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**States of Nature and States of Mind:
A Generalised Theory of Decision-Making,
evaluated by application to Human Capital
Development**

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States of Nature and States of Mind: A Generalised Theory of Decision-Making, evaluated by application to Human Capital Development

By EMBREY, I.P.*

Canonical economic agents act so as to maximise a single, representative, utility function. However there is accumulating evidence that heterogeneity in thought-processes may be an important determinant of individual behaviour. This paper investigates the implications of a vector-valued generalisation of the Expected Utility paradigm, which permits agents either to deliberate as per Homo-economics, or to act impulsively. That generalised decision theory is applied to explain irrational educational investment decisions, persistent social inequalities, the crowding-out effect, the pervasive influence of non-cognitive ability on socio-economic outcomes, and the dynamic relationships between non-cognitive ability, cognitive ability, and behavioural biases. These results suggest that the generalised decision theory warrants further investigation.

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Neoclassical Expected Utility Theory explains all individual differences as the result of heterogeneity in tastes. However there is now compelling evidence that Homo sapiens also exhibit heterogeneity in thought processes. Camerer, Ho and Chong (2004) present a convincing case that experimental participants implement one of a *cognitive hierarchy* of decision strategies, and Crawford, Costa-Gomes and Iriberri (2013) review the experimental literature to conclude that this *level-k* approach is now best practice in the modelling of strategic interaction. Empirically, several recent papers in the consumer choice literature have explicitly rejected the hypothesis that thought-process heterogeneity can be adequately modelled *as if* it were taste heterogeneity (Swait and Bernardino 2000, Swait and Adamowicz 2001, Hess, Stathopoulos and Daly 2012, Kaplan, Shifan and Bekhor 2012, Vij and Walker 2014). Such evidence can be criticised on the basis that an econometric model with greater degrees of freedom will always achieve a better fit, however the findings are sufficiently strong and repeatable to suggest that the theoretical implications of thought-process heterogeneity warrant investigation. Accordingly, this paper analyses the implications of the simplest possible generalisation of Expected Utility Theory that admits heterogeneous thought processes.

The generalised decision theory incorporates two distinct utility formulations, to represent two distinct thought processes. This approach naturally operationalises the quintessential human conflict between deliberative and impulsive thought processes, which is described by the extensive psychological ‘dual-self’ literature, and which has recently been popularised by Kahneman (2011) and Peters (2012)¹. Thus, under the proposed model, agents may deliberate as per Homo economicus, but may alterna-

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¹For an exposition of the dual-self paradigm see Kahneman and Frederick (2002); for a review of psychological theories based upon it see Alós-Ferrer and Strack (2014); for a discussion of its neurological and evolutionary justifications see Cohen (2005).

tively act on impulse, and each agent’s propensity to act deliberatively is modelled
 30 as an individual- and situation-specific probability distribution. This generalised decision theory sits within the class of general random utility models that was formally defined by Manski (1977), although it is distinguished from existing theory since the *choice problem generating process* is explicitly modelled².

One application for which heterogeneous thought processes may be particularly
 35 salient is in understanding the educational investment decisions of children. Although each of us will, on occasion, act without first considering the consequences of that action, children are particularly likely to do so; consequently they are particularly likely to make grossly suboptimal educational investment decisions (Lavecchia, Liu and Oreopoulos 2015)³. Accordingly, Section II applies the generalised decision theory to model the human capital development process, thereby yielding intuitive yet
 40 original explanations for several empirical truths. These include: under-investment in education by a substantial minority of individuals, strong inter-generational persistence of social inequalities, dynamic complementarity between cognitive and non-cognitive abilities, divergent development pathways dependent upon small changes
 45 in early-life experiences, and an explanation for the observed relationships between IQ, Cognitive Reflection (as measured by the Cognitive Reflection Test of Frederick 2005), behavioural biases (including present-bias and risk-aversion), and other social outcomes (such as health and financial decision-making). These results suggest that the generalised decision theory has the potential not only to improve our understand-

²In Manski (1977) the *choice problem generating process* is an arbitrary probability distribution over the set of possible (choice-set, decision-rule) pairs. When studies such as Costa-Gomes and Crawford (2006) empirically designate individuals with a particular decision rule, they are implicitly assuming the existence of some individual- and situation-specific choice problem generating process. This paper explicitly models that same process, and allows it to evolve as children develop into adults.

³Other common situations in which unconsidered decision-making is particularly likely include: intoxication, addiction, sleep deprivation, malnutrition, stress, poverty, and morbidity (Metcalf and Mischel 1999, Donohew et al. 2000, Goldman 2012, Mani et al. 2013).

ing of specific behavioural anomalies, but also to bring together diverse strands from the existing literature.

The concept that deliberative thought processes may not always override individuals' impulsive responses is not new; it was discussed by Plato (ca. 380 B.C.), Smith (1759), and Marshall (1890) amongst others. However, the psychological literature has only recently converged toward a default-interventionist paradigm to formalise that concept (Evans and Stanovich 2013)⁴. The default-interventionist paradigm is also closely aligned with the perspective which Bechara (2005) distils from the neuroscientific literature, however it is at odds with all existing economic dual-self theories (Embrey 2017). Moreover, the existing economic dual-self literature maintains the Neoclassical assumption of thought-process homogeneity, either by assuming that some meta-rational process mediates between the alternative utility formulations (e.g. Fudenberg and Levine 2006), or by assuming that context alone perfectly determines which utility formulation will predominate (e.g. Thaler and Shefrin 1981).

The proposed model is therefore most closely related to the those of Laibson (2001) and Bernheim and Rangel (2004), since, although neither is framed as a dual-self theory, each describes addiction as an alternative, flawed, decision process. Nevertheless, in those models addictive thinking is triggered whenever an external cue is received, which leads their authors to focus on a representative and completely informed agent's rational response to that situation. By contrast, the present model emphasises the dynamic consequences of individual heterogeneity in thought processes, for everyday situations where individuals may not even be aware that they have made a decision, much less possess complete knowledge of their own decision

⁴Under the default-interventionist description of dual-selves: individuals will act on impulse unless deliberative reason intervenes in their decision-making. Under the alternative, parallel-processing, description: individuals always determine both an impulsive and a deliberative optimum, and both thought processes influence every decision.

processes⁵. Such situations cannot be characterised by any single representative agent, unless impulsive and deliberative decision processes happen to coincide.

75 The model is formally set out in Section I, whereafter Section II discusses its implications in the context of the existing literature. Whilst several of those implications are accommodated only as primitive assumptions in the existing literature, others are already addressed by a number of competing theories. Such Neoclassical theories are typically more mathematically elegant than the generalised theory, however
80 that mathematical elegance should not be mistaken for parsimony. The Neoclassical approach requires three layers of assumption: firstly, the set of relevant motivations is postulated; secondly, a functional form for each motivation is prescribed; finally, the functional form of a single-valued objective function is also prescribed, whereby those disparate motivations are assumed to be traded-off against each other. The
85 generalised approach also requires the first two layers of assumption, but it does not impose any homogeneous rule by which disparate motivations must be traded-off. Thus, *ceteris paribus*, the law of parsimony would favour the generalised theory (Ockham ca. 1323); a conclusion which holds *a fortiori* since that generalised theory provides an unified explanation for a number of open empirical questions⁶.

