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‘A behavioural model of investment appraisal and its implications for the macroeconomy’

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A behavioural model of investment appraisal and its implications for the macroeconomy

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Abstract

Sub-optimal levels of investment in fixed capital are a pressing problem for modern economics. Behavioural economics provides some potential explanations, but behavioural economic insights are not commonly incorporated into standard capital investment models which capture neither the diversity of investment appraisal techniques used in practice, nor the range of decision-making styles used by real-world businesses. In filling these gaps, this paper brings together insights from capital investment theory with insights from behavioural economics to develop a behavioural economic model of investment appraisal, allowing for boundedly-rational investment decision-making. This model is applied in a macroeconomic analysis to show how the misapplication of investment appraisal criteria, especially under conditions of endemic uncertainty, is associated with sub-optimal levels of macroeconomic investment – with negative macroeconomic implications in terms of production, employment, productivity, wages and cyclical volatility.

JEL codes: E29, E70, D22, D25, M21
Keywords: investment, heuristics, bias, behavioural macroeconomics

Under-investment in capital assets[1] is a perennial problem for advanced economies. In explaining and rectifying the problem, a key challenge comes in capturing the behavioural economic insights driving sub-optimal capital investment in the real world, especially when uncertainty is endemic. Mainstream investment models are founded on the Jorgenson model (Jorgenson 1963, 1971, 1996; Hall and Jorgenson 1967) in which businesses invest in fixed capital to

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[1] Capital investment, for example investment in buildings, plant, machinery and equipment, is also commonly referred to as fixed asset investment. For the purposes of this paper, capital investment and fixed asset investment are interchangeable concepts not to be conflated with financial investment.

the point where the user cost of capital and the marginal productivity of capital are equalised. The Jorgenson model suffers from limitations in terms of its static analysis and its associated neglect of expectations formation. Subsequent refinements within a rational expectations framework, including the q/adjustment cost and real options models, incorporate discounting and quantifiable risk (Hayashi 1982, Abel 1983, Brainard and Tobin 1977). Nonetheless, limitations remain. The Jorgenson, q and real options models are limited by their assumptions about the nature of capital – a theme which addressed by Harcourt (1965, 1968, 1969, 1972).

These models also pre-date the development of behavioural economic models of unstable time and risk preferences and heuristical decision-making. This paper reconciles these divergent models of capital investment and brings them together with insights from behavioural economics to illustrate the macroeconomic implications of the misapplication of investment appraisal criteria at a microeconomic scale. Specifically, in filling the gap in behavioural macroeconomic investment theory, this paper combines insights from behavioural economics with earlier literatures on investment appraisal techniques in analysing the use of algorithmic versus heuristical approaches to investment appraisal and the implications in terms of insights from behavioural economics about time inconsistency. These insights are then applied in showing how the misapplication of investment appraisal criteria at a microeconomic level contributes to underinvestment and investment volatility in the macroeconomy, with negative implications for output, employment, labour productivity, wages and cyclical volatility.

The paper proceeds as follows: Section 1 summarises mainstream models of fixed asset investment and their applications to investment decision-making in practice, for example via investment appraisal methods including discounted cash flow (DCF) tools - net present value (NPV) and the internal rate of return IRR); the payoff period (POP) criterion; and the accounting rate of return (ARR). Section 2 analyses the implications of these methods from the perspective of behavioural economic lens, drawing on Simon's (1955, 1979) distinctions between unbounded/substantive, bounded and procedural rationality to show that there is a limited equivalence of the criteria under restrictive assumptions of static expectations. Section 3 focuses specifically on behavioural biases associated with time inconsistency to show that the use of POP methods embeds instability and discontinuities in the implicit discount rates, contributing to instability in the capital-intensity of production techniques selected, with instability increasing as the target payoff period decreases. Section 4 applies these insights to a behavioural analysis of capital investment in the macroeconomy to explore the macroeconomic consequences of time inconsistent investment decision-making at a microeconomic. Section 5 outlines the main implications, conclusions and directions for future research.

