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My research mission: an executive summary

It is widely accepted that life is not fair. However, I do not accept this status quo, and so I work to reduce the inequality of opportunity in our society. In particular: I seek to understand, to explain, and to improve the cognitive and non-cognitive development of young people from disadvantaged backgrounds. My work is informed by five years as a classroom teacher in a comprehensive school in Birmingham, it is enabled by four years as a student of mathematics at Warwick University, and it is built upon four years as a student and a researcher in the Economics Department at Lancaster University.

Thus far, my key findings include: first, that divergently low levels of educational investment could arise as a rational response to early disadvantage; second, that a generalisation of Expected Utility Theory could enhance and extend this result to provide an unified explanation for multiple dimensions of poverty; and third, that there is strong empirical support for my generalised decision theory within the context of educational development. A central implication of my theoretical explanation for educational divergence is that an individual's noncognitive *propensity to think analytically* should be an important determinant of their ongoing cognitive development, and so I estimate the simultaneous production technologies of cognitive and noncognitive development to test that hypothesis. I find remarkably strong corroboration for my theoretical analyses.

My findings have important implications for economic theory and for public policy. They suggest that the former might benefit from broader application of my generalised decision theory, and they suggest that the latter might reduce societal inequality by supporting disadvantaged children to develop their noncognitive ability to think analytically. My present and future research priority is to develop, pilot, evaluate, improve, and disseminate practical measures which support disadvantaged young people to break-out of negative developmental pathways.

My work 2016-2019

The Education Trap: Could a grades-focused educational system be perpetuating poverty in advanced economies? – presented at the EEA conference 2019; submitted to JEBO in July 2019.

In this paper I develop a model for the mechanism of educational investment. I propose that cognitive development arises as the cumulative consequence of many incremental participation decisions, such as whether to attempt the present classwork task, and whether to revise for tomorrow's test. I solve this dynamic participation supergame to show that children with more than a critical threshold level of early disadvantage endogenously separate onto a divergent low-investment pathway at equilibrium. This result implies that the ostensibly poor educational investment decisions of disadvantaged children may arise as an optimal response to their early disadvantage – thus a grades-focussed education system could trap disadvantaged children into intergenerational poverty. As a consequence, I conclude: i. that it will become increasingly difficult to compensate for early disadvantage as a child ages; ii. that high innate ability could be observationally equivalent to an advantageous early educational environment; and iii. that

traditional interventions which target the individual could be both less effective and more costly than interventions which target the educational system. Such systemic intervention would replace grades-focussed payoffs that celebrate a child's current attainment level with learning-focussed payoffs that celebrate increments in that level.

States of Nature and States of Mind: A generalized theory of decision-making
– published in Theory and Decision, May 2019

In this paper I propose a generalisation of Expected Utility Theory, under which agents will either follow the analytical preferences of Homo Economicus, or else they will act so as to satisfy their impulsive desire. This model of human decision-making has strong intuitive appeal, particularly when applied to incremental participation decisions such as those described in *The Education Trap.* I sketch a diverse set of applications of this generalised decision paradigm to provide intuitive, parsimonious, and unified explanations for: the crowding-out effect, educational under-investment, persistent socio-economic inequalities, the pervasive influence of noncognitive ability on life outcomes, and the dynamic relationships between cognitive and noncognitive ability. These results suggest that each individual's *propensity to think analytically* – that is the probability with which they will adopt an analytic, rather than an impulsive state of mind – could be a decisively important noncognitive ability.

A Review of Dual-self Modeling – submitted to Economic Surveys in February 2019

In this paper I review both the foundational assumptions and the existing implementations of dual-self modelling in the economic literature.[1] I begin by establishing that the generalised decision framework from *States of Nature and States of Mind* requires a strictly weaker assumption set than Expected Utility Theory, and by demonstrating that the latter is only defensible in specialised circumstances which admit precisely one viable objective function. I then taxonomise the existing dual-self literature into five categories, to find that most of this literature maintains the strong assumptions of Expected Utility Theory, either directly – by imposing a meta-rational trade-off between states of mind – or indirectly – by assuming that each decision context is characterised by one dominant state of mind. Only a few papers allow individual heterogeneity to affect an agent's propensity to think analytically, and of these only my own work relaxes the assumption that agents internalise complete information of both their analytic and their impulsive decision-processes.