90 Section III extends the model across the school-to-work transition, and uses it to simulate the life-course. This not only enables us to analyse the pathways which may lead to social exclusion, but also to evaluate hypothetical interventions which might seek to alter those pathways. Those evaluations lead to a more nuanced version of the crowding-out hypothesis, and suggest that each individual's outcomes
95 may be substantially determined by social factors, such as the extent to which their

⁵If one were to assume the existence of some representative agent with complete self knowledge of the generalised decision theory presented here, then their *ex-ante* optimal decision-making could, indeed, be represented as Neoclassical utility maximisation (Karni and Safra 2016).

⁶For a more complete comparison of the theoretic merits of each approach see Embrey (2017).

familial and educational environments enable them to try their best and view mistakes positively. That conclusion brings economic understanding closer to the health inequalities literature, which considers unhealthy decisions to be a downstream product of socio-economic determinants, rather than a consequence of heterogeneity in individual tastes (Graham 2007, Watt 2007).

I. A Dual-Self Model of Human Capital Development

Agents are assumed to face a series of minor decisions, which cumulatively determine an outcome of interest. This paradigm could apply to health outcomes (shall I smoke another cigarette? avoid exercise today? eat fast-food rather than cook?...); employment outcomes (shall I search for jobs this morning? apply for this role? prepare for this interview?...); or educational outcomes (shall I attempt today's classwork? revise for tomorrow's test? take up this extra-curricular opportunity...). As these examples demonstrate, the complex decisions of traditional economic theory can often be broken down into series of binary decisions, and so the model presented here will adopt the simplifying assumption that all such elemental decisions are binary. For specificity, this model will investigate educational outcomes, whence the typical decision will be whether to attempt or avoid a task/opportunity. Nevertheless, Section III will show that the concept of human capital provides a natural extension of the present theory from educational to employment outcomes.

Each individual decision will be made according to Figure 1, wherein an agent's 'state of mind' determines which of two standard Expected Utility maximisation problems will be solved⁷. Agents therefore respond to an educational opportunity

⁷The representation used here is subtly distinct from that of Savage (1954), in which states of nature are predetermined; however it is pragmatically equivalent since its Bayesian Nash equilibria are given by the same utility maximisation problem. The formal distinction is discussed in Embrey (2017); however this paper simply adopts the cleaner visual representation.

either by deliberately optimising their human capital development, in which case the right-hand decision tree provides a descriptive theory of their decision-making process, or by satisfying their impulsive desire, in which case the left-hand decision tree provides an *as if* theory of their decision-making outcome. The generalised decision theory could therefore be reduced to a Neoclassical model by the imposition of any functional form by which agents should trade off the disparate motivations represented by each decision tree⁸.

Figure 1: A Generalised Decision Framework, Applied to Human Capital Development

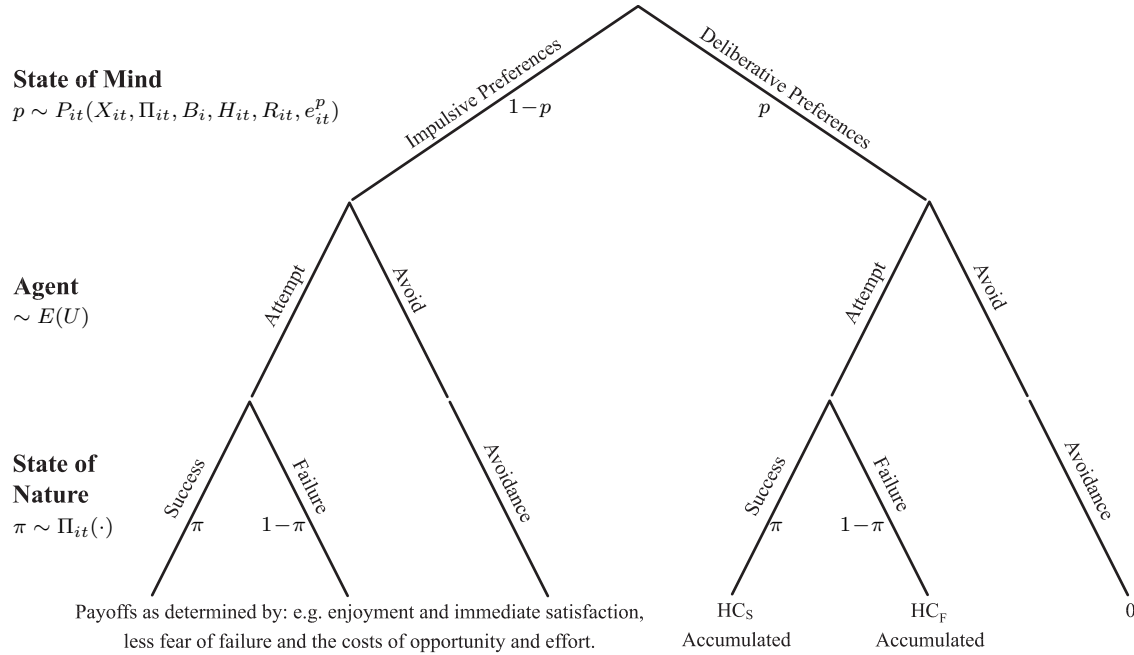


Figure 1 models the decision process of agents with imperfect self-control: their impulsive decision will be overridden by deliberative preferences only with probabil-

⁸Superficially, the entirety of Figure 1 could also be framed as a Neoclassical model by defining s_{it} as an indicator variable for the state of mind of agent i at time t . All agents would therefore maximise the representative utility function: $s_{it} \cdot (\text{Deliberative Payoffs}) + (1 - s_{it}) \cdot (\text{Impulsive Payoffs})$. This approach would be reminiscent of the incentive salience model proposed by Lades (2012).

ity p_{it} . An agent's state of mind is therefore determined according to a realisation of p_{it} , which may itself be influenced both by the 'human nature' of agent i , and by the specific context of decision t . Pertinent contextual factors could include: the nature of the potential action, the nature of the outside option, the framing of the decision, the influence of peers and adults, and myriad other aspects of the exogenous state of nature. In order to model these contrasting influences, p_{it} is taken to be a random draw from a distribution $P_{it}(X_{it}, \Pi_{it}, B_i, H_{it}, R_{it}, e_{it}^p)$, which is the pdf of the agent's probability of exerting self-control across all potential decision circumstances. The realised draw therefore manifests all decision-specific contextual factors, whilst the distribution $P_{it}(X_{it}, \Pi_{it}, B_i, H_{it}, R_{it}, e_{it}^p)$ describes an agent's 'human nature' as a function of their current characteristics X_{it} , cognitive ability Π_{it} , background B_i , decision history H_{it} , responsiveness to consequences R_{it} , and unobservable heterogeneity e_{it}^p . P_{it} is therefore closely aligned to the psychological trait of conscientiousness, and will be seen to characterise an agent's non-cognitive ability.

