Neuro-finance:

Can Neurosciences explain Financial Crises?

Francesca Papa
BA in Politics, Philosophy and Economics
LUISS University

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ABSTRACT

The aim of this paper is to emphasise the effectiveness of behavioural and neuro economics in enriching conventional economic models. We will thus begin by introducing the field of behavioural economics and presenting the contribution of the most prominent behavioural economists. We will then examine the subfields of neuroeconomics and neurofinance and examine some of the critiques that have been addressed to these disciplines. And finally, through the case study of the most recent financial crises, we will see why neurofinance is needed if we are to understand our economic world.

1. Introduction

On February 23, 1995, Nick Leeson, futures trader at Barings Bank, did not show up at work. There was a handwritten note on his desk. It just read: *"I'm sorry"*. When his colleagues found it, Nick had already fled Singapore and flown to Kuala Lumpur.

But Nick's legacy to Barings Bank was much more substantial than the three handwritten words he had hurriedly scribbled. In fact, he was leaving behind him a catastrophic trading debt of £827 million (US$1.4 billion) for his employers. When Barings management found out, it was too late: three days later the bank collapsed and was eventually bought by the Dutch bank ING for the symbolic amount of £1.[1] What had happened? How did the collapse of Britain's oldest merchant bank come about?

It all begun three years earlier, when Nick Leeson was hired by Barings Future Trading in Singapore. He started managing Barings investments in the Singapore International Monetary Exchange (SIMEX) and notably investments in futures markets and derivatives on the Japanese Nikkei index. At first, he made millions of profits for Barings on the Far East markets and was very successful - in 1993, his individual profits made up more than 10% of Barings' total profit.

However, when Leeson's luck on the trading floor started to decline, he was unable to properly handle his losses. For years, he hid all his losses in one of Barings' error accounts: account 88888 (8 is the lucky number in Chinese numerology). Such accounts are not uncommon in the trading market and are usually used to correct minor trading mistakes. However, while the account had initially been created with the good intention of covering up the mistake of an inexperienced colleague, Leeson soon started to use account 88888 to covertly obscure his own mounting debts.

As his losses grew, he started asking for extra money from the Barings headquarters in London so as to finance his shady activities. In an attempt to recover the losses he had already made, Leeson became involved in increasingly speculative and risky trading operations: "Starting to panic, he was doubling up again and again. But the losses mounted as his gambles on Nikkei futures failed. Soon

[1] Titcomb, James. "Barings: The Collapse That Erased 232 Years of History." (23 Feb. 2015) *The Telegraph*. Telegraph Media Group.

Leeson was behind $100 million, then $500 million. In the course of one year he managed to wipe out the entire capital of Barings Bank**.**"[2].

In the end, Barings Bank, a historical 232-year-old bank with many important clients (among which the Queen of England), went bankrupt. After months of being on the run between Malaysia and Thailand, Leeson was finally found in Germany and sentenced to spend six-and-a-half years in a prison in Singapore.

The story of Leeson and Barings is representative of **the role that psychological factors may play in economic and financial decisions**; it is a classic example of the potential economic impact of feelings such as fear and hubris. There is indeed evidence that Leeson's trading followed a ruinous doubling pattern[3]. Confronted with mounting debts, Leeson did not try to come up with a good stop loss strategy. He panicked, hid his losses and doubled his investment bets, in the hopes of recovering the money he had lost. In his own words: "I was determined to win back the losses. I traded harder and harder, risking more and more. (…) But first thing on Monday morning I found that I had to use the 88888 account again ... it had become an addiction.*"*[4]

Behind Leeson's behaviour stands a principle that is well-known in the study of decision-making and which is "one of the biggest potential exposures of every major financial institution"[5]: **aversion to loss.** Leeson's anecdote exemplifies how in finance, where most activities involve some degree of risk, fear of losing can have catastrophic consequences. Traders may be unable to handle panic and may end up doubling up their investments just as gamblers increase their bets when they face significant losses (in gambling this is known as Martingale strategy).

Of course, the doubling strategy that traders adopt is not the only option they have, nor is it the most rational. When confronted with losses, the most logical thing they could do is to follow one simple principle: "If you find yourself in a hole, stop digging". In Leeson's case, if he had reported his losses and stopped investing one month earlier (i.e., by the end of January 1995), "the total loss

[2] Pressman, Steven. "Rogue Trader: I Brought Down Barings Bank and Shook the Financial World." (April, 1997) *Southern Economic Journal* V63.N4, Southern Economic Association. Web.
[3] Brown, Stephen J. and Steenbeek, Onno W., "Doubling: Nick Leeson's Trading Strategy" (2000). NYU Working Paper No. FIN-00-058. Available at SSRN: https://ssrn.com/abstract=1300736
[4] Leeson, Nick, "Rogue Trader" (1996). London: Little, Brown and Co. pp.63-64
[5] Lo, Andrew W., "Fear, Greed, and Financial Crises: A Cognitive Neurosciences Perspective", (October 2011), printed in "Handbook of Systemic Risk", edited by J.P. Fouque and J. Langsam, Cambridge University Press, 2013.

would have been about one quarter of the eventual loss and this could probably have been absorbed by Barings, saving the bank as an independent entity"[6].

