of outcomes. Decision-makers who are forward-looking and consistent in their discounting of future prospects – as seen in rational expectations versions of consumption and investment theory – are utilising algorithms.

Heuristics and algorithms can be distinguished in terms of their complexity: an algorithm is a complex analytical solution requiring a high degree of rationality. A heuristic is defined by Simon as a common-sense rule of thumb based on experience and intuition and much more likely to be used by the majority of decision-makers because implementing heuristics in practice is much more feasible than implementing complex algorithms. Under conditions of fundamental uncertainty, heuristics will often be the best decision-making tool because so little is known about what is going on or what might happen in the future (Todd and Gigerenzer 2012). In other words, when uncertainty is profound and expectations cannot be quantified under any scenario, then it is much more reasonable to rely on heuristics than on spurious optimisation techniques.

In a macroeconomic context, heuristics will be especially useful in understanding SMEs' investment activity – and SMEs play an especially important macroeconomic role because they contribute significantly to macroeconomic performance in terms of production and employment. But whilst heuristics might be useful approximations on average at a microeconomic level, they are also associated with systematic biases (Tversky and Kahneman 1974, Kahneman and Tversky 1979) which, when magnified at an aggregate macroeconomic scale, can create significant problems for behavioural macroeconomic analysis. The presence of these biases implies that real-world macroeconomies are likely to diverge significantly from

the stylised models of macroeconomies analysed via mainstream models grounded in principles of optimisation and rational expectations.

In capturing bias in behavioural macroeconomic models, there are a number of key questions to address. Assuming away unexpected events, why do businesses and households make mistakes in practice? What explains their behavioural biases? What are the macroeconomic implications of biases magnified on an aggregate macroeconomic scale? There may be mistakes or omissions at a number of stages of consumers' and businesses' decision-making processes: in gathering information about the various options available today; in forming expectations to predict future events and consequences. Households may make mistakes in balancing the future consequences of their decisions around balancing consumption versus savings today with implications for their income on retirement. Businesses planning to invest for the future may make mistakes in their expectations of future sales revenues, relative costs of labour versus capital in the future and/or the cost of borrowing, especially as information about these factors will be clouded by unpredictable macroeconomic events and shifting labour market conditions. Poor information about inherently uncertain future events will increase the reliance of businesses and households on heuristics and therefore increase their susceptibility to heuristical bias. If information is missing or misinterpreted, if there are asymmetric information and principal-agent problems associated with adverse selection and moral hazard, then there will be a widening divergence between the macroconomic reality and the predictions from rational expectations macroeconomic models.

In terms of the key sources of bias that might lead to the widest divergences from the stylised rational expectations models, these include: status quo bias, conventions and herding; shifting time and risk preferences; business heuristics; and optimism bias and animal spirits – as explored below.

<b> **Status quo bias, conventions and herding**

The static expectations hypothesis is a macroeconomic corolloary of status quo bias in behavioural microeconomics. A form of status quo bias, i.e. the bias which makes decision-makers slow to shift away from their reference points, is seen in mainstream models of business investment. For example, Jorgenson's early models of fixed asset investment assumed static expectations – businesses assume that current state of affairs will continue into the future, and

this decision inertia parallels status quo bias. Also, Keynes (1936) focussed on the extent to which the current situation dominates decision-making: "it is reasonable, therefore, to be guided to a considerable degree by the facts about which we feel somewhat confident, even though they may be less decisively relevant to the issue than other facts about which our knowledge is vague and scanty (Keynes, 1936, p. 148). Whilst static expectations are found in early versions of neoclassical theory (including Jorgenson's early versions of neoclassical investment theory) it is an assumption that is in essence more consistent with Keynesian principles – for example, the Keynesian consumption function building on Keynes's (1936, 1937) 'fundamental psychological law' that the propensity to consume will be determined as a fixed proportion of current income (in contrast to monetarist and rational expectations models of consumption smoothing based on far-sighted expectations of future income). The principle of a static relationship between consumption and incomed also forms the foundation for multiplier-accelerator theories of output and investment.

In terms of social influences in mainstream macroeconomic models, behavioural macroeconomic analyses of these influences also builds up from Keynes's macroeconomic analyses of herding and conventions in financial markets and their impact on real activity, especially fixed asset investment (Keynes 1930, 1936, 1937). The concept of a convention connects with behavioural economics' heuristics because following others is a quick decision-making short-cut which people use when information is complex and difficult to navigate and interpret (Baddeley 2018, 2019). The macroeconomic implications link with Keynes's insight that conventions in the macroeconomy are 'established as the outcome of the mass psychology of a large number of ignorant individuals is liable to change violently' (Keynes 1936, p. 154). Psychological factors underlie the maintainance of conventions because people prefer stable routines; conventions lull anxiety created by uncertainty about the future (Earl 1983, Lawson 1995).