1 Mainstream investment models applied to investment appraisal in practice

The starting point for mainstream macroeconomic models of capital investment is the Jorgenson model (Jorgenson 1963, 1971, 1996; Hall and Jorgenson 1967), founded on Cobb and Douglas production assumptions (Cobb and Douglas 1968).[2] Firms take inputs of capital and labour and use them to maximise the value from inputs of labour and capital and this will be achieved when the user cost of capital and the marginal productivity of capital are equalised. The original Jorgenson model embedded many simplifying assumptions, including the neglect of expectations, uncertainty and risk. Implicitly, early versions of the Jorgenson model embedded the implicit assumption of static expectations, i.e., that current conditions are likely to persist into the future. From any perspective, this neglect of dynamics is anomalous given the forward-looking nature of fixed investment activity and its overarching goal, which is to forgo current consumption by investing in capital assets today in order to generate magnified returns from production in the future.[3] From a behavioural perspective, the absence of assumptions about expectations formation is an especially critical gap given that decisions today with consequences for the future are especially prone to systematic decision-making biases given cognitive limits on decision-makers' ability to plan for the future. In part, limitations associated with the omission of dynamics from the original Jorgenson model were addressed in subsequent refinements within a rational expectations framework, including q/adjustment cost models of investment. These models combine forward-looking rational expectations with assumptions of homogenous capital and constant returns to show that average q (as can be measured using Tobin's q – the ratio of stock market valuations to the current replacement cost of capital) can proxy for unobservable marginal q under some conditions (Abel 1983, Hayashi 1982, Brainard and Tobin 1977). These models were further developed in real options theory to capture the dampening impacts of uncertainty[4] in raising the hurdle rate of return on investment – i.e. the rate of return which an investment must match or exceed in order to be judged viable (Pindyck 1991, Dixit and Pindyck 1994).

These models pre-date recent developments in behavioural economics, in particular insights from behavioural economics exploring the anomalies that emerge in decision-making when time and risk preferences are unstable and/or when heuristics (simplified decision-making tools) are used. Whilst behavioural macroeconomics has explored the impacts of behavioural influences on consumption, labour markets and asset markets (e.g. see Akerlof 2002, Driscoll and Holden 2014), behavioural influences on aggregate investment have not explored in depth, except indirectly via the analysis of aggregate supply/demand,

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[2] See Junankar (1972), Chirinko (1993), and Baddeley (2003) for a survey of investment theory and modelling strategies.

[3] The Jorgenson, q and real options models are also limited by other assumptions, including assumptions about the nature and homogeneity of capital, see Harcourt (1968, 1969, 1972).

[4] With uncertainty embedded as a specific form of measurable risk (Knightian risk) and not in terms of fundamental, immeasurable uncertainty (Knightian uncertainty).

consumption, impacts of learning on expectations, and impacts of animal spirits on business confidence (e.g. see Akerlof and Shiller 2009; de Grauwe 2011, 2012; Baddeley 2014, 2016, 2017; Howitt and McAfee 1992; Katona (1946); Gabaix 2020; Farmer and Guo 1994; and Evans and Honkapohja 2001).

1.1 Common investment appraisal techniques

Jorgenson's model has practical relevance because it forms the basis for what is widely regarded as the foundation of best practice in real world investment appraisal viz. the net present value (NPV) rule. NPV is constructed around the discounted stream of expected future gross profits as measured by the discounted cash flow (DCF). Refinements of NPV methods have also been combined with insights from real options theory in a practical context. Applying to decisions about choosing between different techniques for production, as outlined in Harcourt (1968), when choosing between j techniques, the ith optimising firm should choose the jth technique which maximises V^j – the net present value of technique j over the period $t = i$ to $t = n$:

$$V^j = \sum_{t=i}^{n} \frac{\left(Q_i - C_i^j\right)}{\left(1+r\right)^i} - K_j \tag{1}$$

where Q is revenue, C_i^j is the variable cost of production for technique j in period t=i, and K^j is the capital cost of technique j. The discount rate, assumed equal to the interest rate (given the related assumption of perfect capital markets), is given by r. Profit-maximising firms will use (1) to invest in fixed capital until the point at which the costs and benefits are equalised, i.e., when $V^j = 0$.[5] This is broadly equivalent to the theoretical result from the Jorgenson model in which the user cost of capital is equated with the marginal productivity of capital.

The NPV is used specifically in identifying the internal rate of return (IRR), where the internal rate of return is identified as the discount rate at which the cost of an investment project equals the discounted stream of expected future revenues from an investment, i.e., where $V^j = 0$ and the NPV associated with technique j is equal to 0. Thus, the optimal IRR can be derived from the NPV rule as r^*, where r^* is the r that equates the discounted stream of net revenue (revenue minus variable costs of production) with capital cost:

$$IRR = \sum_{t=i}^{n} \frac{\left(Q_i - C_i^j\right)}{\left(1+r\right)^i} = K_j \tag{2}$$

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[5] There are logical inconsistencies with this approach as an optimisation rule circling around the idea that costs and benefits should be equalised at the margin, not in total/on average. This also connects to a problem characterising some capital investment theories in which stocks of capital goods are conflated with flows of investment. Stock-flow versions of q theory, incorporating adjustment costs, address this limitation via various additional assumptions, including those of constant returns to scale and homogenous capital, see, for example, Abel (1983) and Hayashi (1982).

NPV and IRR are relatively complex techniques and may not be so widely used, especially by the smallest businesses.

