Homo economicus?

Neuroeconomics and other disciplines aim to identify the biological traits governing our financial behaviour, but not without accompanying criticism

The current financial and economic crisis is the worst since the stock-market crash of 1929. As with every complex phenomenon, a mixture of causes have been put forward: the housing-market bubble, risky mortgage loans, 'toxic' financial products, high personal and corporate debts, inaccurate credit ratings, and much more. The shockwaves have spread so rapidly and hit so hard that entire banking systems have collapsed, turning once wealthy countries into debtors that need to be saved by loans from other nations or the International Monetary Fund; Iceland being the most visible example.

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With such devastating effects, economists are getting their share of the blame. Why has the crisis not been foreseen by their mathematical models? If financial decisions and capital markets are driven by rational thinking, then why does the manner in which the crisis developed seem so irrational? Is there something else besides the crude analysis of numbers and facts that should be taken into account when explaining and forecasting how humans deal with money?

These questions have been around for some time, and both economists and biologists have put forward various responses. First was 'behavioural economics', which incorporates psychological and emotional factors into models of individual decision-making. In the late 1990s, neuroeconomics emerged, spurred by the tools of neurobiology to analyse the molecular and physiological mechanisms by which decisions are made. "We define neuroeconomics as the convergence of the neural and social sciences, applied to the understanding and prediction of decisions about rewards, such as money, food,

information acquisition, physical pleasure or pain, and social interactions," wrote John Clithero and colleagues in a recent paper on the topic (Clithero *et al*, 2008). "Economics provides descriptive tools and conceptual resources for describing human decision-making behaviour. The task of neuroeconomics is to describe the neural mechanisms that underlie human decision-making behaviour," said Carl Craver, a philosopher of neuroscience at Washington University in St Louis (MO, USA). "One central question, then, is whether the decision-making perspective on behaviour makes sense from the brain's-eye view. Do the mechanisms in the brain correspond in any tidy way to the taxonomy of decision-making phenomena that behavioural economists describe?"

Among the experimental approaches that have been used in neuroeconomics, brain functional magnetic resonance imaging (fMRI; Fig 1) had a crucial role. Scans of selected areas of the brain such as the striatum, posterior parietal cortex or the amygdala in both animals and humans facing situations in which risk, reward, profit, gains and losses had a role, have been used extensively (Glimcher & Rustichini, 2004; Clithero *et al*, 2008). Other, non-invasive methods of brain stimulation have also been used, such as transcranial magnetic stimulation and transcranial direct current stimulation (Glimcher *et al*, 2009).

But there is more than just brain imaging. Scientists are also looking for the genetic determinants of economic behaviour; such studies are generally centred around the genes for the neurotransmitters dopamine and serotonin, which seem to have important roles in decision-making. Recently, Jonathan Roiser and colleagues at University College London, UK, investigated how economic decision-making is affected by two variants—the 'short' and 'long' alleles—of the serotonin transporter gene *5-HTTLPR* and how this correlates to the activity of the amygdala, an area of

the brain implicated in processing emotions (Roiser *et al*, 2009). "Our research demonstrates that an individual's genetic make-up influences an economic decision-making bias known as the 'frame effect'. The frame effect occurs when the phrasing (or 'framing') of a decision affects an individual's eventual choice, even when the meaning of the decision is not changed," explained Roiser. "So, for example, a supermarket might advertise their yoghurt as '99% fat-free' as opposed to '1% fat', though these two statements mean the same thing."

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Roiser and colleagues asked volunteers to decide whether or not to gamble £50 with a 'gain frame' and a 'loss frame'. In the 'gain frame', option A was to keep £20 and option B was to gamble, with a 40% chance of keeping the full £50 and a 60% chance of losing everything. In the 'loss frame', option A was definitely to lose £30 and option B was the same as above. Individuals with the short/short genotype were found to be significantly more susceptible to the framing effect than the carriers of the long/long genotype. "In this study, we were able to demonstrate that the amygdala was more active during decisions where the frame influenced an individual's choice in carriers of the genotype more vulnerable to the bias," said Roiser. "This suggests that the bias in the 'short/short' individuals may have been driven by automatic emotional responses to the framing of the question, over-riding analytic decision-making processes," which take place in other areas of the brain. Translating to real life, this would mean that, for example, traders, who need to make quick estimations of risk and consistent decisions, no matter how the information is presented to them, would perform better if they had

the long gene variant, Roiser speculated (University College London, 2009).