These conventions also connect with status quo bias because conventions are associated with the continuance of current conditions. Thus, conventions will become self-fulfilling prophecies and, once the convention is established, assuming that it will continue is not unreasonable and is consistent with Simon's procedural rationality.[2] Also, it is reasonable for an ignorant individual to rely on conventions because other economic actors may be acting on better

[2] See also Pesaran (1990), Lawson (1995).

information and, then, “we endeavour to fall back on the judgement of the rest of the world which is perhaps better informed” (Keynes 1936, p. 217).

In the aggregate context of macroeconomics, conventions introduce complexities in terms of the overlap between the microeconomic decisions of households and businesses and the macroeconomic consequences: feedback effects ensure that individuals are affected by the aggregate, and aggregate outcomes are affected by individuals’ decisions. For example, social drivers of consumption on a macroeconomic scale include the interactions of Veblen effects and demonstration effects, triggering conspicuous consumption of luxury goods which spreads through the macroeconomy as consumers make their own decisions about luxury consumption on the basis of observing what others are doing – themes explored in macroeconomic models constructed on insights about consumer sentiment, for example see Curtin (2019) and Wärneryd (1999).

Learning in the context of multiplier-accelerator models is analysed by Acemoglu (1993), who combines a rational expectations approach with a macroeconomic accelerator model in analysing the role played by output as a signal to businesses of what other businesses are planning. The positive externalities generated by technological innovations, learning by doing, innovation and growing aggregate demand will generate output growth. Businesses will use this output growth as a type of heuristic – as a signal that other businesses are investing, and this heuristic will encourage businesses to follow the crowd, triggering herd behaviour as businesses follow each other with their investment plans.

<b> **Shifting risk and time preferences**

Macroeconomic drivers are also affected by biases associated with shifting time and risk preferences – for example, as identified by Strotz (1955), Ainslie (1991), Laibson (1997) and others in the context of time preference, and by Tversky and Kahneman (1974), Kahneman and Tversky (1979) and others in the context of risk preferences. These approaches contrast with rational expectations models of the macroeconomy which are founded on the idea that households smooth their consumption over their lifetimes. In rational expectations models, households’ consumption smoothing is enabled by the presence of perfect financial markets via which households can borrow or save at a real interest rate that reflects their rate of time preference, i.e. the discount rate capturing the extent to which they value future consumption

over present consumption. This discount rate is assumed to be a stable constant, unchanging over time.

But a key insight from behavioural economics is that the discount rate is not a stable constant. Microeconomic behavioural analyses of consumption include Thaler's mental accounting model, which focuses on the idea that that money is not completely fungible (Thaler 1985, 1990). In contrast to a rational expectations world in which rational agents' decisions do not change unless information changes, decision-makers will treat the same amount of money in different ways depending on the context and framing. For example, Thaler's experimental evidence demonstrates that people will spend a windfall gain of $2,400 in different ways depending on how they receive the windfall. A windfall received as a series of monthly payments results in spending $1,200. A windfall received in a single lump sum results in spending £785. A windfall received as an inheritance will not be spent at all. Thaler interprets this experimental evidence as reflecting the fact that people's perceptions of the money they receive and their decisions to consume versus save is not treated as if it is a single optimisation problem. It is as if people have different mental accounts into which they allocate the money they receive in different ways. This explains why people build-up credit card debt at very high interest rates whilst, at the same time, they put their savings away in accounts earning just very low interest rates.

Another anomaly from the behavioural literature which is inconsistent with rational expectations macroeconomic models is reflected in a large volume of experimental evidence from psychology as well as economics. This experimental evidence shows that people do not have stable discount rates. Instead they tend to exhibit present bias – their discount rates are higher when making decisions over a short time horizon than when they are making decisions over a longer time horizon. In addition, there may be significant individual differences in people's planning for the future. This insight has external validity and has been seen also in natural experiments. For example, a study of the retirement decisions of US military personnel showed that military personel had heterogenous preferences when deciding between pensions received as a lump sum payment versus pensions received as a regular stream of annunities over time; the choices between these two options driven by individual differences in terms of military rank, education and age (Warren and Pleeter 2001).