Alternative, simpler investment decision criteria include the payoff period (POP)[6] and accounting rate of return (ARR) criteria, which are defined as follows:

$$POP = \sum_{i=1}^{b} \left(Q_i - C_i^j \right) \geq K_j \tag{3}$$

where b is the POP i.e., the minimum number of years of revenues net of variable costs it would take to pay back the original investment costs K^j:

$$b = \frac{K^j}{\sum_i^b \left(Q_i - C_i^j \right)} \tag{4}$$

The accounting rate of return (ARR) is the undiscounted cashflow as a proportion of capital cost:

$$ARR = r = \frac{\sum_{i=1}^b \left(Q_i - C_i^j \right)}{K^j} \tag{5}$$

As a corollary of the arithmetic relationship between NPV and IRR, there is a simple algebraic relationship between POP and ARR and ARR is the inverse of the POP:

$$\rho = \frac{1}{b} \tag{6}$$

The different techniques have different limitations. DCF techniques NPV and IRR are widely accepted in the business world as the best practice investment appraisal tools. These tools are grounded in the principles of dynamic profit maximisation. In theory, assuming a perfect world of measurable uncertainty, unbounded rationality, rational expectations and informally efficient financial markets, NPV and IRR algorithmic tools will enable the identification of optimal paths for investment. Given that the POP and ARR techniques are static and neglect both discounting and expectations, in a world in which the appropriate discount rates are easy to identify and unbiased expectations can easily be formed, POP and ARR are sub-optimal, and there would be little debate about the superiority of DCF methods. In the real world however, complications arise because the DCF methods are difficult to apply in practice, for example because discount rates are not easy to identify, because uncertainly is not measurable and/or because unbiased expectations are not easily formed.

Even the relatively sophisticated NPV tools are limited in terms of their theoretical foundations and are not designed to capture shifts in capital intensities, capital deepening and capital switching, endogeneities and feedbacks effects associated with shifts in factor productivity (Harcourt 1968). The "textbook" presentations of DCF, NPV and IRR investment appraisal techniques

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[6] Also referred to as the payback period (PBP) criterion.

may not connect well with how real-world entrepreneurs and investors make their decisions in practice and so may lack external validity either if they are not commonly used and/or if they are misunderstood and mis-applied in practice. For this reason, simpler investment appraisal techniques including the POP criterion and the ARR may be preferred in practice, especially by small and medium-sized enterprises (SMEs) who may not have the expertise or business infrastructure to employ the more sophisticated DCF techniques.

2 Investment appraisal techniques: a behavioural analysis

In addition to any potential problems with real-world applicability of textbook investment appraisal techniques, an additional limitation for the practical application of investment appraisal techniques is that the behavioural assumptions implicit to these approaches do not capture how real-world businesses operate. From a behavioural decision-making perspective, DCF methods are relatively sophisticated methods which are relatively cognitively demanding to apply in practice, and also require access to information that may be difficult to identify and forecast. For DCF methods to work well, they depend on the assumption that decision-makers are rational farsighted optimisers, an assumption that has been shown in behavioural and experimental evidence to be problematic.

2.1 Substantive and procedural rationality: Algorithms versus Heuristics

In unravelling the relevance of these behavioural constraints, insights from Simon's (1955, 1979) analyses of bounded rationality illuminate some of the dimensions of rationality likely to be relevant for businesses in the real world. Simon makes a distinction between substantive rationality – such as is consistent with the application of mathematical optimisation tools – and procedural rationality, consistent with what Simon terms "appropriate deliberation" i.e., the application of common-sense, intuition, experience, and implicit knowledge (Simon 1979). Fitting-in with Simon's taxonomy, DCF techniques, including NPV and IRR are algorithms used to identify an optimal path for investment, the application of which is consistent with an assumption of substantive rationality. POP and ARR are heuristics, the application of which is consistent with Simon's conception of procedural rationality (Meeks 1991, Baddeley 2006).

Heuristics as procedurally rational tools worked in some limited contexts. POP/ARR heuristics can be used simply as a target to exceed rather than a precise optimal point to achieve. In terms of target heuristics, if a business targets a particular pay-back period $\bar{b}$, this can be re-expressed as:

$$POP = \bar{b} = \frac{K^j}{\sum_i^{\bar{b}} \left(Q_i - C_i^j \right)} \tag{7}$$

This implies an equivalent target ARR:

$$ARR = \rho = \frac{\sum_i^{\bar{b}} \left(Q_i - C_i^j \right)}{K^j} \tag{8}$$

Also, heuristics and algorithms are not necessarily mutually exclusive and may be used in combination. Applying specifically to the context of capital investment, as Harcourt (1968) notes, there is a pressure to educate businesses in using algorithmic techniques but does this preference really make a difference if POP and ARR are approximately as effective as DCF investment appraisal rules? Decisions formed from applying simple heuristical rules will approximate complex DCF algorithmic rules under certain conditions (Gordon 1955; Harcourt 1968; Sarnat and Levy 1969; Ramsey 1970; Dudley 1972; Kay (1976) and Wright 1978; Gronchi 1986 and Baddeley 2006). Specifically, relatively complex DCF investment appraisal methods can be approximated using these simpler techniques on the assumption that expectations of future cash-flows are determined by current cash-flows, consistent with a static expectation assumption (as noted above, as is implicit to early versions of the Jorgenson model). Under these conditions, POP and ARR can be justified as NPV/IRR short-cuts on the basis that they give approximately the same answers. This can be shown algebraically assuming static expectations. If C is the cost of an investment project and is the annual revenue from the project (assumed to be constant each year, given expectations of future revenue based on current conditions). If there is a one-year delivery / installation lag before revenues accrue, NPV will be equal to zero when:

$$C = \sum \frac{\bar{q}}{(1+\rho)^t} \tag{9}$$

Multiplying through by $\frac{1}{(1+\rho)}$:

$$\frac{C}{1+\rho} = \sum \frac{\bar{q}}{(1+\rho)^{t-1}} \tag{10}$$

Subtracting (10) from (9) gives:

$$\sum \frac{\bar{q}}{(1+\rho)^t} - \sum \frac{\bar{q}}{(1+\rho)^{t-1}} = \frac{\bar{q}}{1+\rho} \tag{11}$$

By extension, under uncertainty, b and ARR may also approximate a real options algorithm when short target payoff periods are equivalent to high hurdle rates of return. From equations (5) and (6), POP is the inverse of the ARR:

$$POP = b = \frac{C}{\bar{q}} = \frac{1}{ARR} \tag{12}$$

Given these simplifying assumptions, the implicit discount rate will be the inverse of the pay-off period:

$$\rho = \frac{\bar{q}}{C} = \frac{1}{\bar{b}} \tag{13}$$

Therefore, assuming static expectations, POP and ARR heuristics are equivalent to NPV and IRR algorithms. Under these conditions, judgements about complex and uncertain things (e.g. an appropriate discount rate) may be not be required. In some situations, these heuristics may even be more effective investment appraisal guides than the relatively complex NPV and IRR algorithms because their simplicity means that mistakes are less likely.

There are significant divergences between the textbook theory and real-world practice with respect to capital investment decision-making and appraisal tools, in part reflecting the fact that NPV and IRR rules are difficult and confusing for real-world businesses, especially the smallest SMEs (e.g., micro-businesses) to implement in practice. Survey evidence shows a majority of real-world businesses, especially SMEs, are more reliant on simple POP and ARR investment appraisal techniques, though more recent surveys suggested that DCF methods are becoming more commonly used (Arnold and Hatzopoulos, 1999, Drury et al. 1992, Neild, 1964). No statistical comparisons are possible but to illustrate the trends brsoadly: in Neild's survey DCF algorithms were used by just 3% of engineering firms; 88% were using pay-off periods or simple measures of profit (Neild, 1964, pp. 30-44). Sangster (1993), from a survey of 500 Scottish firms, observed that organisational change together with expanding access to information technology may have disrupted these tendencies for small companies and large companies to use different investment appraisal criteria – though 78% were still reliant on the POP. Later evidence from a survey of Cambridgeshire businesses showed significant differences in criteria adopted POP was used by 81% of firms – including 70% of small businesses; for DCF methods, these were used by 34% of the firms surveyed, and by 25% of small businesses relative to 43% of large firms (Baddeley 2006).

3 Heuristics and Bias: Time-inconsistency in investment decision-making

Assumptions of static expectations can be justified, even in a non-behavioural context, if there is limited knowledge and information around which to build more complex assumptions about expectations. However, a more serious dynamic limitations of the POP and ARR heuristics comes in the context of discounting – with policy-relevant implications as well as methodological implications. The discount rate, the rate of time preference, is a crucial piece of information that is especially relevant in the context of investment appraisal given that capital investment is all about planning for the future. In a world of endemic uncertainty, accurately identifying the appropriate discount rate is essential in quantifying the relative benefits of investment spending today in terms of the present value of revenues expected for the future. However, quantifying accurate discount rates in practice is likely to be difficult if not impossible, especially for innovative investment projects because uncertainty will limit the extent to which the lifespan and future benefits of capital investments can be predicted.

In terms of standard (non-behavioural) discount functions, the Jorgenson, q and real options models outlined above embed exponential discounting and time-consistent preferences. With exponential discounting, the rate of time preference is stable and consistent. To illustrate consistent time preferences with an example, if a business is planning for a one-year investment project starting in a year's time, then they will discount this in the same way as if they are planning for a one-year investment project starting tomorrow. Connecting with the discussion of substantively rational algorithms and procedurally rational heuristics, as outlined above, exponential discounting complements relatively complex, forward-looking algorithms, consistent with substantively rational optimisation strategies which are the focus of the Jorgenson, q and real options theories. However, behavioural economics and related experimental and other empirical evidence has shown that decision-makers' preferences are not always time-consistent. How a decision-maker judges the benefits and costs of a decision today offering rewards over the near-term differs from how they judge the benefits and costs of a decision planned for implementation in the relatively distant future, even if every other aspect of the options is identical.