Modeling Advanced Persistent Threat Campaigns: Multiple Choice Criteria and Stepping-Stone Attacks – joint with Kim Kaivanto; revise and resubmit at Risk Analysis

This paper applies the generalised decision theory to the context of phishing and related social engineering attacks. We provide an explanation for previously-documented phenomena including: the high societal susceptibility to social engineering attacks; the weak association between performance in explicit phishing-identification tests and true susceptibility; the ineffectiveness of many traditional training programmes; and the prevalence of stepping-stone attack patterns.

[1] The dual-self paradigm is that popularised by Daniel Kahneman in *Thinking Fast and Slow.*

Re-estimating the Technology of Cognitive and Noncognitive Skill formation

– submitted to JHR in May 2019

In this paper I lay the foundations for an empirical test of the theoretical work outlined above. There are several empirical challenges that such a test must overcome: i. a child's cognitive and noncogntive skills (such as their propensity to think analytically) develop simultaneously, ii. there are multiple additional inputs to cognitive development, including iii. parental investment, which may be endogenous, and iv. possibly unobserved confounding inputs. These problems are addressed by a programme of work lead by James Heckman and Flavio Cunha, which culminates in their 2010 Econometrica paper: *Estimating the Technology of Cognitive and Noncognitive Skill Formation.* In the course of adapting that work to test my theoretical models, I encountered and corrected several important errors and omissions in the existing econometric model. These include: relaxing over-identifying restrictions, nesting the production function, and replacing the flawed anchoring procedure with an explicit normalisation of the production function (see below), as well as several more minor corrections in the model's implementation. This paper shows that these developments greatly improve the fit of the model, and they reverse some counter-intuitive findings that previously emerged from it.

On the Benefits of Normalization in Production Functions

– submitted to the Journal of Economics in April 2019

In writing the previous paper I uncovered an inconsistency in CES-family production functions that has not received adequate exposition in the literature. In this paper I show that the share parameters of such functions can be arbitrarily manipulated by the selection of alternative units for any one input. I link this result to the concept of normalisation that exists within specific fields of macroeconomics, and I derive correct interpretations of CES share parameters as the share of total resource that should optimally be dedicated to each input along the normalisation ray through the production space.

Noncognitive Skills: Theory and Empirics – Job Market Paper, not yet submitted

This paper uses the empirical procedures developed above to test the theoretical models proposed in my earlier work. I first derive rigorous hypotheses that formalise the predicted effects of each postulated noncognitive input from *The Education Trap,* then I operationalise those inputs within the Millennium Cohort Study to find statistical corroboration for each hypothesis. In addition, I operationalise cohort-members' propensity to think analytically, and I find that the effect of that noncognitive skill on cognitive development during compulsory schooling years is substantially and significantly larger than any other candidate noncognitive skill at any period, including the benchmark proxy measure used elsewhere in the literature. These results add substantial weight to the implications derived from *The Education Trap* and from *States of Nature and States of Mind.* In particular they suggest: i. that individual-level interventions should seek to develop children's propensity to think analytically, ii. that traditional individual-level interventions could be less effective than the specific systemic interventions that I derive in the *Education Trap*, and iii. that economic models of situations in which multiple objective functions could be relevant should consider using the generalised decision theory that I propose in *States of Nature and States of Mind.*

My future intentions

I intend to work towards a reduction in the inequality of opportunity within our society. As such, I will pursue the following activities:

The development, implementation, and evaluation of educational policy initiatives

Two of my specific ideas in this area are: parent-and-child classes toward *nat-5* qualifications in mathematics that focus on metacognition and practical empowerment; and the development of a formal *higher* course in coaching learning, wherein older pupils are trained in metacognition and practical empowerment and then practice coaching younger pupils in their learning whilst gaining accreditation through experience- and research-based assignments.