Yet, unfortunately, it is quite frequent for economic agents to take risky steps to get away from a dangerous position and the phenomenon has been widely studied in the past few decades. Both Shapira[7] and Kahneman and Tversky[8] have shown that individuals are more risk-seeking when it comes to avoiding losses than when it comes to making profits. Indeed, there also exists a neurophysiological basis for our gains-losses asymmetry[9]. In a study at Stanford University, Kuhnen and Knutson have shown that when subjects make a risk-seeking choice, they evaluate the potential monetary gain with the same reward circuit activated by cocaine (the nucleus accumbens), while risk-averse investors who face the possibility of monetary loss activate the same neural structure that is associated with disgust (the anterior insula)[10]. It is therefore both for psychological and neurophysiological reasons that, when facing mounting losses, investors are easily misled into acting out of fear and risking more than they should.

But "it is not just people like Nick Leeson, not just the new financial entrepreneurs"[11] who grapple with the complexity of our 'risk society' (as sociologist Ulrich Bech has defined it[12]): we all do. As Gerd Gigerenzer would put it: we all know how to read and write, but we are unable to handle uncertainty — we are 'risk illiterates'[13].

More in general, we are pray to a great deal of pitfalls in our decision-making processes. As we will see in later sections of this paper, the kind of psychological factors which influenced Nick Leeson's behaviour is ever-present in human decision-making. And yet, unfortunately, the economic discipline has traditionally neglected to take into account such psychological/cognitive

[6] Brown, Stephen J. and Steenbeek, Onno W., "Doubling: Nick Leeson's Trading Strategy" (2000). NYU Working Paper No. FIN-00-058. Available at SSRN: https://ssrn.com/abstract=1300736
[7] Shapira, Z.B., "Organizational decision making"(1997). Cambridge: Cambridge University Press.
[8] Kahneman, D., Tversky, A., "Rational Choice and the Framing of Decisions" (1986).. Journal of Business 59 (4, pt.2), 251-278.
Significant quote: "A significant property of the value function, called *loss aversion*, is that the response to losses is more extreme than the response to gains. The common reluctance to accept a fair bet on the toss of a coin suggests that the displeasure of losing a sum of money exceeds the pleasure of winning the same amount."
[9] Lo, Andrew W., "Fear, Greed, and Financial Crises: A Cognitive Neurosciences Perspective", (October 2011), printed in "Handbook of Systemic Risk", edited by J.P. Fouque and J. Langsam, Cambridge University Press, 2013.
[10] Kuhnen, C. M. and Knutson, B.,"The neural basis of financial risk taking" (2005). Neuron 47, 763–770.
[11] Giddens, Anthony. "Risk and responsibility" (1999). *The modern law review* 62.1 : 1-10.
[12] Ulrich, Beck. "Risk Society: Towards a New Modernity" (1992). New Delhi: Sage. (Translated from the German Risikogesellschaft, 1986.)
[13]Gigerenzer, Gerd. "Risk Savvy: How to Make Good Decisions." (2015) London: Penguin. Print. Quote: "the problem is not simply individual stupidity, but the phenomenon of a risk-illiterate society"

aspects of our choices. Economic theory has generally assumed that: "people solve important problems as economists would."[14].

Instead of looking at the human mind from a holistic point of view, economics long "conceptualised a world populated by calculating, unemotional maximizers that have been dubbed Homo Economicus."[15] This appealingly practical and simple model has often been justified because it is easy to formalise and to include in computations. And yet it is an unrealistic and inaccurate description of the average economic agent. The 'as if' approach that regarded humans 'as if' they were fully rational was a useful abstraction "as long as the brain remained substantially a black box" [16] and as long as the behavioural mechanisms that govern decision-making were unclear/unknown. Today, with mounting experimental and scientific evidence disproving the idea that humans are unboundedly rational creatures, research has clarified that it is both possible and necessary to translate psychological ideas into formal economic models.

Behavioural and neuro-economics are the new fields that attempt to bring these psychological insights into the economic discourse, after almost a century of separation between the disciplines of economics and psychology. In the last two decades, behavioural economics has become a prolific domain of academic research and scholars are increasingly recognising that "virtually every field of economics could benefit from giving greater scrutiny to the role of Humans"[17]. Behavioural economics has therefore been applied to studies in finance, law, development economics, game theory, macroeconomics, environmental economics and many other areas of research.[18]

The aim of behavioural economics is two-fold. On the one hand, it identifies the deviations of our behaviour from assumed standards of rationality, i.e. it diagnoses the ways in which humans 'predictably err'[19]. On the other hand, it shows the ways in which such deviations from traditional models may be relevant to economic and financial contexts.

[14] Thaler, Richard and Benartzi, Shlomo. "Save More Tomorrow☐: Using Behavioral Economics to Increase Employee Saving" (2004), Journal of Political Economy, vol. 112, no. 1, pt. 2, University of Chicago.
[15] Mullainathan, Sendhil and Thaler, Richard H., "Behavioral Economics" (September 2000). MIT Dept. of Economics Working Paper No. 00-27. Available at SSRN: https://ssrn.com/abstract=245828 or http://dx.doi.org/10.2139/ssrn.245828
[16] Camerer, Colin; Lowenstein, George and Prelec, Drazen. "Neuroeconomics: How Neuroscience can inform economics" (March 2005) Journal of Economic Literature Vol. XLIII, pp. 9–64.
[17] Thaler, Richard H. "Misbehaving the Making of Behavioural Economics" (2016). London: Penguin, Print.
[18] Camerer, Colin; Lowenstein, George and Prelec, Drazen. "Neuroeconomics: How Neuroscience can inform economics" (March 2005) Journal of Economic Literature Vol. XLIII, pp. 9–64.
[19] Thaler, Richard H., and Cass R. Sunstein. "Nudge: Improving Decisions about Health, Wealth, and Happiness" (2009). London: Penguin, Print.