3.1 Implications for capital investment discounting

Embedding insights from behavioural economics into the analysis of capital investment decision-making, there is an important distinction between the types of sub-optimal approaches which business decision-makers may adopt in assessing the present value of future cash-flows. They might:

Ignore discount rates deliberatively

An undiscounted POP or ARR calculated correctly may be less precisely accurate but unbiased on average. As fuzzy quick decision short-cuts, using POP and ARR may be consistent with broader procedural conceptions of rationality. It is reasonable for a business decision-makers to conclude that forming precise estimates of the value of future rewards is unfeasible and so 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. Applying to capital investment and investment appraisal, procedurally rational business decision-makers may deliberately and reasonably prefer ARR or POP heuristics over complex DCF appraisal methods which are difficult to implement in practice. When heuristics are used in this way – i.e., deliberatively not unintentionally – as quick decision-making short cuts, this parallels the ways in which heuristics are captured in behavioural economic analyses of "smart" heuristics, e.g., see Gigerenzer et al. (1999), Gigerenzer and Brighton (2011).

Embed incorrect discount rates

Incorrect discount rates can take two forms in practice: first, decision-makers may ignore the discount rate completely; and second, they may embed an incorrect discount rate in practice. When ignoring the discount rate, business decision-makers may be ignorant about the difference between the current value of current rewards and the present value of future rewards. Implicitly, albeit unintentionally, they will be applying a discount rate of zero to future cash-flows over the short time horizon they are considering. In other words, over a short time-horizon – say 5 years, they are treating all cashflows as the same, regardless of when these cash-flows arrive. It does not follow, however, that they are infinitely far-sighted, as would be the case if they were substantively rational decision-makers embedding a zero discount rate in general because, beyond their short time horizon, future rewards are implicitly accorded an infinite discount rate, as explained in more depth below.

There is some empirical evidence that business decision-makers want to use DCF methods but do not see the connection with discount rates, with a survey of Cambridgeshire businesses showing that some businesses, especially SMEs, claimed to use DCF methods whilst also stating that discount rates are not relevant to their DCF calculations (Baddeley 2006). This indicates either that these businesses were ignorant or confused about the fundamentals of DCF methods. Biases created from this 'discount rate neglect' will be corollaries of biases associated with, for example, base rate neglect, one of the forms of heuristic bias (i.e. biases generated from the use of heuristics) explored extensively in the literature on risk misperceptions, as pioneered by Tversky and Kahneman (1974) and Kahneman and Tversky (1979, 1982). Similarly, if DCF methods are calculated using exponential discount functions but using an incorrect discount rate, then an NPV calculated using the wrong discount rate could introduce significant bias into investment appraisal decisions.[7]

Use a behavioural (hyperbolic or quasi-hyperbolic) discount function

In other words, decision-making is distorted by time inconsistency and present bias. To capture this, behavioural economics theory has developed alternative functional forms for discount functions, including hyperbolic and quasi-hyperbolic discount functions (Ainslie 1991, Strotz 1955, Frederick et al. 2002, Laibson 1997, Harris and Laibson 2001, Angeletos et al. 2001, O'Donoghue and Rabin (2015), Cohen et al. 2020, Angeletos and Huo 2021). Quasi-hyperbolic discount functions, also know as $\beta\delta$ models, have been embedded into behavioural business cycle models (Laibson 1997, Harris and Laibson 2001, O'Donoghue and Rabin 2015), in which the exponential discount factor $\frac{1}{(1+\rho)}$ is augmented with a present bias parameter β to give a discount factor:

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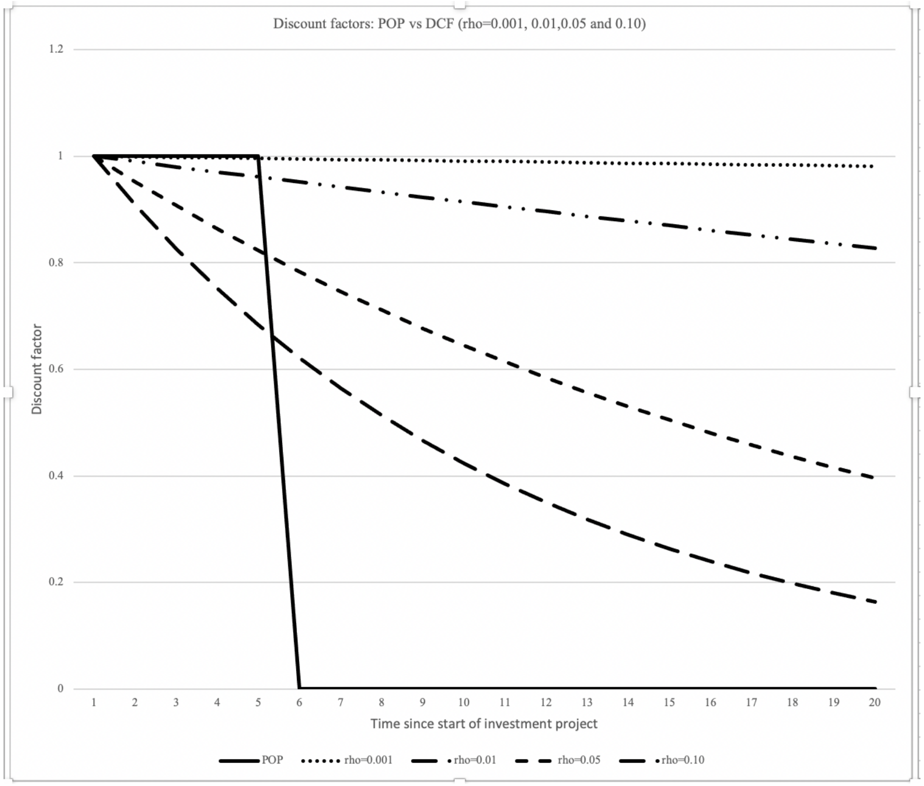
[7] In practice, except when implicit discount rates are 0 or infinite, it is difficult to know whether or not the wrong discount rate has been used given that, as a rate of time preference, it is in essence a subjective preference. Also, even substantial divergences in discount rates away from the cost of borrowing may be difficult to disentangle from subjective risk preferences.

$$D(x) = \begin{cases} 1 & if\ x = 0 \\ \beta \cdot \delta^x & if\ x > 0 \end{cases} \tag{14}$$

This will generate a problem of time inconsistency and present bias – but, paralleling the literature on time inconsistency amongst consumers (O'Donoghue and Rabin 1999, 2001), in some cases when decision-makers are relatively sophisticated and aware of their susceptibility to present bias and time inconsistency then these decision-makers may adopt pre-commitment strategies to bind themselves to more far-sighted capital investment decisions.

3.2 POP and ARR heuristics: implicit discount rates

The insights about the shift in discount rates from zero discount rates over the short-term to infinitely large discount rates over the medium to long-term, as noted in section b. above, can be applied in capturing the different outcomes from the application of POP and ARR versus DCF methods. In using POP and ARR heuristics as short-cuts in place of the DCF methods, present-biased decision-makers will focus their investment appraisal on revenues and costs over a short time horizon, implicitly incorporating a discount rate of zero on revenues and costs accruing over the relatively short time horizon over which a POP heuristic is targeted. Over this time horizon, with no discounting of future revenues and profits accruing over the POP planning period, future revenues and costs will be equivalent to current revenues and costs. By contrast, revenues and costs outside the POP period are ignored, effectively applying an infinitely high discount rate on revenues and costs beyond the POP period. Thus, the discount factors implicit to POP and ARR are essentially non-parametric equivalents of behavioural discount functions, with the implicit discount rate jumping between 0 and 1. In other words, implicit discount rates are 0 and the discount factor is equal to 1 for cashflows estimated to accrue over the payback period and cashflows accruing over the short-term are treated as equivalent to current cashflows. After that, however, the discount rate jumps to an infinitely large rate, with a discount factor of zero implicitly assigned to future cashflows expected to accrue after the payback period has ended. This discontinuity in the discount function at the time the POP planning period ends creates a specific form of present bias. This is illustrated in Figure 1.



Comparison of DCF discount rates and implicit discount rate given a 5 year target POP

Figure 1 shows the time-path of the implicit discount rate given a POP of 5 years[8] (equivalent to a hurdle rate of return of 20%) in comparison with a range of DCF (exponential) discount factors given discount rates of 0.001, 0.01, 0.05 and 0.10 respectively.

To summarise, applying insights from behavioural economics to investment decision-making the dynamics of capital investment appraisal, investment planning is susceptible to two key distortions relating, first, to assumptions about expectations; and second, to implicit assumptions about the discount rate. Investment appraisal heuristics generate time-inconsistency in practice. Thus, the POP and ARR investment criteria will lead decision-makers to over-estimate the value of small, short-term projects and under-estimate the value of large long-term projects. The net impact will depend on the productive life of the fixed assets under consideration; capital investments which quickly depreciate will be less susceptible to this problem of present bias than investments with low deprecation rates. On the other hand, fixed assets with relatively long lifetimes and which depreciate more slowly may take longer to pay off but they will also be generating cashflows over a long time horizon.

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[8] The POP series is based around a 5 year payoff period because this payoff period is commonly used in practice by many businesses, especially SMEs.