Initiatives such as these require connections, stakeholder buy-in, and funding. I intend to actively pursue each of these prerequisites, for example by working part-time in schools, by reaching out to colleagues involved in I-SPHERE and in the scholar programme at Heriot-Watt, by reaching out to researchers working in the Robert Owen centre for Educational Change at Glasgow, and by devoting time to developing funding proposals, including for the UKRI Future Leaders Fellowship.

Part-time work as a high-school teacher will be important: i. in maintaining the currency of my understanding of the educational sector, ii. in providing connections with gatekeepers and stakeholders in schools, and iii. in providing the stimulus for new policy initiatives. In addition to my own ideas, I would like to set up a system whereby teaching professionals are empowered to develop and contribute their own suggestions for educational policy initiatives.

A potential long-term objective in this area would be to set up a school in a deprived neighbourhood which embodies a learning-focussed, rather than a grades-focussed system. Such an institution would embed policy initiatives such as those outlined above, it would explicitly focus on empowered analytic decision-making, and it would probably implement a radically different provision: for example with hours of 09:00-17:00, within which the last portion of each day would be dedicated to worthwhile extra-curricular pursuits that provide the opportunity to develop noncognitive skills, including self-worth, determination, and the pursuit of long-term development.

Further experimental and theoretical work on individual decision-making and motivation

The objectives of such work are threefold. First, to extend, refine, and challenge my own understanding of individual decision-making and motivation as it pertains to educational development; second, to articulate and to disseminate that understanding within the scientific community and beyond; and third to develop the reputation and impact of my research within the scientific community.

Specific ideas in this area include: an application of Nash Equilibria to classroom dynamics; an application of the theoretical approach developed above to labour-market outcomes; experiments to investigate the theoretical understanding of the crowding-out phenomenon that was derived above; (field-)experimental work on applications of one's propensity to think analytically to phishing risk and to other phenomena; work to collate and assess the evidence on links between one's propensity to think analytically, the cognitive reflection test, and multiple dimensions of socio-economic inequality; follow-up work on the foundations and broad applicability of the generalised decision theory; empirical and econometric work on the determinants of youth unemployment;

empirical work on the interactions between gender, self-confidence, and labour-market outcomes; and empirical work to quantify the relative contributions of signalling cf. learning through education toward life outcomes.

Holistic contribution toward the big picture of inequality in opportunity

It is important to be familiar with the broader landscape of social inequality in order to identify opportunities for contribution. There are a variety of organisations working to provide descriptive insights into that landscape, for example the team focussing on children's outcomes within the Scottish Centre for Administrative Data Research, but there are also significant gaps in our knowledge in this area. In particular, there may be scope to learn from the Opportunity Insights group at Harvard who have developed opportunityatlas.org, which is an interactive resource for exploring spatial inequalities in the US. This is not a field of research in which the Spatial Economics and Econometrics Centre at Heriot-Watt has yet been involved, but it could potentially become so in the future.

Dissemination and impact of my work

The research programme outlined In this document can only achieve its purpose if its findings are widely disseminated and acted upon. One means towards this end is to publish my research in high-level scientific journals, but there are many other important pathways through which to achieve a positive impact. These include: collaboration with other researchers, including those in other disciplines and other locations; presentation of my work at academic and policy conferences in multiple disciplines; actively reaching out to policy-makers and to public bodies such as the Scottish Poverty and Inequality Commission; and active engagement with popular and social media regarding news-worthy initiatives and results.

An additional consideration under this title is the development and empowerment of others. In this vein it would be beneficial to invest effort into the recruitment PhD candidates who wish to work in the areas complementary to this research programme. This could not only increase capacity for the development of existing ideas, but it could also bring in new perspectives and new ideas. A long-term approach toward this objective could include the provision of a (possibly inter-university) masters module in the economics of inequality and/or behavioural decision-making, and possibly the provision of a joint undergraduate programme between economics and psychology.