The reason why it is important to enrich the economic discipline so as to make it more accurate and more resemblant to the real world - the reason why behavioural economics is worth exploring- is that, as influential as it is today, the discipline of economics cannot afford to rest on flawed premises. If it is true, as Thaler suggests, that "economists carry the most sway when it comes to influencing public policy", if they do "hold a virtual monopoly on giving policy advice"[20], then economics cannot be based on incorrect assumptions. Now that economics has become the "grammar of politics"[21], it must distance itself from all sort of mythologies, among which the presumption of human rationality and the efficient market hypothesis.

Given the pre-eminence of economics in the "marketplace of ideas"[22] and its overarching impact on the wider society, we have to make sure that the arguments with which economics informs policy-making are legitimate and that the policies that economic theory suggests actually deliver effective results. Behavioural economics can help in doing just that. This is why national governments are increasingly relying on behavioural teams to include insights from various social sciences in the formulation of public policies. The government of the UK has instituted an influential Behavioural Insights Team in 2010, while Obama has embraced behavioural economics by instituting a Social and Behavioral Sciences Team in 2014 as part of the White House Office of Science and Technology Policy.

Such behavioural experts have turned necessary in the aftermath of the most recent financial crisis, which has highlighted the inadequacy of traditional economic instruments. Indeed, prior to the breakout of the crisis, almost no economist had understood the threatening state of the economy. Between 2004 and 2005, a number of well-known policy makers and important economists repeatedly underestimated the severity of the economic state of affairs, writing articles such as 'No Housing Bubble Trouble' (Alan Reynolds, *The Washington Times*, January 2005) and 'What Housing Bubble?' (Neil Barsky, *The Wall Street Journal*, July 2005). Alan Greenspan, Chairman of the US Federal Reserve, as well as his successor Ben Bernanke, seemed to share the general belief that a bubble was not on the way and that increases in real-estate prices largely reflected 'strong economic fundamentals'. In August 2008 (!), Olivier Blanchard, IMF chief economist at IMF, stated that "The state of the macro is good"[23] right as the US financial market was about to

[20]Thaler, Richard H. "Misbehaving the Making of Behavioural Economics" (2016). Penguin, Print.
[21] Laurent, Éloi. "Nos mythologies économiques", (2016). Les Liens qui libèrent.
[22] Drezner, Daniel W. "The Ideas Industry" (2017) New York, NY: Oxford UP.
[23] Blanchard, Olivier J., "The state of the macro" (August 2008), Working Paper 14259 (http://www.nber.org/papers/w14259),
National Bureau Of Economic Research

crash. A careful case study of the GFC may thus reveal a failure of traditional economic theory and indicate the need to modify old assumptions.

But why should we turn to behavioural and neuroeconomics? What have been the main findings of the field? In the section that follows, we will review some of the major contributions of behavioural economics and finance and we will look, by way of example, at some heuristics and bias that make us less rational than what classical economics assumes. Subsequently, in Chapter 3, we will have a closer look at recent developments of behavioural economics. In particular, we will discuss neuroeconomics and its validity. We will see how neurosciences can help us know more about the mental reasoning processes involved in financial decisions. Finally, in Ch 4, through an overview of the causes of financial crises, we will discuss whether behavioural and neuroeconomics can help us complement our economic knowledge and help us explain financial phenomena.

2. How do behavioural theories differ from mainstream economics?

2.1 Core economic premises

When fulfilling its basic role of analysing how finite resources can be allocated to satisfy infinite needs, economics starts from the assumption that people will normally make the best of their limited budget. This is known as the principle of constrained optimisation: given a restrained budget, people will choose the optimal bundle of goods and services they can afford and firms will maximise their expected returns. This maximisation of resources rests on the premise that people have knowledge of what is optimal for them, i.e. that they base their economic decisions on unbiased, "rational" expectations.

In economics and finance, rationality is considered to imply two things. As reported by Egidi: "First, when they receive new information, agents update their beliefs correctly, in the manner described by Bayes' law. Second, given their beliefs, agents make choices that are normatively acceptable, in the sense that they are consistent with Savage's notion of Subjective Expected Utility (SEU)."[24]

Assuming that, in this respect, economic agents are rational, as well as well-informed and self-interested, we can then expect that, in perfectly competitive markets where prices fluctuate freely, a general equilibrium will be reached between supply and demand. As studied by economists such as

[24] Egidi, M. "Behavioral finance and cognitive psychology: where do we stand?" (2011). Prepared for the seminar "Finanza, comportamenti, regole, istituzioni", Luiss University

Neumann, Debreu, Arrow, and McKenzie, this equilibrium, achieved through a series of voluntary economic exchanges, will reflect a situation of Pareto efficiency, where no one is made worse off by the improvement of someone else's status.[25]

More specifically, to draw a clearer picture of the economic context: the so-called 'classical economics' school states that the economy is self-regulating and will meet the needs of the market by reaching maximum efficiency on its own, while 'neoclassical economics' expands on this idea by also recognising the role of individuals in the economy. This second form of economic analysis specifically relies on three major assumptions: individuals are rational; individuals have limited income therefore they strive to maximise utility; and lastly, all individuals act independently of each other. These two school of thoughts together created the traditional idea of the economy as a self-regulating entity with an underlying component of individuals who are acting in their self-interest.