4 Present-biased capital investment and its macroeconomic consequences

Under-investment in fixed capital assets is a perennial problem for advanced economies. When capital investment is sub-optimal, multiplier effects from investment will be less, employment and production fall and unemployment rises. Harcourt (1969, 1972) explores the macroeconomic implications from applying different appraisal techniques, with alternative projects ranked differently depending on the investment appraisal rule adopted. Rules that are a good fit with a world in which uncertainty is absent, expectations are fulfilled, and the rate of profit is unambiguous are not necessarily a good fit with messy reality. Accountants' "Golden Age" investment decision-making criteria will be misleading in practice, generating deviations between ex ante and ex post rates of profit when quasi-rents from individual machines in the capital stock are distorted by anomalies in the depreciation rate, when the capital stock is growing and when the mix of fixed assets that comprise the capital stock are shifting. The net impact of using the POP as a rough rule of thumb for investment appraisal in these circumstances will depend on the productive life of the fixed assets, depreciation methods and temporary fluctuations in profits and growth rates (Harcourt 1965).[9] Given the complexities and divergences between the different investment decision criteria, when businesses use different heuristics then this will lead to significant differences in the techniques employed with effects which are similar to those accounted for by changes in factor costs and prices, with implications in terms of shifts in labour productivity, wages and employment with implications for capital intensity and labour productivity (Harcourt 1968, 1972).

Using target POP and ARR tools to guide capital investment decisions, will lead deviations between ex ante and ex post rates of profit with significant implications for productivity growth and macro performance. Adding in insights from behavioural economics, as analysed above, discontinuities in the discount rates/discount factors implicit to the POP and ARR criteria, are associated present bias and will contribute to uneven patterns of capital investment because, depending on the length of a capital investment's useful life, the degree of present bias is increasing as the length of the payback period decreases. Therefore, using POP and ARR to appraise large capital investment projects with large sunk costs will lead to under-investment in these types of fixed assets because the present value of cash-flows accruing over a longer time horizon will be underestimated.

Some of these impacts can be captured by bringing together the conventional analysis of Cobb-Douglas production, consistent with the Jorgenson model outlined above, with a behavioural analysis of the POP heuristics. In conventional production theory, the isoprofit relationship can be proxied by cashflow defined

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[9] See also Keynes (1936) on links between depreciation and user cost and Fisher and McGowan 1983 and Fisher (1984) extending Harcourt's insights into an analysis of depreciation rate anomalies, in which there are no simple rules of thumb to enable adjustment.

as revenue minus variable costs of production, simplified by assumption to include just labour costs, giving cashflow C:

$$C = pQ - wL \tag{15}$$

Assuming a payback period target of b, then the payback rule is given by:

$$b(pQ - wL) \geq i \tag{16}$$

It follows that:

$$L = \frac{p}{w} - \frac{1}{bw} \tag{17}$$

and the discount factor is b, not $\frac{1}{1+\rho}$ as would be used by businesses adopting DCF investment appraisal tools embedding exponential discounting.

Businesses will choose the technique which maximises revenue net of labour costs given a POP of b years. This gives the following equality between the labour requirement – l and b:

$$l = \frac{p}{w_m} - \frac{1}{bw_m}i \tag{18}$$

Diagrammatically adapting Harcourt (1972, Figure 2.3, p. 61), as shown in Figure 2, this equality constraint is depicted as the line bb. The line qq is equivalent to an isoquant – representing a fixed output produced from varying combinations of capital and labour. For an investment decision-maker utilising a POP heuristic, the preferred technique, defined in terms of the capital-labour required for production, will be determined where bb and qq intersect, i.e. at p_1 and p_2, associated with (sub-optimal) equilibrium labour-output and capital-output ratios of (l_1, k_1) and (l_2, k_2) respectively. Both these points (p_1 and p_2) are sub-optimal relative to the point of profit-maximising optimal equilibrium, as depicted by the tangency point of bb and qq, identified at l^*k^* on a higher isoquant. These sub-optimal equilibria will be associated with a lower volumes of production and a capital-labour ratio which is either too capital-intensive (as at p_2) or too labour-intensive (as at p_1) relative to the optimal capital-labour ratio (as at p^*) – with implications for the productivity of labour and capital.

So, different investment appraisal techniques will generate instabilities in the rankings of alternative investment projects. Systematic biases will generate distortions towards or away from capital intensive techniques, with macroeconomic implications in terms of potential for instability in the form of capital switching between sub-optimal capital-output and capital-labour ratios. There are significant macroeconomic implications from the use of POP heuristics in real-world capital investment decision-making. Whilst POP and ARR heuristics may be useful, fuzzy approximations at the microeconomic level of the individual firm, at a macroeconomic level, when these biases are scaled-up and multiplied then this has the potential to contribute to substantial and systemic problems of sub-optimal and volatile investment at a macroeconomic scale, with serious