In another study, Camelia Kuhnen and Joan Chiao from Northwestern University at Evanston (IL, USA) asked subjects to make several investment decisions and to allocate funds between a risky and a safe asset (Kuhnen & Chiao, 2009). The outcome was analysed in relation to the variants of two genes, *5-HTTLPR* and the dopamine D4 receptor (*DRD4*), which previous studies have associated with the processing of risk and reward. The scientists found that a specific genetic ensemble is statistically linked to either a risk-averse or a risk-prone behaviour. In particular, the *5-HTTLPR* short/short allele carriers took 28% less risk than those carrying the short/long or long/long alleles, whereas *DRD4* 7-repeat allele carriers took 25% more risk than individuals without the 7-repeat allele. "These findings provide novel evidence of a genetic basis for financial choices," the authors concluded. Independent work on *DRD4* from a Swedish and American team obtained comparable results (Dreber *et al*, 2009).

The role of the endocrine system in financial decision-making is also coming under scrutiny. John Coates and Joe Herbert at the University of Cambridge, UK, measured the levels of endogenous testosterone and cortisol in a group of male traders in the City of London (Fig 2). Testosterone levels were found to be higher on days when the trader made more money than average, whereas cortisol levels rose when the trader experienced increased uncertainty of return, investment risk and market volatility (Coates & Herbert, 2008). These findings fit well with the role of testosterone and cortisol in responses to 'winning' and 'threat/stress' situations, respectively. "Our results point to a further possibility: testosterone and cortisol are known to have cognitive and behavioural effects, so if the acutely elevated steroids we observed were to persist or increase as volatility rises, they may shift risk preferences and even affect a trader's ability to engage in rational choice," the authors wrote.

These findings pair with others from a more recent study. This time, Coates and colleagues measured the second-to-fourth digit length ratio (2D:4D) in male 'high-frequency' traders (Coates *et al*, 2009). High frequency or 'noise' trading needs particular skills because traders must scan monitors continuously and react quickly to price

Fig 1 | An example of functional magnetic resonance imaging brain scans. A brain scan illustrates areas that become active when the subject is presented with a stimulus or a task. Credit: Kalina Christoff, University of British Columbia, Vancouver, BC, Canada.

oscillations, on a time scale of minutes or even seconds.

Prenatal androgens are known to influence brain development by increasing its later sensitivity to testosterone, thus shaping future behavioural traits such as risk preferences, heightened vigilance and speed of reactions. Of several markers proposed for prenatal androgens levels, the 2D:4D ratio is one of the most reliable—apparently because digit growth and gonadal development are linked by the common influence of the *hox* genes; a relatively longer fourth finger indicates higher prenatal androgen exposure. The hypothesis formulated by Coates' team was that a higher prenatal testosterone exposure would improve a trader's performance: traders with a lower 2D:4D ratio would make greater long-term profits and would remain in the business for a longer period of time. Intriguingly, their predictions were fulfilled; furthermore, the results showed that the lower a trader's 2D:4D ratio, the more money he made as the market increased. "[I]f markets select traders on the basis of their profitability and their occupational preferences, then low-2D:4D traders will continue to influence asset prices and equilibria in some of these sectors. Contrary to the assumptions of the rational expectations hypothesis, financial market equilibria may be influenced as much by traders' biological traits as by the

truth of their beliefs," the authors remarked (Coates *et al*, 2009).

"The real challenge posed by neuroscience and endocrinology is, as I see it, threefold," said Coates. "First, scientists in these fields display to economists the rigour and necessity of experimental methods. Too much of economics is like theoretical physics without the experimental side. Einstein needed Eddington, but so far economics has felt it could proceed without the frequent corrections that can only come from experiment. In that sense economics has been closer to theology than science. Neuroscience and endocrinology will provide an important corrective here."

Second, Coates added, endocrinology suggests an important criticism of the efficient market hypothesis. "If, as our research suggests, steroids shift risk preferences systematically across the business cycle, destabilising it, then the markets may not be the self-righting entities previously thought by the efficient market theorists," he said. Third, showing that a surrogate marker of prenatal androgens predicts success in high-frequency trading suggests an important anomaly for the efficient market hypothesis. "According to this hypothesis the markets are random and no one can outperform others over the long term," Coates said. "Granted you can have successful traders over the long term, like Warren Buffett,

Fig 2 | The trading floor. Credit: the National Academy of Sciences, USA.

but these people are in the same position as someone who has just flipped 100 heads in a row. The important point is that you cannot say in advance who that person will be. Our bio-marker suggests you can."