Any agent's action under either thought process is determined by the Bayesian Nash Equilibrium of its corresponding subgame, which itself is contingent upon the agent's believed probability of success at the task in question. The true probability of success π_{it} of agent i at time t will, for any given task, be drawn from $\Pi_{it}(X_{it}, P_{it}, B_i, H_{it}, e_{it}^\pi)$, the agent's current cognitive ability distribution across possible tasks. An agent's believed probability of success is therefore given by some decision-weighting function $w_{it}(\pi_{it}, \cdot)$, which may also be a function of state variables $\Pi_{it}, p_{it}, X_{it}, B_i, H_{it}$. Thus, under either thought process, the task will be attempted if and only if

$$w_{it}(\pi_{it}, \cdot) \cdot [\text{payoff}|\text{success}] + (1 - w_{it}(\pi_{it}, \cdot)) \cdot [\text{payoff}|\text{failure}] > [\text{payoff}|\text{avoidance}]$$

Since payoffs are formally defined up to affine transformation, we may normalise the payoff of avoidance to be 0 under either thought process⁹. Thus, for each thought process, whenever the payoffs to success and failure have the same sign, that sign will determine participation. Otherwise, there will be a critical cognitive ability level

$$\pi_{it}^* = w_{it}^{-1} \left(\frac{-[\text{payoff}|\text{failure}]}{[\text{payoff}|\text{success}] - [\text{payoff}|\text{failure}]} , \cdot \right)$$

which determines whether the agent will attempt the task, given their current state variables. π_{it}^* is well defined, provided the induced map $w_{it}(\pi_{it}) | \cdot$ is injective for any values of \cdot . This condition is weak, since it is sufficient that $\frac{\partial w_{it}(\pi_{it}, \cdot)}{\partial \pi_{it}} > 0$, which will hold provided individuals have non-zero awareness of their own cognitive ability.

Thus Π_{it} and P_{it} parametrise the agent's current cognitive and non-cognitive abilities respectively, and crucially affect their decision outcome in period t . The period t decision outcome, in turn, determines $\Pi_{i,t+1}(H_{i,t+1}, \cdot)$ and $P_{i,t+1}(H_{i,t+1}, \cdot)$, according to its human capital development implications. An individual's human capital development is therefore modelled as a dynamic process throughout their educational journey, in which their abilities develop according to the outcomes of many minor participation decisions.

II. Implications for Human Capital Development

In order to analyse the implications of this model, it is necessary to impose some conditions on its payoffs. Firstly, we adopt the standard assumption that agents' deliberative payoffs reflect the human capital implications of each outcome, less the opportunity cost of their accrual; this ensures that the generalised model nests the canonical human capital investment model of Becker (1962, 1964), whenever

⁹For simplicity the payoff from task avoidance is assumed to be deterministic, however allowing a stochastic avoidance payoff would not affect the model's qualitative implications.

$p_{it} \equiv 1 \forall i, t$. Secondly, we impose the strong simplifying assumption that payoffs are homogeneous for all agents. This serves our present purpose by permitting an analysis of the novel implications of heterogeneity in thought processes, without any confounding source of individual differences. Nevertheless, a more realistic model would admit both sources of heterogeneity. One important capability of a model with both sources of heterogeneity would be to analyse the consequences of habit-formation in impulsive preferences — as per the psychological understanding of Kahneman and Frederick (2002), and the economic model of Laibson (2001). That analysis is left to future research.

This paper will now discuss the contribution which the proposed theory can make toward our theoretical understanding of six important empirical truths. For each of those phenomena, this section outlines the limitations of the existing knowledge, before explaining how the proposed model could overcome those limitations.

GROSSLY SUBOPTIMAL HUMAN CAPITAL INVESTMENT

The canonical theory of human capital development as an optimal investment decision (due to Becker 1962, 1964) forms the basis of most existing theories of educational investment. Within that framework, under-investment has been derived as the result of bounded rationality, credit constraints, and additional behavioural motivations. Empirically, Jensen (2010) finds that both credit constraints and bounded rationality (in the form of limited knowledge of the returns to education) are important factors in the Dominican Republic; although credit constraints only affect the poorest families in that study, and seem not to be a major factor in the developed world (Oreopoulos 2007). Similarly, Jensen states that limited knowledge is unlikely to be an important factor in the developed world, and Rouse (2004) finds firm evidence to support that statement. Nevertheless Lavecchia, Liu and Oreopoulos

(2015) survey a large number of nudge-based interventions to find that some succeed in altering the perceived benefits of post-compulsory education, which implies that bounded rationality could contribute toward under-investment in education.

The foremost behavioural motivation that could lead to under-investment in education is present-bias. This concept has intuitive appeal, as has been articulated by Lavecchia, Liu and Oreopoulos (2015), and has strong experimental support (e.g. Shoda, Mischel and Peake 1990). Nevertheless, Oreopoulos (2007) estimates the parameters of a standard investment model which incorporates present-bias to find that an implausibly large degree of bias would be necessary to completely explain observed under-investment. This is a common challenge for any theoretical approach that adapts the canonical utility function: given plausible parameter values, any such adaptation will be bounded within a certain proximity of the normatively optimal prediction, yet many individuals make grossly sub-optimal educational investment decisions (Harmon, Oosterbeek and Walker 2000). As an illustrative example, Cunha and Heckman (2008) incorporate a psychic cost of effort to explain educational underinvestment, and estimate the implicit value of that cost to be commonly in the order of \$500,000 for college attendance.

One approach which could strengthen the predicted effect of present-bias would be to incorporate various other, complementary, behavioural motivations. For example, Wang and Yang (2003) and Köszegi (2006) include a payoff to self-worth within their agents' objective function, which induces a psychic cost of failure within educational participation decisions. Agents who value self-worth are therefore less likely to attempt educational tasks than those who do not. Analogously, Akerlof and Kranton (2002) include a payoff to social identity within their objective function, thereby predicting that those agents who are neither cool enough to fit in with the 'leading crowd', nor intelligent enough to fit in with the 'nerds', might choose to reduce their

educational effort such that they fit in with the ‘burnouts’. These highly specific behavioural motivations are, in outcome, observationally equivalent to an increase in the opportunity cost of education.

The model proposed in Section I is agnostic about the source of present-bias, but proposes an alternative description of its influence in decision-making. Rather than splicing additional behavioural motivations into the canonical human capital pay-off function, those motivations are instead considered to constitute an alternative thought process. In practical terms, individuals are not required to trade-off deliberative and impulse motivations in an idiosyncratic manner, but rather have an idiosyncratic propensity to act impulsively, as opposed to following a deliberative thought-process¹⁰. The latter approach is aligned with the perspective advanced by Lavecchia, Liu and Oreopoulos (2015), and this paper demonstrates that it yields markedly distinct dynamic implications, that is: agents of the latter type do not act *as if* they were agents of the former type. The most importantly different implication is that, under the generalised theory, the decision outcome for an agent who acts impulsively could be arbitrarily distant from the normatively optimal outcome; whence grossly suboptimal decisions are to be expected. Moreover, the effects of those suboptimal educational effort decisions will be magnified over time, due to the model’s implied self productivity and dynamic complementarity of cognitive and non-cognitive skill development.