This fundamental economic principle, as linear as it can appear, is nonetheless a house of cards relying on an unsustainable structure. Many points of departure of economic reasoning are plane assumptions such as 'Economic agents select what they prefer' or 'Individuals are fully informed'; assumptions which, in light of advances in behavioural studies, turn out to be not only simplistic but also incorrect. People are often unable to solve the optimisation problems they face in ordinary life - let alone to solve them optimally- and the opinions upon which they base their decisions are far from being unbiased.

2.2 Prospect Theory and cognitive biases

We deviate from the standard economics concept of rationality both in the way we make judgements and in the way we make choices. This has been captured in Kahneman and Tversky's Prospect Theory[26], a descriptive theory which overviews the numerous ways in which we depart from rational choice. The theory draws the distinction between automatic and controlled thinking processes and is grounded on the evidence that, more often than not, people tend to use mental shortcuts (heuristics) to process complex information. This phenomenon may turn useful in situations in which we need a fast reaction to an impelling stimulus, but can also generate systematic errors of assessment, known as cognitive biases, which may impair our decision-making

[25] Hausman, D.M., "The philosophy of economics: an anthology" (2008) New York: Cambridge University Press.
[26] Kahneman, Daniel and Tversky, Amos, "Prospect Theory: An Analysis of Decision under Risk," (March 1979). Econometrica. Vol. 47 (2). p 263-91. See also: Kahneman, Daniel, Slovic, Paul and Tversky, Amos, 1982, Judgement under Uncertainty: Heuristics and Biases, Cambridge and New York: Cambridge University Press.

skills. Some emblematic examples include overconfidence, the endowment effect, conservatism, anchoring and confirmation biases, as well as deducing the likelihood of an event based on "salience" (availability heuristics) or "similarity" (representativeness heuristic)[27].

To illustrate the potential impact of this sort of human 'misbehaving', let us examine some interesting cases of cognitive biases which have been studied in environmental economics and psychology. These examples show us that cognitive biases not only differentiate us from the traditional economic agent archetype, but also affect our world in sensible and dangerous ways. We should thus study deviations from rationality not only to correct economic theory and bring it closer to the reality, but also to possibly correct behaviours that heavily impact the real world in a number of ways that goes well beyond pure and abstract economics.

Let us consider for example the so-called 'optimism bias', which is our predisposition to systematically think that bad things are more likely to occur to other people than to ourselves[28]. In the context of environmental psychology, as studied by Gifford, Scannel et al., this cognitive distortion is also known as the 'spatial bias' and is described as the tendency to estimate that global environmental conditions are worse than local ones. What this means is that we will erroneously attribute the highest level of severity to environmental risks that are far from us, even when this is not necessarily the case. And since we care the least about problems that are far from us, this unfortunately also means that we paradoxically will feel the least responsible for those risks that we perceive as more severe[29].

A similar bias, known as the 'present bias' applies to time perception. Humans tend to focus on the present and discount concerns perceived to be in the far-off future, such as climate change (World Bank Development Report 2015)[30]. Both the spatial and the present bias are forms of judgemental discounting that can have disruptive consequences on sustainable behaviour. If conditions are presumed to be worse 'elsewhere and later'[31], individuals may have less motivation to act against climate change here and now.

[27] Mullainathan, Sendhil and Thaler, Richard H., "Behavioral Economics" (September 2000). MIT Dept. of Economics Working Paper No. 00-27. Available at SSRN: https://ssrn.com/abstract=245828 or http://dx.doi.org/10.2139/ssrn.245828

[28] Gifford, R., Scannell, L., Kormos, C., Smolova, L., Biel, A., Boncu, S., & Uzzell, D. "*Temporal pessimism and spatial optimism in environmental assessments: An 18-nation study"* (2009). Journal of Environmental Psychology, 29, 1–12.

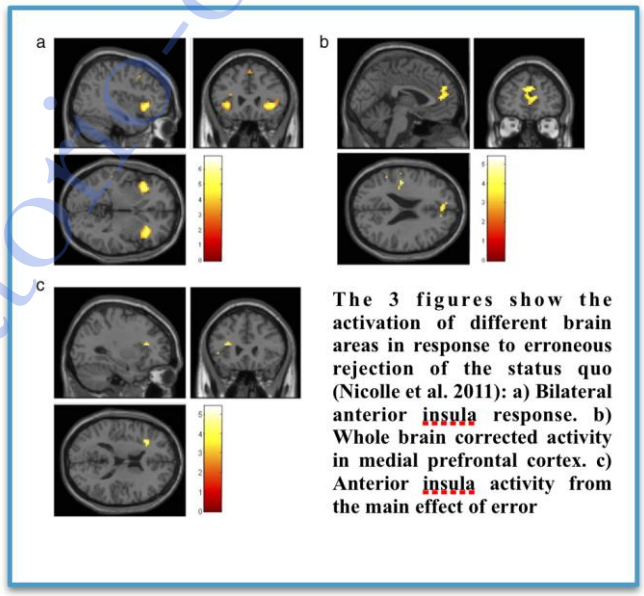
[29] Uzzell, D. L. "The psycho-spatial dimensions of global environmental problems". Journal of Environmental Psychology, 20, 307–318. 2000.