Behavioural life-cycle models blend together elements of the rational expectations macroeconomic models, replacing standard exponential discount functions (which are consistent with stable discount rates) with quasi-hyperbolic discount functions (which allow discount rates to vary) with the aim of building a model which can capture the anomalous propensity of households to accumulate high-cost revolving debts, e.g. via credit cards, whilst simultaneously holding large stores of illiquid wealth or saving at low interest rates (Angeletos et al. 2001, Laibson et al. 2007). These models are then used to simulate macroeconomic outcomes in a methodology similar to the methods used in calibrating DSGE real business-cycle models. The empirical limitations include the absence of reliable and objective methods for quantifying the parameters embedded within the simulations.

Alternative behavioural approaches to consumption include macroeconomic behavioural analyses of consumer sentiment, as pioneered by George Katona, and these approaches are consistent with the idea that the psychology of consumers is also an important driver of consumption in the macroeconomy, with the psychology underlying the formation of expectations and thus operating as an 'intervening variable' (Katona 1951, Wärneryd 1999, Curtin 2019)[3]. In contrast to rational expecations models which focus on economic and financial drivers, behavioural economic analyses of consumer sentiment capture the impact of non-economic drivers – including emotions such as fear, nervousness, optimism and euphoria. Emotional influences on the macroeconomy are likely to be stronger and more complex than when Keynes and Katona were writing and there is a burgeoning interest amongst macroeconomists in news-based measures of sentiment and uncertainty (for example see Baker, Bloom and Davis, 2016; Curtin 2019). The easy access to credit which is a feature of modern, financially deregulated economies means that the purchase of consumer durables and luxuries can pick-up quickly when positive consumer sentiment is driven by buoyant macroeconomic conditions. In very recent times, news is having a much quicker and more destablising impact on emotions because of online social media – with implications for consumption's impact on aggregate demand.

<b> **Business investment heuristics**

[3] See also Earl (2005) on some of the connections and barriers between economics and psychology in the context of psychological economics more generally.

In this section, in order to illustrate some key insights, the behavioural economic insights explored above are applied specifically to the role of business in the macroeconomy – in terms of employing workers, investing in capital and/or production. Business investment decisions can be understood in terms of they ways in which entrepreneurs and business managers use heuristics versus algorithms to guide their investment, employment and production decisions. As explored above, algorithms are more likely to be associated with a rational expectations model and heuristics are more likely to be associated with a behavioural approach – as explained below.[4]

The starting point for algorithmic, rational expectations approaches to business investment is Jorgenson' neoclassical model of fixed asset investment (Jorgenson 1963) and its variants. These models embed assumptions that firms are operating within a rational choice framework, using complex mathematical techniques of constrained optimisation to identify analytical solutions for maximising profits and minimising costs. In these mainstream investment models, built on assumptions of perfect information and rational choice, businesses invest in fixed assets to maximise their profits over an infinite time horizon by calculating the net present value (NPV) of a project using calculations of an investment project's expected discounted cashflow (DCF) relative to its capital cost. The starting point for these models is the a production function via which firms' decisions are made within a 'black box'. Investors calculate the inputs going in and the outputs coming out, but do not know, or care, what happens in between (Cobb and Douglas 1968).[5] In addition, Jorgenson's investment theory assumes constant returns to scale and homogeneity of capital, as captured in the Cobb Douglas production function (CDPF). The overall result is that profit-maximising firms will invest up to the point where the user cost of capital and the marginal productivity of capital are equalised. Jorgenson uses a range of simplifying assumptions. Essentially, in Jorgenson's model behavioural/psychological factors are confined to the error term of the CDPF. There are limitations associated with the restrictive assumptions of Jorgenson's approach, but the specific and central limitation of Jorgenson's model is twofold: it does not consistently capture expectations and uncertainty; and it does not capture the ways in which real-world entrepreneurs and investors decide.

[4] See also Baddeley (2003) for a survey of alternative approaches to modelling macroeconomic investment.
[5] There is a separate and important literature on behavioural theories of the firm, for example see Cyert and March (1992).