Generally, behavioural aspects that are now considered to have a role in individual—and possibly collective—financial decision-making might have evolved in association with events such as migration, territory exploration or sexual competition, which all involve an element of novelty and risk. "We speculate that financial risk-taking may result from evolutionarily adaptive mechanisms that encourage novelty-seeking behavior," wrote Kuhnen & Chiao (2009). If this evolutionary perspective is correct, then the 'animal spirits', which some economists indicate as the real key to comprehend why and how an economy fluctuates (Akerlof & Shiller, 2009), might be, in part, deeply rooted in the relationship between genes, hormones and neurological circuits that scientists have just begun to uncover.

Not surprisingly, many remain critical of neuroeconomics—even when reinforced by genetics and endocrinology—and its claims to describe how the financial side of the brain works. Even if this were possible, radical sceptics think that it would have no impact on how economists see the 'real' world (Anon, 2008). "I

have severe reservations about the neuroeconomics program, its rhetoric and pretensions," said Ariel Rubinstein, an economist at the University of Tel Aviv, Israel, and New York University (NY, USA). "Standard experiments provide little information about the procedures of choice as it is difficult to extrapolate from a few choice observations to the entire choice function. If we want to know more about human procedures of choice we need to look somewhere else." Rubinstein concedes that people differ in the manner in which they make decisions and that economic theory requires models of how individuals make choices that are inconsistent with the rational paradigm. Yet, for him, neuroeconomics is not going to contribute much to the construction of these models. "I hope that brain studies will not get control of economics. The world will be very different if we view human interactions from [a] 'scientific' point of view. I hope that economics remains linked to humanities and not to the sciences," he said. "In the meantime, I am curious how brain studies can influence economics. This is far from being clear."

Once the global financial crisis is over, will economists be more prone to consider neurological and/or biological and psychological factors when building their models?

"Yes, some people are sceptical about the contribution of neuroscience to economics, as people are always with new fields in science, and it is natural to try to find out how much a new discipline might contribute in the future," said Wolfram Schultz, a neuroscientist at the University of Cambridge, UK. From a biological point of view, he added, behavioural economics offers an array of tasks that can be used to study neural correlates of decision-making. "This is one of the key promises of neuroeconomics. But I would be surprised if neurobiology itself would not help resolve a number of long standing issues in behavioural economics and irrational decision-making, but maybe not as much as one might hope—or maybe even more, who knows," said Schultz. "I would definitely not close the door to neuroeconomics."

"The new field of neuroeconomics has indeed come in for some serious criticism from mainstream economists," Roiser conceded. "Part of this, of course, is purely defensive. But part of it may be justified in that it is not clear what we are to do with results showing, say, that a certain part of the brain, say, the shell of the nucleus accumbens, lights up before someone makes an irrational risk-taking choice," he said. "But what is economics to do with this information? Recommend that, say, one set of bankers be replaced with another? That is impractical and hiring on the basis of DNA [is] illegal. Economics is at [the] bottom a policy science and so far neuroeconomics has been relatively mute on the practical implications of its findings. But it is early yet, so we have still to see the full impact of neuroscience on economics."

"In terms of my general view of neuroeconomics [...], I believe that the field of economics, which I think of as the description, modelling and prediction of human financial behaviour, can only be strengthened by adding informative findings from psychology and neuroscience," said Coates. "[F]or example, I believe that emotional processes play a role in influencing financial decisions, and that adding emotion to economic models will likely provide a more complete description of human financial behaviour, improving our models and hence our predictions," he said. "However, of course, we should not add components to economic models until we are sure they are robust and true, otherwise the models will only get worse, underscoring the importance of sound and reliable evidence."

There seems to be a consensus on the fact that neuroeconomics is still in its infancy and, so far, its potential in describing human economic behaviour remains unclear. Even when coupled to genetics and endocrinology, the evidence provided so far, although inspiring, mainly consists of statistical correlations, with little explanation for the underlying mechanisms. "Neuroeconomics is one of many interfield sciences that make up contemporary cognitive science and neuroscience. One lesson of the last fifty years of neuroscience is that no single perspective or technique suffices to explain everything we want to explain about cognition," noted Craver. "That said, the test of such interfield projects is whether the fields ultimately make joint progress, whether the results in one field can be used to constrain theories in the other or, short of that, to guide the experimental investigations in the other."