[30] World Development Report 2015: Mind, Society and Behaviour. World Bank. 2015

[31] The Dragons of Inaction: Psychological Barriers That Limit Climate Change Mitigation and Adaptation. Gifford R. American Psychological Association Vol. 66, No. 4, 290–302. 2011.

Of course instances of cognitive biases abound outside the field of environmental psychology as well - a plethora of academic studies has highlighted the flaws and biases of our capacity to make forecast and decisions. To consider one more example, let us examine the so-called 'status quo bias' (or 'inertia'). As described by Thaler, the status quo bias is people's "tendency to stick with the status quo or default option."[32]. The bias has been confirmed in a significant number of decision-making experiments, which have proven that people disproportionately prefer permanence over change. Interestingly, studies show that people prefer the status quo option **whatever it implies**, i.e. regardless of whether it is the best option. Such studies have for example been carried out by Samuelson and Zeckhauser in the domain of health plans and retirement programs[33] and have revealed that the status quo bias takes place even when transition costs are low and the weight of the decision is high.

From a psychological point of view, the roots of the status quo bias are loss aversion, incorrectly perceived sunk costs, and regret avoidance. The neural bases of the phenomenon have also been studied: a 2011 study by Nicolle et al. has discovered that erroneously rejecting the status quo produces more neural activity - notably more activity in the anterior insula and in the medial prefrontal cortex— than erroneously accepting the status quo (see figure) . This difference may play a role in constructing our perception of regret and may facilitate the emergence of the status quo bias in successive choices.[34] Once identified the neural pathways connected with the status quo bias, research studies at UCL have also concluded that the harder the decision we have to make, the more likely we are to maintain our original baseline position. [35]



The 3 figures show the activation of different brain areas in response to erroneous rejection of the status quo (Nicolle et al. 2011): a) Bilateral anterior insula response. b) Whole brain corrected activity in medial prefrontal cortex. c) Anterior insula activity from the main effect of error

[32] Thaler, Richard H., and Cass R. Sunstein. "Nudge: Improving Decisions about Health, Wealth, and Happiness" (2009). London: Penguin, Print.
[33] Samuelson, W.; Zeckhauser, R. "Status quo bias in decision making". (1988) *Journal of Risk and Uncertainty*. **1**: 7–59. doi:10.1007/bf00055564.
[34] Nicolle, A.; Fleming, S. M.; Bach, D. R.; Driver, J.; Dolan, R. J. (2011). "A Regret-Induced Status Quo Bias". *Journal of Neuroscience*. **31** (9): 3320–3327. doi:10.1523/JNEUROSCI.5615-10.2011. PMC 3059787 . PMID 21368043.
[35] Fleming, Stephen; C. Thomas; R. Dolan (February 2010). "Overcoming Status Quo Bias in the Human Brain". *Proceedings of the National Academy of Sciences of the United States of America*. **107** (13): 6005–6009. doi:10.1073/pnas.0910380107. PMC 2851882 . PMID 20231462.

In light of this myriad of documented psychological mechanisms, we have to rethink the validity of traditional economics, which, as we have seen, relies on inexact characterisations of human behaviour. How can economic models, however mathematically sophisticated, be useful epistemological tools if they are built on simplifications, on "premises assumed without evidence, or in spite of it"? [36]

2.3 The "As if" Approach

A justification for ignoring psychology and relying on simplified assumptions can be found in Pareto's view that "Pure political economy has a great interest in relying as little as possible on the domain of psychology" and in Friedman's theory of 'positive economics'. Indeed, Friedman proposed two criteria for assessing theories that use assumptions A to formulate predictions P:

1. "Assumptions A should be judged by the accuracy of the predictions P they mathematically imply.
2. Since false assumptions can yield accurate predictions, even if assumptions appear false their empirical weakness should be tolerated if they lead to accurate predictions P." [37]

In other words, Friedman believed that the unrealism of economic assumptions is of little importance as long as the consequent predictions are correct, believing that the character of the economic discipline is normative and that measuring individual behaviour is inessential. But if false assumptions A lead to a correct prediction P, they necessarily do so because of a latent repair condition R, which deserves to be the center of progressive research (e.g. we should study whether R is systematic or random). At the same time, it is also clear that better predictions can only come from better assumptions and this is why we should explore the new assumptions coming from psychological and neuroscientific evidence: "The hope is that models based on those alternative assumptions will explain anomalies and make interesting new predictions."[38]

Economists have accepted the inaccuracy of their models for far too long, accounting for errors in their predictions by simply including an "error" term in their computations. And, as Thaler points out, "as long as the errors were random—that is, the model's predictions were too high or too low

[36] Peacock, Thomas Love, "Crochet Castle" (1831), London: reprinted by Penguin (1969)
[37] Friedman, M. "The Methodology of Positive Economics" (1953) as reported by Camerer in "Neuroeconomics: Using neuroscience to make economic predictions"
[38] Camerer, Colin; Lowenstein, George and Prelec, Drazen. "Neuroeconomics: How Neuroscience can inform economics" (March 2005) Journal of Economic Literature Vol. XLIII, pp. 9–64.

with equal frequency—then all was well."[39] After all, traditional economists argue, economics could never possibly grasp the universality and totality of human experience, even if it aimed to. In this sense, economists were confident that relying on a distorted image of individuals (an image that regarded individuals "as if" they behaved in rational and sophisticated ways) would nonetheless produce reliable results.