To capture expectations and uncertainty, rational expectations theory has evolved analytically rigorous models to capture the impacts of expectations and uncertainty on investment. These models are roughly consistent with neoclassical investment theory's rational optimiser framework because they are generally built on models of quantifiable uncertainty i.e. Knightian risk. Starting with expectations, Jorgenson's baseline neoclassical model is founded on the assumption of static expectations – businesses assume that current state of affairs will continue into the future, and this decision inertia parallels status quo bias: businesses are slow to adjust their expectations. This first set of limitations associated with Jorgenson's model has been partly addressed via subsequent refinements from the rational optimiser perspective, for example, various versions of q theories, many of which focus on the existence of adjustment costs within a stock-flow consistent model (e.g. see Abel 1983). In q theories, marginal q pertains to the marginal benefits of an incremental investment in terms of discounted expected future profits from the investment relative to its marginal cost but the empirical problem is that marginal q is unobservable and therefore uncertain.

Transposing these insights into macroeconomic theory, assuming constant returns to scale and homogeneity of capital, the expectations of dividends and profits for marginal investments will proxy dividends and profits in aggregate and thus stock market capitalisations across an economy's stock markets will give an unbiased measure of rational investors' expectations of the discounted streams of future profits from current investment activity, at least for listed companies (Hayashi 1982). Average q is used as an empirical proxy for marginal q with immeasurable expectations proxied by stock market valuations. In practice, average q is equivalent to a valuation ratio i.e. the ratio of stock market capitalisations to the current replacement cost of capital. This connection between stock markets and fixed asset investments is grounded on the assumption that stock markets reflect all relevant and currently available information about the value of a firm's capital stock. In this way, share prices and stock market valuations are used as proxies for expected future profits and dividends. A further limitation however is that this solution also depends on the empirically-fallable efficient markets hypothesis assumption that financial markets are informationally efficient i.e. adjust rapidly in response to news, efficiently to process all currently available information about future profits and dividends so that asset prices will reflect forward-looking rational expectations of profits and dividends from fixed asset investments (Brainard and Tobin 1977).

Another group of rational expectations models capture the impact of uncertainty on business decision-making, for example as outlined in Dixit and Pyndyck in the context of fixed asset investment models (Pindyck 1991, Dixit and Pindyck 1994). Uncertainty is embedded within a rational optimising framework by extending Jorgenson's model and the q models to capture the depressing impact of uncertainty on fixed asset investment in a world in which sunk costs are large and so problems of irreversibility in investment are substantial. Uncertainty is likely to affect large, capital-intensive projects more than smaller scale, less capital-intensive projects because the negative relationship between investment and uncertainty is driven by the interplay between uncertainty and irreversibility. When uncertainty and irreversibility coincide, businesses will be reluctant to commit to large scale fixed asset investment projects because significant uncertainty means that they have limited reassurances that they will be able to recoup the sunk costs of their investments and the opportunity cost of exercising an option to invest rises accordingly. Larger investment projects involve larger sunk costs and irreversibility. The 'trigger rate of return' – that is, the rate of return needed to ensure that an investment project pays for itself in terms of discounted future cash-flows – will be elevated and, with uncertainty having an aggregate impact across the macroeconomy via its inverse relationship with business confidence, investment activity will falter, with negative consequences for employment, production and growth in the macroeconomy. These real options theories reconcile limits on planning for the future by assuming that businesses will build buffers into their investment appraisal rules, raising the trigger/hurdle rates of return at which they are prepared to implement investment projects to take account of uncertainty – with the consequence that fewer investment projects will be implemented – thus leading to lower rates of investment both at the firm level and at an aggregate macroeconomic scale.

The Jorgenson, q and real options models outlined above are set in a world of quantifiable Knightian risk rather than fundamental, immeasurable Knightian uncertainty. In reality, uncertainty is not measurable and so it is not feasible for businesses to use complex rules/algorithms. In reality, Knightian uncertainty will transform the way in which businesses decide about their fixed asset investments.[6] Complexities are especially salient in the context of macroeconomic investment models. Risk and uncertainty are especially pertinent to the analysis of business fixed asset investment because investment is by its nature a forward-looking activity the success of which is determined by how accurately business decision-

[6] See Meeks (1991) on rationality and uncertainty in investors' decisions.

makers are able to forecast the future. In turn, investment is critical to macroeconomic growth and production. Understanding how business investors' expectations are formed in a world of risk and uncertainty is therefore a key challenge for macroeconomic theory.

Once a macroeconomist allows that uncertainty is immeasurable, the capacity for substantive rationality is removed. Thus, the distinction between heuristics and algorithms can be used to separate the different types of investment decision rules used by real-world businesses. In the context of fixed asset investment, procedurally rational investors will use common sense rather than complex mathematical techniques in assessing investment plans. A procedurally rational investor operating in a world of bounded rationality (in which the sensible application of mathematical constrained optimisation techniques will be impossible because nothing is precisely measurable) will not be able to quantify a NPV/DCF algorithm. Different investors, faced with the same information, may form different expectations reflecting arbitrarily assigned margins of error.