Once the global financial crisis is over, will economists be more prone to consider neurological and/or biological and psychological factors when building their models? "It is one thing to describe how people ought to behave if they are optimally rational and quite another to describe how people in fact behave. Behavioural economists have known this for some time," said Craver. "I have yet to see a case where the added prefix 'neuro' adds a new or useful corrective to predictive economic models. That's not to say it will never happen; it's just to say that I haven't seen it yet." For Rubinstein, "neuroeconomics will remain a hot topic in economics during the coming decade, probably one of the hottest. This is not because of any truth that is waiting to be discovered or some

urgent real-world problem that needs to be solved. [...] The rise of neuroeconomics is coming at a point in time when economic theory is not producing any exciting insights" (Rubinstein, 2008).

Don Ross, a professor of economics at the University of Cape Town, South Africa, and the University of Alabama at Birmingham (USA), has a clear view of the field's development. "A great deal of publicity and buzz has surrounded early work that doesn't really establish the clear sorts of results people imagine," he said. "In consequence, I think the hyping of early neuroeconomics will be succeeded by a period in which expressions of disenchantment and disappointment will be common. Much of this will go too far." According to Ross, neuroimaging technology will improve, as will the ability of scientists to constrain structural models of economic choice with reliable and discriminating neural processing data.

"Mature neuroeconomics will not consist in breathless reports to the effect that (for example) a 'greed centre' in a specific part of the brain makes investors act like myopic idiots," Ross remarked. Rather, parameters representing neural learning of value will become more common in microeconomic models of small-scale phenomena, and there will be a sub-specialization that refines the estimation and testing of these parameters to increasingly advanced levels of sophistication. "This will then be a new source of input to standard microeconomics, not a revolutionary replacement of it," said Ross. "Such work won't make for cover stories in *Time*—or in *Nature*, for that matter—but it will be good, solid science."

REFERENCES

- Akerlof GA, Shiller RJ (2009) *Animal Spirits: How Human Psychology Drives the Economy and Why it Matters for Global Capitalism*. Princeton, NJ, USA: Princeton University Press
- Anon (2008) Do economists need brains? *The Economist*, July 24. http://www.economist.com/finance/displaystory.cfm?story_id=11785391
- Clithero JA, Tankersley D, Huettel SA (2008) Foundations of neuroeconomics: from philosophy to practice. *PLoS Biol* **6**: e298
- Coates JM, Herbert J (2008) Endogenous steroids and financial risk taking on a London trading floor. *Proc Natl Acad Sci USA* **104**: 6167–6172
- Coates JM, Gurnell M, Rustichini A (2009) Second-to-fourth digit ratio predicts success among high-frequency financial traders. *Proc Natl Acad Sci USA* **106**: 623–628
- Dreber A, Apicella CL, Eisenberg DTA, Garcia JR, Zamore RS, Lum JK, Campbell B (2009) The 7R polymorphism in the dopamine receptor D4 gene (*DRD4*) is associated with financial risk taking in men. *Evol Hum Behav* **30**: 85–92
- Glimcher PW, Rustichini A (2004) Neuroeconomics: the consilience of brain and decision. *Science* **306**: 447–452
- Glimcher PW, Camerer CF, Fehr E, Poldrack RA (2009) Introduction: a brief history of neuroeconomics. In *Neuroeconomics. Decision Making and the Brain*, PW Glimcher, CF Camerer, E Fehr, RA Poldrack (Eds), pp 1–12. London, UK: Academic
- Kuhnen CM, Chiao JY (2009) Genetic determinants of financial risk taking. *PLoS ONE* **4**: e4362
- Roiser JP, de Martino B, Tan GCY, Kumaran D, Seymour B, Wood NW, Dolan RJ (2009) A genetically mediated bias in decision making driven by failure of amygdala control. *J Neurosci* **29**: 5985–5991
- Rubinstein A (2008) Comments on neuroeconomics. *Econ Philos* **24**: 485–494
- University College London (2009) UCL study: genes influence economic decision-making. Press release, May 5. <http://www.ucl.ac.uk/news/news-articles/0905/09050505>

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