The first academic paper to defend this 'As If' approach was Friedman and Savage's ''The Utility Analysis of Choices Involving Risk", in which they explicitly assumed that even if it is "patently unrealistic to suppose that individuals consult a wiggly utility curve before gambling or buying insurance"[40], for practical reasons, we can assume that, when making economic decisions, individuals act **as if** they rationally took into account the expected utility and the probability of events.

To this assumption, Shiller would reply that this "as if" approach is a form of wishful thinking, that it is idealistic to believe that models based on unrealistic assumptions can produce reliable predictions. Indeed, if this were the case, "We would have powerful tools to study and to quantify the financial world around us"[41]. And yet, to summarise the counterargument with a quote by Egidi: "Unfortunately, elegance is hardly synonym of realism"[42].

There exists no 'invisible hand' that may annul the deviations of human behaviour from assumed standards of rationality and turn humans in "as if" creatures. Mullainathan and Thaler have indeed discredited the idea that the there may be any self-regulating force counteracting human errors: the market per se cannot wipe out irrationality, nor can evolution, nor can learning: "Many economists have argued that a combination of market forces (competition and arbitrage) plus evolution should produce a world similar to that described in an economics textbook: do only the rational agents survive? Or, do the workings of markets at least render the actions of the quasi-rational irrelevant?(…) Markets per se do not necessarily solve the problem (…) markets per se cannot be relied upon to make economic agents rational." Even if the market provides incentives for individuals to act rationally, it cannot force them into making the best economic decisions.

[39] Thaler, Richard H. "Misbehaving the Making of Behavioural Economics" (2016). London: Penguin, Print.
[40] Friedman M, Savage LJ "The utility analysis of choices involving risk." (1948) J Polit Econ 56(4):279–304
[41] Shiller, RJ, "From efficient markets theory to behavioral finance" (2003). J Econ Perspect 17(1):83–104
[42] Egidi, M. "The Economics of Wishful Thinking and the Adventures of Rationality." *Mind & Society* 13.1 (2014): 9-27.

Other critics of behavioural theories base their defence of unbounded rationality on evolutionary grounds. They claim that the survival-of-the-fittest process that regulates all natural selections is also at work in economic markets, supposedly knocking out those individuals who fail to maximise profits. This argument is for example supported by Alchian[43], who claims that, in perfectly competitive markets, competition will serve as a selection force weeding out all non-rational firms which are unable to maximise profits[44].

There is, however, a fallacy in this evolutionary line of reasoning, a logical flaw. Yes, evolution might favour the most *rational* actors and compensate them with higher profits. But, on the exact same logical grounds, we might as well argue for the opposite argument. We could conclude that, on the contrary (!), evolution favours the survival of *irrational* economic agents, who economise on their computation ability and save more time and energy than rational agents do. Also: if evolution is at work, why are we not perfect yet? When will evolution reach its final stadium and make us all rational traders? This is the weakness of the evolutionary viewpoint: its flexibility can be used to argue for very different stances.

The final point supporting the "as if" argument is that, over time, people will supposedly learn from their mistakes and stop indulging in non-rational behaviours. However, as any smoker would recognise, one does not easily learn from his or her failures and it is easy to turn systematic mistakes into bad habits. To err is human, to persist in error is even more human. In addition, in many cases, such as in one-shot decisions, we do not even have the opportunity to learn from our mistakes. Unless you believe in reincarnation and in memory of past lives, you will agree that: "The number of times we get to learn from our retirement decisions is low (and possibly zero). The opportunity cost of experimenting with different ways of choosing a career can be very high."[45]

In conclusion, it is not possible to justify unbounded rationality on the basis of merely theoretical and speculative arguments. There is no inherent force (neither competition, nor evolution, nor learning) which can by itself counterbalance humans irrational behaviours in markets and demonstrate the presumed effectiveness of the 'as if' approach.

[43] Alchian AA "Uncertainty, evolution, and economic theory". (1950) J Polit Econ 58:211–221
[44] Egidi, M. "The Economics of Wishful Thinking and the Adventures of Rationality." *Mind & Society* 13.1 (2014): 9-27.
[45] Mullainathan, Sendhil and Thaler, Richard H., "Behavioral Economics" (September 2000). MIT Dept. of Economics Working Paper No. 00-27. Available at SSRN: https://ssrn.com/abstract=245828 or http://dx.doi.org/10.2139/ssrn.245828

2.4 Unbounded Rationality, Unbounded Willpower, Unbounded Selfishness and the Efficient market Hypothesis

According to Mullainathan and Thaler, we should thus reject the "as if" argument and try to modify, through behavioural sciences, 3 main unrealistic assumptions of standard economics: unbounded rationality, unbounded willpower and unbounded selfishness[46]. Let us examine them in greater detail and add to these 3 the discussion of another strong assumption that economists traditionally make, that is, the efficient market hypothesis.