COGNITIVE AND NON-COGNITIVE SKILLS

An extensive literature has demonstrated that non-cognitive skills are pervasively important in the determination of socio-economic outcomes (Heckman 2006, Moffitt

¹⁰This subtle yet profound distinction is discussed in (Embrey 2017), however its intuition is analogous to the distinction between a mixed-strategies agent who always acts as $x\%$ strategy X (and $100-x\%$ strategy Y), and an agent who acts as pure X on $x\%$ of occasions.

et al. 2011, Koch, Nafziger and Nielsen 2015). Nevertheless, there is little consensus over the definition of non-cognitive skills (Humphries and Kosse 2017), and no theoretical exposition of the mechanism by which they influence individual outcomes. The proposed decision theory addresses these open questions, by demonstrating that an individual's propensity to think deliberatively, P_{it} , plays a pivotal role in the determination of their educational and other socio-economic outcomes. This suggests that P_{it} represents a fundamental non-cognitive ability — a characterisation which is closely compatible with the empirical literature surveyed by (Humphries and Kosse 2017).

To clarify the role of P_{it} , we shall restrict our attention to *valid* educational tasks, that is: tasks where the deliberative (Becker 1962) payoff to participation is positive. This is a weak restriction, as the empirical magnitude of the returns to education is likely to render most educational tasks valid, at least until the end of compulsory schooling (see, for example: Harmon, Oosterbeek and Walker 2000, Oreopoulos 2007). Thus (valid) educational task participation is guaranteed under the deliberative thought process, whence any increase in non-cognitive ability will increase participation likelihood. Similarly, an increase in cognitive ability will increase participation likelihood, since, under the impulsive way of thinking, tasks with ambiguous participation payoffs are attempted if and only if $\pi_{it} > \pi_{it}^*$ ¹¹.

Heckman and Cunha (e.g. 2007, 2010) have established that cognitive and non-cognitive skills must exhibit both self-productivity and dynamic complementary, in order to explain nine key stylised facts of human capital development. However, since their theoretical models take that dynamic relationship as a primitive assumption, it is difficult to thereby identify tangible policy or practice implications which could

¹¹This conclusion requires that success \succ failure on an impulsive level, which is widely known to be the case (Bénabou and Tirole 2002). For $\Pi_{i,t}$ to represent greater cognitive ability than $\Pi_{j,t}$ it is sufficient for the latter to stochastically dominate the former.

intervene in the process of skill formation. This paper contributes to the literature
 270 by providing a mechanism which could generate the aforementioned dynamic relationships, and which therefore enables the evaluation of hypothetical interventions.

It has already been seen that increasing either cognitive or non-cognitive ability
 will raise an individual's likelihood of participating in educational tasks. Those tasks,
 by definition, develop an individual's human capital, and so self-productivity and dy-
 275 namic complementarity of cognitive and non-cognitive skills are a direct consequence
 of the proposed model. There are also a number of ancillary mechanisms which would
 reinforce those implications. For example, if there is hysteresis in self-control, such
 that an individual who exhibits deliberative thinking this period thereby increases
 the likelihood of their doing so in future periods, then the ramifications of present
 280 non-cognitive ability would be accentuated. Such Hysteresis could arise through con-
 firmatory bias (Rabin and Schrag 1999), or if impulsive responses develop experien-
 tially (Denes-Raj and Epstein 1994). Similarly, if experiencing success in the present
 task makes future participation more likely (Bénabou and Tirole 2002, Wang and
 Yang 2003), then the ramifications of present cognitive ability would be accentuated.
 285 That effect would arise if, for example, salience and availability affect individuals'
 subjective success probability (Tversky and Kahneman 1974). Table 1 summarises
 this discussion by collating its implied skill development consequences for each out-
 come¹².

¹²These consequences are uncontentious, save that some existing literature assumes that tasks
 develop cognitive ability if and only if success is achieved (e.g. Sjögren and Sällström 2004, Filippin
 and Paccagnella 2012). That view probably arises since those papers conflate skill development
 and educational attainment; nevertheless, the Online Appendix demonstrates that the model's im-
 plications remain qualitatively unchanged under that alternative assumption. This paper therefore
 adopts my personal view that cognitive ability is developed by attempting educational tasks, rather
 than upon receiving a grade for those attempts.

Table 1: The Cognitive and Non-Cognitive Ability Implications of each Outcome

	Avoidance	Failure	Success
Cognitive:	↓	↑	↑
Non-Cog:	↓	↓	↑

PERSISTENCE IN SOCIAL INEQUALITIES

Although the importance of persistent social inequality is well-established (Hobcraft 2002), there is little consensus concerning the mechanisms by which it is perpetuated. Parents, teachers, schools, peers, neighbourhoods, family structure, and family finances, have all been found to affect socio-economic outcomes (e.g. Breen and Jonsson 2005, Carrell et al. 2010, Bradley and Nguyen 2004, Sacerdote 2011, Sparkes and Glennerster 2002, Kiernan and Hobcraft 2001, Gregg and Machin 2000). Each of those factors may therefore contribute toward the observed inter-generational persistence of social inequality. Convincing evidence in this area is limited, partly because each of these factors is closely co-determined with other socio-economic variables (Haveman and Wolfe 1995), but also because the observed effects are probably the compound result of many mechanisms (Koch, Nafziger and Nielsen 2015). The contribution of this paper is to describe one common mechanism which could contribute substantially toward each of the aforementioned effects. It is likely that any individual's early-life propensity to think deliberatively will be shaped by each of the influences listed above, and so those influences will have a lasting effect on skill accumulation and on the normative quality of decision-making in any context where impulsive thought-processes could be expected to favour normatively suboptimal outcomes. Heller et al. (2017) have recently found strong corroborating evidence for the importance of any individual's propensity to deliberate, though they label that

trait inversely as ‘automaticity’.

RELATIONSHIPS BETWEEN ABILITIES AND BEHAVIOURS

Impulsive thought-processes could be expected to favour normatively suboptimal outcomes in contexts such as education, employment, financial, and health decision-making (Lavecchia, Liu and Oreopoulos 2015, Loewenstein and O’Donoghue 2005). Thus, under the model presented here, non-cognitive ability levels should be causally related to individuals’ socio-economic outcomes, through their susceptibility to behavioural bias. This prediction is empirically testable, since the Cognitive Reflection Test (CRT) developed by Frederick (2005) provides a direct measure of individuals’ propensity to deliberately override their impulsive desires. Although there is limited causal research which tests that prediction, correlations between CRT scores, various social outcomes, and behavioural biases including present-bias and risk-aversion, have repeatedly provided circumstantial support for it (Frederick 2005, Oechssler, Roider and Schmitz 2009, Toplak, West and Stanovich 2011, 2014, data from Shenhav, Rand and Greene 2017). Moreover, those behavioural correlations are “so strong” as to be “begging for a theoretical explanation” (Frederick 2005, p.26). The model proposed here provides that explanation, and also explains the weaker but more widely known correlation between cognitive ability and behavioural bias susceptibility, in that the dynamic relationships between cognitive and non-cognitive abilities predict a cross-sectional correlation between those abilities.

INTERVENTIONS AND THE CROWDING-OUT HYPOTHESIS

A large number of studies have attempted to improve individual decision-making by intervening with additional, extrinsic, motivations. These studies have produced inconsistent results (Levitt et al. 2016), which has lead to the development of a

crowding-out hypothesis: the addition of extrinsic motivations may prevent individuals from considering their intrinsic motivations (Gneezy, Meier and Rey-Biel 2011).