In the real-world, many businesses, especially smaller businesses, will be unwilling and/or unable to implement complex optimising algorithms and will prefer techniques that require just simple assumptions based on current conditions. Consistent with this preference, businesses can do their by utilising simple business decision rules anchored around payback periods (PBP)[7] and accounting rates of return (ARR)[8], both of which fit within the behavioural economics conception of a heuristic (Baddeley 2006). These heuristics can help businesses in guiding their decisions about embarking on a new project, expanding or contracting their workforce, or investing to boost their capital stock. They are simple rules of thumb that are possible to implement without stringent requirements. They are relatively quick and easy to calculate and so will be a relatively simple way to navigate information problems and cognitive constraints.

In fact, PBP and ARR techniques approximate complex algorithms under certain conditions (Gordon, 1955; Harcourt, 1968; Sarnat & Levy, 1969; Baddeley and Harcourt, 2021) and so can be used to approximate NPV and DCF algorithms, sometimes without generating significant differences in investment decisions. Also, NPV and DCF algorithms are difficult to

[7] The length of time it takes to generate (undiscounted) cash flows from a project which are sufficient to cover the initial investment cost.
[8] The ratio of (undiscounted) cash flows to the initial investment cost.

use properly and effectively. First, there is the problem of missing information. Questions around how to forecast future revenues and/or how to identify a "correct" discount rate are far from settled questions, meaning that there are practical gaps in implementing these techniques in practice. There is no single robust method for forecasting future revenues or identifying an appropriate discount rate.

Moreover, and consistent with Todd and Gigerenzer's (2012) insight that heuristics will be better than complex decision rules in a fundamentally uncertain world, PBP and ARR heuristics may be more helpful than NPV and DCF algorithms because they do not require complex information about expected future cash flows, discount rates and forward-looking rational expectations. A fixed asset investor may not want to worry about identifying their discount rate either because they do not realise that the value of money changes over time and are ignorant about the trade-offs between present value and current value, or because they judge that current information is fallible and the future is too uncertain for calculations and predictions based around discounting procedures to be of much use. Either way, whether an inappropriate discount rate is used deliberately or by mistake, the consequent flows of fixed asset investment will not be consistent with the optimal decision-making highlighted in the Jorgenson, q and real options models. Overall, business decision-makers may make a procedurally rationaljudgement that the computational and cognitive costs of using sophisticated algorithms are too high relative to the likely benefits in terms of better investment decisions for the future.

In terms of the empirical evidence, interviews conducted in conjunction with the surveys of business leaders in Cambridgeshire (Baddeley 1996, 2006) indicated that some firms' managing directors just did not think that NPV and DCF were valid techniques to use when uncertainty was limiting the availability of clear, reliable information about the future. This survey evidence also showed that, not only are DCF methods less commonly used in practice, when they are used they are sometimes misused suggesting that decision-making biases are likely to distort the correct application of NPV/DCF techniques. For example, survey evidence from Baddeley (1996, 2006) shows that many businesses claimed to use discounted cash flow methods but had anomalously answered 'not applicable' when asked how they selected a discount rate. Those who did nominate a discount rate used the post-tax cost of capital or borrowing costs as a discount rate. They were not using higher discount rates to allow for impacts of uncertainty on sunk investments, as would be consistent with real options theories of investment. This suggest significant sources of bias are associated with the use of

discounting techniques. If these types of bias and mistake are widespread, then there will be negative implications not only for businesses and their employees but also for public sector infrastructure investment, and the macroeconomy as a whole.

<b> **Optimism bias and animal spirits**

Following from the analysis of shifting risk and time preferences and their implications for consumption, inconsistent risk preferences may also affect businesses in terms of cycles of optimism bias and pessimism bias, and their implications for macroeconomic confidence (Baddeley 2016, 2017). Entrepreneurs building their businesses via their fixed asset investments have a significant impact on the macroeconomy via aggregate demand and behavioural influences drive entrepreneurial decision-making even when uncertainty limits their ability to form accurate expectations of future prospects from investments. With uncertainty, the future is not easily quantifiable and so entrepreneurs cannot estimate with any accuracy their expectations of the future benefits from their entrepreneurial investments.