First of all, we need to recognise that economic agents do not possess unrestrained capabilities to process information, that human problem-solving skills are not unlimited. To use a term that was first introduced by Simon in 1995, we could say that human rationality is 'bounded'. "In saying that people have bounded rationality, Simon meant that they lack the cognitive ability to solve complex problems, which is obviously true."[47] With limited brain power and finite time, how can we be expected to solve complex problems optimally?

Paradoxically, it is 'rational' for us to "economise on cognitive faculties" and base our decisions on simple rules of thumb (heuristics).[48] It is hard, and sometimes even impossible, to process the amount of information that everyday decisions imply. In this regard, life is like a chess game: "in many circumstances it is not possible to calculate the optimal strategy, given the computational complexity of the problem."[49] As a result, we often rely on simplified evaluations which may be very inaccurate forecasts of future outcomes and which may push us to commit predictable mistakes. This does not mean that individuals do not strive to behave rationally - in fact, they do strive to behave rationally- but there are cognitive barriers that systematically inhibit their ability to do so.

Simon's concept of ''Bounded Rationality'' thus clashes with Muth's longstanding theory of rational expectations, which states that agents' predictions do not systematically involve forecasting errors and are correct on average. It is interesting to note that Simon's and Muth's conflicting theories were formulated in the same intellectual milieu. As Simon himself noted: "it is not without

[46] Mullainathan, Sendhil and Thaler, Richard H., "Behavioral Economics" (September 2000). MIT Dept. of Economics Working Paper No. 00-27. Available at SSRN: https://ssrn.com/abstract=245828 or http://dx.doi.org/10.2139/ssrn.245828

[47] Thaler, Richard H. "Misbehaving the Making of Behavioural Economics" (2016). London: Penguin, Print.

[48] Conlisk, John, "Why Bounded Rationality?" Journal of Economic Literature. Vol. 34 (2). p 669-700. June 1996.

[49] Egidi, M. "The Economics of Wishful Thinking and the Adventures of Rationality." *Mind & Society* 13.1 (2014): 9-27.

irony that bounded rationality and rational expectations... though entirely antithetical to each other, were engendered in and flourished in the same small business school at almost the same time''.[50]

Secondly, traditional economics assumes that humans are utility maximisers. Yet, outside of economic textbooks, humans hardly know what is best for them and even if they do, they often fail to put it into practice.[51] Humans' willpower and self-discipline are limited. Consider for example the so-called 'planning fallacy'. Everyone will recognise that we are often unable to stick to the plans we set for ourselves; that we have a systematic predisposition to be overly optimistic about how long it will take to finish a project: "Everything takes longer than you think, even if you know about the planning fallacy."[52]

Thirdly, economics has traditionally considered people to be unconditionally and unboundedly selfish. This is clear in many microeconomic case-studies - for example, in the free-rider problem, it is assumed that people will always act in their self-interest and thus will not contribute to the public good unless it benefits them personally and directly. On the contrary, altruism is a big component of the human social existence and individuals often act against their economic self-interest. This is evident when we look at the percentage of people that choose to donate money to charity (e.g. 73.4% of all households in the US in 1993). It is even more evident if we consider the substantial amount of experimental research[53] demonstrating that most individuals make choices based on social preferences. Such studies, mainly coming from social neuroeconomics, show us that people are not necessarily self-regarding and that what they choose is hugely dependent on "a positive or negative concern for the welfare of others"[54] and on other people's opinion about their actions.

Finally, it is important to illustrate the doubts that behavioural finance has raised concerning the efficient market hypothesis formulated by Fama in 1965. The hypothesis stated that markets are inherently efficient: if they were not, then there would be unexplored profit opportunities which rational arbitrage traders or 'smart money' would eliminate[55]. Behavioural finance, notably in the aftermath of 1987 stock market crash, has challenged this long-standing efficient market hypothesis

[50] Simon HA (1991) Models of my life. New York, NY, US, Basic Books xxix
[51] For a reflection on the theme, see: Gallagher, BJ. Why Don't I Do the Things I Know are Good for Me? (2009), Berkley.
[52] Thaler, Richard H., and Cass R. Sunstein. "Nudge: Improving Decisions about Health, Wealth, and Happiness" (2009). London: Penguin, Print.
[53] Fehr, E. and Fischbacher, U. (2003) The nature of human altruism. Nature 425, 785–791; Camerer, C.F. (2003) Behavioral Game Theory – Experiments in Strategic Interaction, Princeton University Press
[54] Fehr, Ernst, and Colin F. Camerer. "Social Neuroeconomics: The Neural Circuitry of Social Preferences." (2007) *Trends in Cognitive Sciences* 11.10. 419-27.
[55] Mishkin, Frederic S., and Stanley G. Eakins. *Financial Markets and Institutions*. (2012) New York, NY: Pearson.

and shown that it is undermined by limits to arbitrage: rational traders can hardly revert the dislocations created by less rational traders.

As Shiller rightly stated, we thus need to "distance ourselves from the presumption that financial markets always work well and that price changes always reflect genuine information''[56].

3. Neuroeconomics and Neurofinance

In the previous pages, we have overviewed some of the ways in which behavioural theories could enrich canonical economic theory and highlighted the main achievements of the field. We will now turn to some of the most recent and fascinating developments of behavioural and experimental economics, by introducing the fields of neuroeconomics and neurofinance. We will explain what neuroeconomics is, we will describe its scope as well as its methods and finally we will present the current academic debate concerning the validity of the field.