335 A classic demonstration of this is provided by Gneezy and Rustichini (2000), who find that the introduction of a charge for any late collection of children from nurseries led to a significant increase in late collections. There are few theoretical explanations for such perverse behaviour, since, under a standard modelling approach, any additional incentive unambiguously has the desired effect. One possible explanation
340 is contributed by Bénabou and Tirole (2006), who derive a crowding-out effect by assuming the existence of a third utility component, which enumerates individuals' social reputation. This innovative approach provides a highly situation-specific insight to human behaviour, at the cost of an extra layer of assumptions.

The model proposed here provides a parsimonious and direct explanation of the
345 crowding-out hypothesis: adding an additional extrinsic payoff could cue an undesirable thought-process. Applied within an educational development context, the implication is that: where extrinsic rewards or sanctions alter a child's impulsive optimum to coincide with their deliberative optimum, short-run cognitive skill development will be ensured, but in the long-run this benefit may be offset since that
350 same intervention could preclude the development of the child's non-cognitive skill (their ability to think deliberatively). This more subtle version of the crowding-out hypothesis also supports the stereotypical teacher's intuition that effective interventions should develop a child's conscientiousness, both by explicitly teaching and implicitly demonstrating a deliberative decision-making processes.

355 CHRONIC NON-EMPLOYMENT

Classically, non-employment is studied as a demand-side phenomenon. The theoretical literature emphasises its macroeconomic determinants, such as distortions

or shocks that prevent the labour market from clearing (Pigou 1933, Keynes 1936), or structural factors, such as stochastic wage offers or imperfect matching technology (McCall 1970, Mortensen 1970, Pissarides 1990, 2000). More recently, economic theory has explained the observed negative employment outcomes for low-skilled population subgroups through skill-biased technological change (Autor, Levy and Murnane 2003), or trade liberalisation (Wood 1995). However none of these theories can explain why any particular individual should experience chronic non-employment, unless there is a persistent dearth of accessible job vacancies in their area. Empirically, this is not the case in the UK: Only 0.4% of inactive UK individuals blame a lack of job vacancies¹³, and, over the most recently available 12 months of data, an average of 274 elementary vacancies per month were notified to job centres in each of the 297 UK Travel To Work Areas¹⁴. Yet around 4.7% of UK individuals fail to gain employment within 24 months of leaving education¹⁵, and these individuals face a substantial risk of chronic non-employment (Gregg 2001). It is therefore important to develop a supply-side theory which can explain these observations.

The canonical theory of labour supply (originating from Wicksteed 1910) can only explain non-employment as voluntary. However, it is doubtful whether 4.7% of society would deliberately choose the strikingly negative financial and non-pecuniary outcomes associated with social exclusion (Hills, Le Grand and Piachaud 2002). In contrast to most existing theory, this paper emphasises that no individual chooses their employment outcomes, but rather they choose the effort which is put into

¹³Jan-March 2017 Labour Force Survey (ONS 2017).

¹⁴Moreover, only 28 of those 3,574 month \times Travel To Work Area observations reported no new elementary job vacancies (ONS 2012). This is a conservative estimate of the number of unskilled job vacancies, since only the Standard Occupational Classifications (SOC2000) ‘elementary’ classifications were included, and since “possibly less than half” of vacancies are reported to job centres (ONS n.d.).

¹⁵Detailed derivation and Stata script available at <https://www.researchgate.net/project/Social-Exclusion-3>.

the job-search process. The job-search process may therefore be modelled by the theory set out in Section I, in which case individuals could remain chronically and involuntarily non-employed as a result of inadequate skill development. Inadequate non-cognitive ability implies a reduced frequency of identifying and engaging with application processes, and inadequate cognitive ability implies a reduced standard of applications, whenever they are attempted.

The direct effect of inadequate skill levels on an individual's job-search activity is likely to be compounded by an indirect effect through educational attainment. Taken together, it is possible that some individuals might never gain employment, because the signal that they send to any prospective employer implies that their marginal contribution to productivity will be below the statutory minimum wage rate. That possibility represents a natural extension to the standard labour-market models of either Spence (1973) or Pissarides (2000), given that this paper predicts grossly suboptimal levels of educational investment from a substantial minority of individuals.

III. Simulating the Life-Course

In order to further investigate the implications of the proposed model, this section applies it to simulate individual development pathways. Relative levels of cognitive and non-cognitive ability are generated across multiple periods of educational tasks and job-search activity, according to the implications that Table 1 summarised for each potential task outcome. Since we are primarily interested in understanding social exclusion, we focus here on a uniform commencement of job-search activity at the end of a compulsory education period. Job search tasks are modelled by the same process as educational tasks, save that the probability of success is reduced, and the duration of each task is increased, to reflect their greater complexity. Additionally,

once success is achieved in the job market, the resulting employment is modelled as
 405 an absorbing state. Although in reality individuals may lose their jobs, the school-to-
 work transition is crucial in the determination of an individual's life-course (Bradley
 and Nguyen 2004), and the specification of an absorbing employment state allows us
 to focus on that transition. Existing theory, such as Pissarides (2000), can provide
 a good description of the unemployment which results from subsequent job loss.

410 This section maintains the assumptions of taste homogeneity, and positive deliber-
 ative participation payoffs for (valid) educational tasks, which were discussed above.
 As an additional simplifying assumption, the impulsive payoff for educational tasks
 is taken to be negative, which simplifies our analysis by ensuring that tasks will
 be attempted if and only if an individual acts deliberately. In doing so, this as-
 415 sumption excludes the case where task participation is universal, and the case where
 only those with sufficiently high cognitive ability have a positive impulsive payoff to
 participation. In both of these cases, individuals with higher cognitive ability have
 a greater chance of positive outcomes than their less able peers, and so excluding
 these cases only attenuates the self-productivity of cognitive ability. This assumption
 420 therefore represents the most conservative possible approach.

In order to simulate the model, various distributional and effect magnitude as-
 sumptions are also required. These are summarised in Table 2 and discussed in the
 Online Appendix, where it is also demonstrated that the qualitative results of the
 simulations are robust to changes in any of these assumptions. Many of the assumed
 425 parameters have been made straightforward to manipulate in the Stata code supplied
 at <https://www.researchgate.net/project/Social-Exclusion-3>.

Figure 2 illustrates the human capital development of 12 'median' individuals across
 500 periods of educational decisions, followed by 201 periods of job search¹⁶. The

¹⁶*Median* in the sense that all simulated individuals have symmetric prior ability distributions

Table 2: Parametric Simulation Assumptions

Parameter	Assumption				Notes
Prior ability distributions	$Beta[2.5, 2.5]$				As per Filippin and Paccagnella (2012); Robust to truncated normal; Robust to parameter variation.
Outcome effects on $Beta[\alpha, \beta]$		Avoidance	Failure	Success	The simplest possible parametrisation of Table 1 that preserves 0.5 as median ability; Robust to truncated normal adaptation.
	$\Delta\Pi$	$[0, +\iota]$	$[+\iota, 0]$	$[+\iota, 0]$	
	ΔP	$[0, +\iota]$	$[0, +\iota]$	$[+3\iota, 0]$	
Outcome magnitude	$\iota = 0.5$				Robust to parameter variation.
Forgetfulness factor	$[1 - b \cdot \ln(\Delta t)]$				As validated by (Rubin 1996); Robust to parameter variation; Robust to omission.
Employment task relative difficulty	$\times 4$				Robust to parameter variation.
Employment task relative duration	$\times 3$				Robust to parameter variation.