As noted above, Keynes's concept of animal spirits parallels insights from behavioural economics about optimism bias and pessimism bias. Animal spirits are psychological urges to act and intervene which are neither rational nor irrational. Keynes observes that decisions:

> 'to do something positive, the full consequences of which will be drawn out over many days to come, can only be taken as a result of animal spirits – of spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities. Enterprise only pretends to itself to be mainly actuated by the statements in its own prospectus, however candid and sincere. Only a little more than an expedition to the South Pole, is it based on an exact calculation of benefits to come … [animal spirits drive entrepreneurs] so that the thought of ultimate loss which often overtakes pioneers ... is put aside as a healthy man puts aside the expectations of death' (Keynes 1936, pp. 161–162).

In the context of business investment plans, Keynes (1936) observes that predicting long-term prospects of new investments is all but impossible and so entrepreneurs are unlikely to be driven by their quantified estimates of their best choices for maximising expected future profits. Instead Keynes describes the entrepreneurial personality in terms of a "sanguine temperament and constructive impulses" and people embarking on business ventures reflecting "business as

a way of life" not as a means to make profit. Thus the entrepreneurial personality influences macroeconomic outcomes – and animal spirits play a central role in this (Keynes 1936).[9] In aggregate, animal spirits will drive the macroeconomy in periods of optimism and confidence, however entrepreneurs are also easily discouraged psychologically by crises of confidence in times of economic adversity and social changes. So, during pessimistic, recessionary/deflationary periods, the reversion of entrepreneurs' animal spirits will slow entrepreneurial investment with magnified impacts on the macroeconomy via slumps in aggregate demand and employment:

> 'if the animal spirits are dimmed and the spontaneous optimism falters, leaving us to depend on nothing but a mathematical expectation, enterprise will fade and die; – though fears of loss may have a basis no more reasonable than hopes of profits had before' (Keynes 1936, p. 162).

So whilst animal spirits at first inspection seem like a force for good in the macroeconomy if, on balance, they do no more than amplify macroeconomic volatility then the positive role of animal spirits is more ambiguous, unless animal spirits' contribution to upswings in good times outweighs their depressing impacts during downswings.

<a> IMPLICATIONS AND CONCLUSIONS

To conclude, behavioural economic influences will have profound impacts on the macroeconomy. Biases associated with heuristics and inconsistences in time and risk preferences will distort future planning by households and businesses. The macroeconomic implications will be substantial and complex because, when biases are aggregated, become systemic and/or are exhibited by a large proportion of businesses and consumers in the real world, they will combine in magnifying under-investment, unemployment and sluggish production during recessionary periods. Present bias will magnify current consumption to the detriment of future consumption, potentially trigger long-term shifts in inequality if poorer households are less able to accumulate wealth to pay for their retirement. Uncertainty will dampen businesses' investments, with knock-on effects for production, employment and growth. So, what are the behavioural macroeconomic policy solutions? As explored above,

[9] See also Katona (1946) and Akerlof and Shiller (2009) for a modern interpretation.

traditional macroeconomic models have not allowed for behavioural biases and psychological influences. The problem from a behavioural economics perspective is that biases are not just random noise. They are systematic biases which will not cancel out in aggregate and, in fact, are likely to be magnified when the herding and conventions outlined above are driving the decisions and choices of businesses and households.

This leads to the broader question of how behavioural macroeconomic policy should differ from conventional macroeconomic policies founded on assumptions of rational decision-making? Behavioural macroeconomic policies designed to take into account of behavioural fallibilities (by policy-makers as well as households and businesses) could address issues of time inconsistency and present bias by embedding pre-commitments into decision-making, thus limiting the extent to which decision-makers shift decisions in response to short-term factors. Behavioural policies designed to boost animal spirits and optimism via improving business confidence and consumer sentiment could have a positive impact on macroeconomic activity, especially through downturns, recessions and depressions. In this, expansionary policies will have benefits beyond the standard multiplier effects if they boost confidence more generally via their impact on optimism and confidence. More generally, behavioural macroeconomic policy provides a potential route out of the political and ideological biases and rhetoric which have driven the pendulum-like oscillation of macroeconomic policy prescriptions in line with political trends – characterised by a series of contests between free-market "hands-off" policy prescriptions and Keynesian interventionist policy prescriptions. In the first instance, more empirical evidence is needed to establish which behavioural influences are important, what sort of impacts they have and how beneficial impacts can be leveraged and negative impacts can be ameliorated. There is growing range of promising data and techniques that could feed into this sort of research agenda. With more evidence about behavioural and psychological impacts on the macroeconomy, this might hopefully lead to a more scientific and less polemical approach to macroeconomic policy-making

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