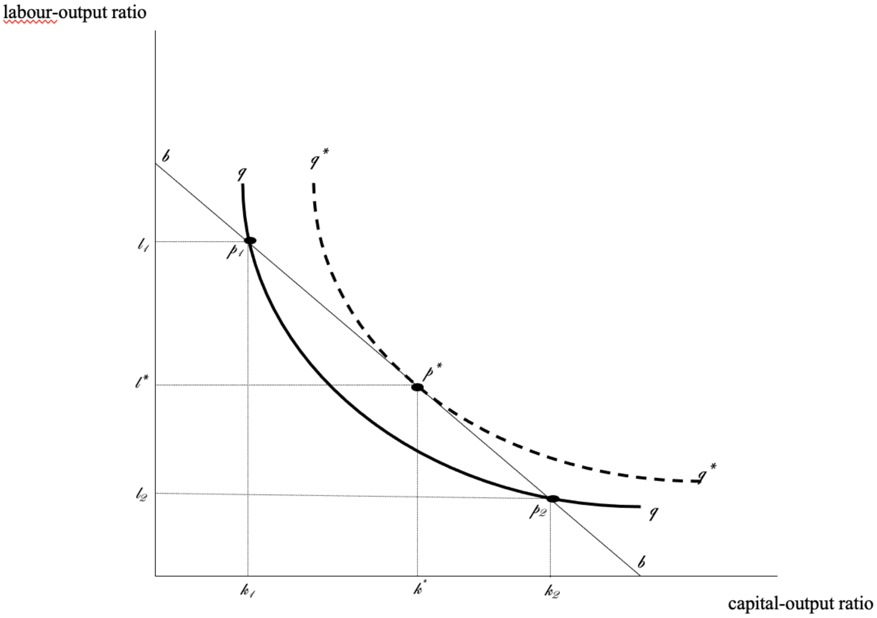

Figure 1: Choice of technique by payback period
[Source: Adapted from Fig. 2.3 from Harcourt 1972, p. 61.]

implications for aggregate demand, production, employment and growth. The sub-optimal use of the POP heuristic (and by extension the ARR heuristic) is potentially more likely to affect the investment activities of (SMEs), which are disproportionately large employers. In terms of implications for employment in the macroeconomy, if time inconsistent investment heuristics as outlined above are widely used – as is likely for small businesses – this may help to explain sustained levels of unemployment as well as underinvestment in the macroeconomy. Volatility in capital investment can similarly be explained by the discontinuities in the discount factors associated with the use of the POP criterion and the associated switching between capital-intensive and labour-intensive techiques, as depicted in Fig. 2. This is consistent with empirical findings from Panagiotidis and Printzis (2021) that the negative impact of uncertainty is intensified for smaller businesses, which could be explained by the fact that they are more reliant on heuristics based around undiscounted cash-flows, thus neglecting the time value of money. In addition, we cannot assume that larger firms with the capabilities to invest in large capital projects eschew simple POP and ARR methods in favour of DCF methods. In fact, recent survey evidence has indicated that even larger firms use a combination of tools, and these trends do not seem to have reversed over time. A recent study of European Union countries found that 90% of firms surveyed used POP in conjunction with other methods and advanced investment appraisal techniques are not used extensively by a large proportion of European corporations (Pawlak and Zarzecki 2020). With POP heuristics being so commonly used, rather than just adopted by a specific minority of firms, the macroeconomic implications are likely to be widespread.

5 Conclusion

In investment appraisal, business decision-makers must forecast the future. In a world of endemic uncertainty, behavioural economics offers key insights about how real-world decision-makers are affected by uncertainty given the limits on information and human cognitive processing abilities. Given these constraints, boundedly rational business decision-makers can save the time, effort and skills required in implementing relatively complex algorithms by focussing their attention on simpler, cheaper heuristics. In the context of capital investment decision-making, business decision-makers will use the POP and ARR as simple heuristics in place of more complex DCF algorithms, including NPV and IRR criteria.

This paper has shown that, from a behavioural economics perspective, the use of heuristics is problematic because there two key limits associated with using POP and ARR: first, the implicit assumption of static expectations; and second, the discontinuities introduced into the implicit discount function, generating time inconsistency and systematic patterns of present bias. Most seriously, problems emerge when the present bias implicit in the use of the POP heuristic leads to excessive discounting of medium- to long-term returns, as are especially relevant for large, long-term investment projects. These projects will be under-valued and under-invested because of the excessive implicit discounting of returns accruing over longer time-horizons. In aggregate, when POP criteria are widely used by a large and diverse range of businesses, then macroeconomic consequences will emerge in terms of unstable and distorted patterns of capital investment in the macroeconomy. This will have wider implications in terms of lower labour productivity and wages, lower employment, higher unemployment and sluggish production. In policy terms, this suggests that greater awareness is needed about the behavioural limitations associated with POP and ARR capital investment appraisal techniques, especially for large, long-term investment projects, including infrastructure projects.

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