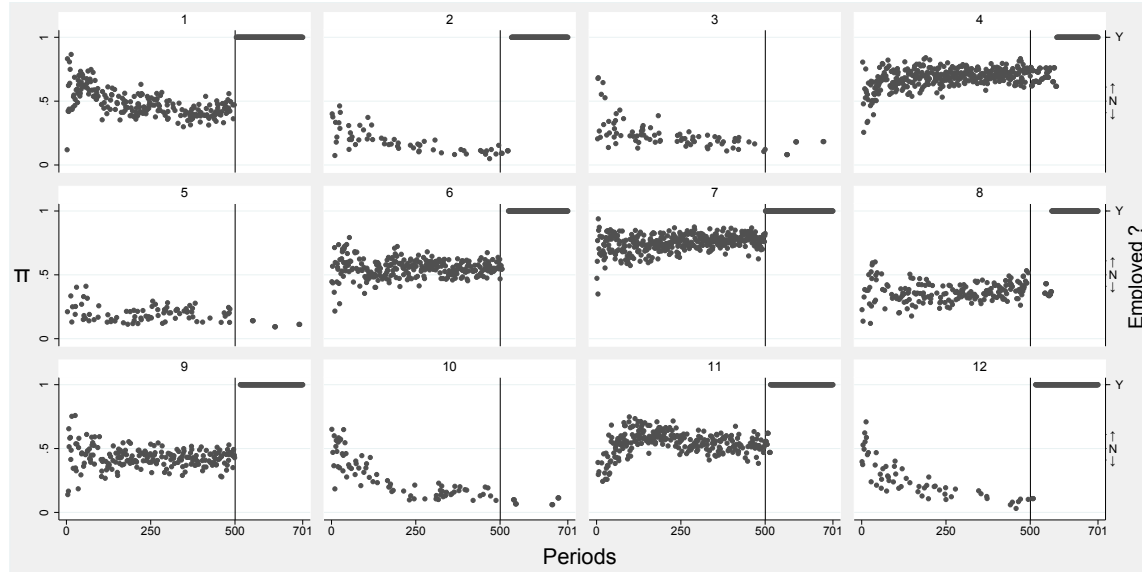
Parametric assumptions for the simulations presented in this paper. In all cases these were also my ‘first guess’ parameter values. A detailed discussion and robustness checks are provided in the Online Appendix.

realised draws from agents’ cognitive ability distributions $\{\pi_{it}\}_t$ are plotted for each
 430 period until they gain employment, at which point their outcome will become fixed
 at Y . An individual’s history of realised π values therefore captures the evolution
 of their full ability distribution through time. In Figure 2 it can be seen, for exam-
 ple, that the variance of these distributions reduces across time for all individuals,
 and most markedly so during their early development. This phenomenon is reminis-
 435 cent of the observations which motivated Case-Based Decision Theory (Gilboa and
 Schmeidler 1995). It can also be seen that many individuals (e.g. 6, 9) remain close
 to the average ability level of 0.5, whilst others diverge towards much higher or lower
 rates of success (eg. 4, 3 resp.).

around 0.5; see the extended discussion in the Online Appendix.

An extended time horizon would better reflect reality, however Figure 3 shows that 500 periods
 is adequate to establish developmental trends, and we are constrained here by legibility.

Figure 2: Simulated Human Capital Development of 12 ‘Median’ Individuals



Simulated cognitive development outcomes for 500 periods of education, followed by 201 periods of Job search, during which the outcome jumps to Y if employment is achieved.

Figure 2 also captures the evolution of agents' non-cognitive ability p_{it} . This can be read off as the trend in the density of π_{it} realisations, since these are only plotted for periods where tasks are attempted. Thus the relationship between cognitive and non-cognitive skill levels is plain: those individuals with upward-trending cognitive ability also attempt tasks with increasing frequency, whereas those with downward-trending success probabilities also exhibit a deteriorating participation likelihood. This demonstrates that dynamic complementarity and self productivity of cognitive and non-cognitive skills can indeed explain substantial levels of inequality in educational outcomes, even for individuals with identical initial ability endowments.

Individuals' employment outcomes are captured in Figure 2 by the number of periods between the start of job search (the vertical line) and the achievement of employment (whereafter outcomes $\equiv Y$). It can be seen that individuals 3, 5, and 10 do not gain employment within 201 periods of job-search, and furthermore that their

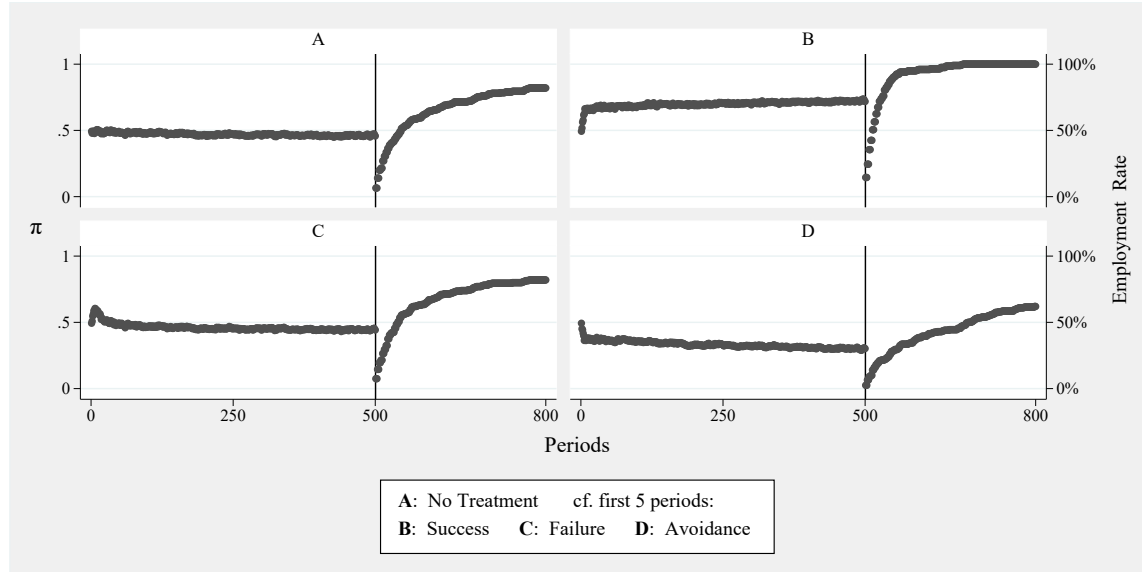
attempts to do so are both irregular and of a low standard. These outcomes contrast with those of individual 7, who develops high levels of ability and gains a job immediately, and individual 4, who experiences unexpectedly poor job-market outcomes, but has developed sufficient non-cognitive ability that they persevere without any noticeable disengagement. The contrasting outcomes of individuals 3 and 4 substantiate the hypothesis of Duckworth et al. (e.g. 2007) that an individual's level of grit may be a key determinant of their life-course.

In order to investigate the origins of the substantial heterogeneity evident above, Figure 3 presents the average treatment effect for individuals whose first five outcomes are exogenously fixed. Panel A shows the average realised cognitive skill levels $\{E_i(\pi_{it})\}_t$ of 200 untreated individuals over the educational phase, and the proportion of those individuals who have gained employment over the job-search phase¹⁷. This panel validates the interpretation of realised π values as relative ability draws, since their expected value closely follows 0.5 across the educational phase. During job-search the cumulative employment rate of untreated individuals demonstrates that, whilst most quickly gain employment, 18% of the cohort remain unemployed after 300 periods of job search. This result reflects reality appropriately well, however a precise interpretation is not intended as it would necessarily rely on some conjectured real-world duration for the model's time periods. Nevertheless, a precise comparison between cohorts is appropriate, since each individual in each cohort has a counterpart in the other cohorts who experiences identical stochastic circumstances. Thus panel A provides a perfect counter-factual against which to compare the treated cohorts.

Panel B of Figure 3 shows the average treatment effect of guaranteed success in each

¹⁷ $n = 200$ was used by Filippin and Paccagnella (2012), and, since Figure 3 shows it to be a sufficiently large simulation cohort to remove almost all of the noise from average treatment effects, it is used here also.

Figure 3: Average Treatment Effects of Early-Life Experiences



Simulated cognitive development outcomes for 500 periods of education, followed by 300 periods of Job search.

During education: Average realised ability draws for 200 individuals per group,

During job search: % of those individuals who have gained employment.

of the first five periods. This treatment not only produces rapid initial development, but also leads to a continuing upward trend in relative ability throughout the educational phase. The resulting improvement in employment outcomes is substantial: this cohort achieves full employment after 175 periods of job-search.

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Panel C shows that the effect of five periods of guaranteed failure is small in the long-run, however an initial spike in cognitive skill levels is evident. These observations are explained by the offsetting effects that experience of failure produces: cognitive ability is developed at the cost of a reduced likelihood of future participation¹⁸. This finding is of particular interest, since it exposes the ineffectiveness

¹⁸The corresponding plot for the evolution of $E_i(p_{it})$ shows a negative initial spike which is almost a precise mirror image of that displayed by $\{E_i(\pi_{it})\}_t$ in Figure 3C. Since this is the only instance in which any cohort's evolution of $E_i(p_{it})$ differs noticeably from its corresponding $E_i(\pi_{it})$ pathway, the former are not reproduced here, but are available in the Online Appendix.

of any intervention which provides sufficient extrinsic motivation to ensure that an individual attempts tasks, but which fails to thereby improve their conscientiousness or intrinsic motivation. Such an intervention might improve that individual's academic attainment for as long as it is maintained, but at the cost of a commensurate reduction in relative non-cognitive ability. It is possible that the modern era of high-stakes school competition might incentivise schools to supply such an intervention throughout a child's education, thereby improving their academic performance at the cost of their non-cognitive development. The detrimental impact of such an intervention would become manifest only upon school graduation.

Panel D of Figure 3 shows that five periods of initial avoidance could have a devastating effect on an individual's developmental pathway. This cohort develops markedly lower skill levels during the educational phase, and fewer than half of them have gained employment by the time that cohort B are fully employed. This is remarkable, since, at the commencement of job search, the initial five periods of treatment account for less than 0.2% of the agents' forgetfulness-adjusted memories. Nevertheless, the results are in keeping with the empirical literature, which has firmly established the importance of early life investment in skill development (e.g. Cunha, Heckman and Schennach 2010). It is interesting to note that the development pathway of a 'median' individual who experiences initial disadvantage is observationally equivalent (after those few periods) to an individual who is endowed with lower ability levels. Thus, in this model, social factors could explain up to the entire variation in observed educational, employment, or health outcomes.

The simulations presented in Figure 4 investigate the extent to which an effective later intervention could counteract initial disadvantage. An intervention is conceptualised here as an exogenous force which ensures that individuals attempt all tasks. As such, intervention is guaranteed to improve cognitive ability (the probability of task

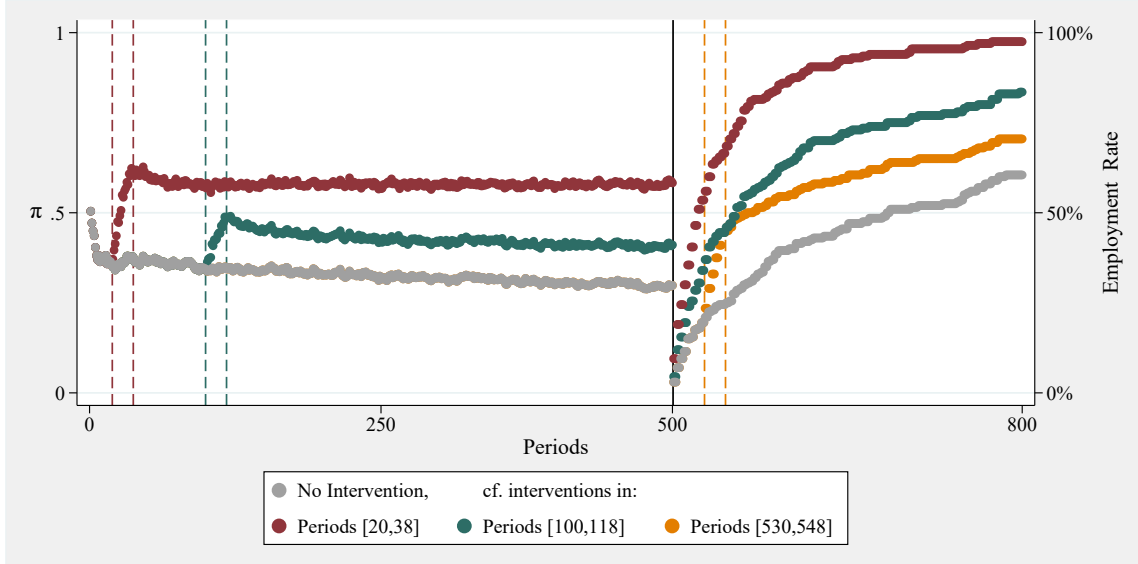
success), however its effect on non-cognitive ability (the probability of attempting tasks) is uncertain — individuals' participation likelihood will increase if and only if they experience some success. This conceptualisation of an intervention is commensurate with the provision of support in the form of encouragement, mentoring, or academic/job-search assistance, but contrasts with enforced or 'bribed' participation which could reduce its subjects' independent participation likelihood. As noted in the analysis of Figure 3C above, any intervention which failed to develop the intrinsic participation likelihood of its subjects should, under the present framework, be modelled as guaranteed failure, whereby short-run cognitive benefits would be offset by non-cognitive losses which would manifest only once the intervention was removed¹⁹.

The grey points in Figure 4 illustrate the baseline outcomes of a cohort of 200 individuals who are disadvantaged by five periods of initial task avoidance. Each set of coloured points represents a counterfactual cohort which experiences the aforementioned disadvantage, but also 18 periods of effective intervention — hence these cohorts follow the baseline until the onset of that intervention. It can be seen that an intervention starting at period 20 has considerably greater impact than an intervention starting at period 100, although further investigations suggest that rate of decline in intervention efficacy is quite low thereafter. Where an intervention takes place during job search, it benefits from the added possibility that some of its subjects' attempts might successfully result in employment. However, since this is more likely to be the case for those individuals who were more likely to gain employment anyway, the employment rate increases markedly more slowly than that of the base-

¹⁹An alternative intervention which guarantees success would be straightforward to programme, but is difficult to envisage in reality: for example children who suspect that their success has been falsely inflated tend to suffer reduced confidence, and in any case one cannot sustain false appearances of success indefinitely. Similarly, the act of providing an individual with a job would not, in itself, improve their ability to succeed in applying for future jobs (although the human capital gained whilst in artificial employment might improve future success likelihoods, precisely as per the intervention modelled here).

line thereafter. This is a manifestation of the dead-weight loss associated with an untargeted intervention (Besley and Kanbur 1991).

Figure 4: Average Treatment Effects for Interventions by Time Point



Simulated cognitive development outcomes for 500 periods of education, followed by 300 periods of Job search.

During education: Average realised ability draws for 200 individuals per group,

During job search: % of those individuals who have gained employment.

Interventions each last 18 periods, and are demarcated by dashed lines of the corresponding colour; Interventions provide guaranteed participation in educational | job-search activities.

Figure 4 demonstrates that, within the proposed model, intervention will be considerably more effectual if it takes place before individuals become trapped into a downward spiral of deteriorating participation and outcomes. This conclusion was also reached by Lavecchia, Liu and Oreopoulos (2015) in their survey of the behavioural economics of education. It is also worth noting that any individual who grows up with a familial and social context that is sufficiently supportive so as to ensure perpetual participation, would effectively be in a state of continual intervention. Thus, even an individual with a particularly low ability endowment would be likely to

achieve a high level of success if they were socially advantaged. Indeed further analyses suggest that a cohort with an ability endowment corresponding to 200 periods of initial avoidance could, by period 500, achieve an average ability level in excess of any in Figure 3, if they were supported to attempt every educational task thereafter. Conversely, if an individual's familial and social circumstances constantly reduce their likelihood of participation, even a highly effective early intervention could be overturned if it is not followed up. Thus the proposed model can explain high levels of intergenerational persistence in educational, employment, or health outcomes whenever an individual's background affects their task participation decisions.

These simulations have demonstrated that the proposed model can explain substantial heterogeneity in individuals' outcomes as the result of small differences in their early-life experiences. Further, it has demonstrated that an individual's propensity to apply an economically rational thought-process could be at least as important as their cognitive ability level in the determination of those outcomes. Since these results were derived despite maintaining the strong assumption of taste homogeneity, they suggest that heterogeneity in thought processes may indeed be an important source of individual differences.

The proposed model therefore implies that the environment in which young people develop could have far-reaching consequences, independent of any innate individual characteristics. This conclusion has clear policy implications. One implication is that parents and educators should attempt to foster supportive home and educational environments, specifically by encouraging children to try their best and to view mistakes positively. Another implication is that effective support for new mothers and young children could represent an extremely worthwhile investment, and that such support will be effective whenever it develops those children's non-cognitive skill levels; specifically their conscientiousness, openness to experience, and resilience to

disappointment. Furthermore, those non-cognitive skills should remain a key focus
 570 throughout the educational system. On a practical level, this could be achieved
 by an investigative pedagogy where open tasks predominate, and by an increased
 recognition of sports and the arts, since the intrinsic appeal of those activities could
 motivate participants to try their best and learn to overcome failure.

IV. Discussion and Conclusion

575 This paper has responded to the accumulating evidence that *Homo sapiens* ex-
 hibit heterogeneous thought-processes, by generalising the Neoclassical modelling
 approach to admit two distinct utility formulations. Commensurate with the default-
 interventionist paradigm, agents' deliberative reasoning is assumed to override their
 impulsive response according to an individual- and situation-specific probability dis-
 580 tribution. This approach is the theoretical dual of the common empirical practice
 that allows each individual to implement any of a finite mixture of possible decision
 processes, and it operationalises the much older concept that individuals may act
 “variously and accidentally, depending on whether mood, inclination, or self-interest
 happens to be uppermost” (Smith 1759, p.276). This paper has demonstrated that
 585 such thought-process heterogeneity can explain substantial individual differences —
 even for agents with homogeneous tastes — a finding which suggests that the Neo-
 classical approach may sometimes misrepresent the former source of heterogeneity
 as the latter.

Thought-process heterogeneity is an essential feature of any decision situation
 590 wherein individuals *may* act without first considering the consequences of that ac-
 tion. Such situations include the class of minor decisions that incrementally affect
 individuals' educational, employment, or health outcomes. This paper applied the
 generalised decision theory to describe educational investment decisions, and thereby

provided an explanation for several empirical puzzles. For example, a non-negligible
595 proportion of society is observed to develop such low human capital that they be-
come socially excluded: this paper suggests that those individuals never choose that
outcome, but rather that it arose as the cumulative consequence of many minor
decisions, any of which could be determined according to impulsive rather than de-
liberative thought processes.

600 The proposed model therefore implies that an individual's propensity to act delib-
eratively should constitute their fundamental non-cognitive ability. That characteri-
sation contributes the first concrete concrete theoretical description of non-cognitive
ability, and it provides a mechanism by which non-cognitive ability would be a dy-
namic complement of cognitive ability. By endogenising the observed dynamic re-
605 lationships between cognitive and non-cognitive ability, the proposed model is also
able to explain each of the nine stylised facts of human capital development listed by
Heckman and Cunha (2010), chief among which is a path dependence within human
capital development in the spirit of Arthur (1992). Such path dependence brings
economic understanding closer to the epidemiological literature, in which an individ-
610 ual's outcomes are considered to be determined by their social situation, rather than
their idiosyncratic tastes.

This paper has also begun to explore the wider applicability of the generalised deci-
sion theory. That exploration has yielded a direct theoretical basis for the crowding-
out hypothesis; namely that the provision of an additional, extrinsic, motivation
615 may have the perverse effect of cueing an undesirable thought-process. Similarly,
the empirically puzzling relationships between cognitive ability, non-cognitive abil-
ity, behavioural biases, and socio-economic outcomes were seen to arise as direct
consequences of the generalised decision theory. It therefore seems likely that other
empirical puzzles might also arise as consequences of that theory. For example, it is

known that factors which appear to be orthogonal to individuals' tastes, such as the font-size of experimental instructions and concurrent cognitive load, can have a significant influence over decision-outcomes (Alter et al. 2007, Shiv and Fedorikhin 1999). Although such findings challenge the commonly maintained hypothesis that economic agents differ only in their tastes, they are commensurate with those orthogonal factors' likely influence on any individual's propensity to think deliberatively — a mechanism which this paper has demonstrated to be a credible source of individual differences. Further research is therefore needed to explore the implications of the generalised decision theory more fully.

In many situations, the generalised decision theory is likely to yield little additional insight over the Neoclassical approach. In particular, it seems reasonable to model individuals as agents who maximise one single, representative, utility function for applications within the traditional economic domain of profit maximisation, or for any application wherein the theorist seeks to prescribe a normatively optimal trade-off between conflicting motivations. Furthermore, in those situations the Neoclassical approach will provide a more mathematically elegant solution than its generalisation. Nevertheless, this paper has derived original and intuitive explanations for individuals' observed decision-making in behavioural situations, as a result of the strictly weaker assumption set which underlies that generalised theory. Therefore, future theoretical research should explicitly consider whether the Neoclassical 'single-self' assumption is appropriate, and, if not, whether the generalised decision theory proposed in this paper could better describe their agents' decision-making.

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