3.1 The neuroscientific contribution to the study of economics and finance

As the intuitive etymology may suggest, neuroeconomics and neurofinance are the interdisciplinary areas of academic research which seek to study the neurophysiological correlates of economic and financial decision-making. The aim of the neuroeconomic enterprise is to integrate research from a panoply of social and natural sciences: notably neurosciences, economics & finance, biology, cognitive and social psychology.

Neuroeconomics and neurofinance can thus be defined as the "convergence of neural and social sciences"[57], to which traditionally distinct disciplines each bring their own peculiar contribution. Economics and finance bring statistical models and theoretical principles to scrutinise (e.g. constrained utility functions, assumptions of rationality). Recent advances in psychology add knowledge of cognitive mechanisms and biases. Neuroscience, thanks to improvements in brain-imaging experimental techniques, allows us to scan brain activity and observe the "biology" of our decisions. In addition, novel insights are coming from many diverse fields such as genetics[58] and

[56] Shiller RJ (2003) From efficient markets theory to behavioral finance. J Econ Perspect 17(1):83–104
[57] Clithero, John A., Dharol Tankersley, and Scott A. Huettel. "Foundations of Neuroeconomics: From Philosophy to Practice." *PLoS Biology* 6.11 (2008): n. pag. Web.
[58] See for example: Caldu X, Dreher JC (2007) Hormonal and genetic influences on processing reward and social information. ANYAS 1118: 43-73; Zak, P. J. 2002. Genetics, family structure, and economic growth J. Evol. Econ. 12, 343–365; Zak, P. J. and Park, K.-W. 2002 Population genetics and economic growth. J. Bioecon.4, 1–37.

computer science[59]. Given its composite and multidisciplinary nature, neuroeconomics thus aims to expand the evidential base of economics both directly (by directly assessing and improving "the predictive and exploratory power of economic models"[60]) and indirectly (e.g. by enriching psychology, which in turn can impact economics through behavioural advances).

It remains to be seen whether, as Fumagalli suggests, 1) unifying the heterogeneous branches of knowledge of economics, finance, psychology and neuroscience is *feasible* and 2) whether this union, provided it is feasible, "brings valuable modelling and theoretical benefits to NE's parent disciplines."[61]

The greatest potential of neuroeconomics is to take us on a journey to unexplored brain lands and show us what really lies behind our choices. What motivates our actions? What inhibits them? **What is the relation between mind and behaviour?** What's the relation between our brains and ourselves? Are our actions retraceable to biological mechanisms? While these are questions that go well beyond pure neuroscience and expand to philosophy of the mind and existentialism, neuroeconomics may still be key in decoding the structure and functioning of human thinking processes. In doing so, neuroeconomics may either "incrementally" enrich the conventional economic account of decision-making or it may, more "radically", lead to a "paradigm shift" (as Kuhn would define it) in the economic discipline. [62]

If and how neuroeconomics will impose itself in the economic discourse is however still a matter of controversy, as we will discuss in paragraph 3.3. What is certain is that neuroeconomics is calling into question the traditional 'revealed preference' model of economics, which equated "unobserved preferences with observed choices"[63] on the assumption that, as Jevons pessimistically stated[64], humans do not possess the capabilities to look inside the brain's black box.

[59] Bogacz R (2007) Optimal decision-making theories: linking neurobiology with behaviour. Trends Cogn Sci 11: 118-125.
[60] Clithero, John A., Dharol Tankersley, and Scott A. Huettel. "Foundations of Neuroeconomics: From Philosophy to Practice." *PLoS Biology* 6.11 (2008): n. pag. Web.
[61] Fumagalli, Roberto. "Five Theses on Neuroeconomics." *Journal of Economic Methodology* 23.1 (2015): 77-96. Web.
[62] This incremental vs radical impact of neuroeconomics was first conceptualised in: Camerer, Colin, George Loewenstein, and Drazen Prelec. "Neuroeconomics: How Neuroscience Can Inform Economics." *Journal of Economic Literature* 43.1 (2005): 9-64. Web.
[63] Camerer, Colin, George Loewenstein, and Drazen Prelec. "Neuroeconomics: How Neuroscience Can Inform Economics." *Journal of Economic Literature* 43.1 (2005): 9-64. Web.
[64] "I hesitate to say that men will ever have the means of measuring directly the feelings of the human heart." from Jevons, William S. 1871. The Theory of Political Economy. London : Macmillan and Co.

Advances in neuroscience are seriously challenging this pessimistic view, as new technologies are enabling us to explore "the entire process of decision making, from initial perception of a stimulus …to valuation and motivation, and the very act of choosing"[65], thus illustrating ways in which knowing more about our brains will mean knowing more about economic agents. The pioneers of neuroeconomics and neurofinance are working to demonstrate which brain areas are responsible for reward and risk assessment[66], which areas account for resolution of uncertainty[67] and which neural substrates guide our reaction to fair and unfair offers (as we will see in section 3.4).

Importantly, neuroeconomics is showing us that humans are incapable of gaining full awareness of the automatic and emotional operations that take place in their brain. Our cognitive deliberation is not always in control of the unconscious and affective processes that guide our actions. Our behaviours thus "need not follow normative axioms of inference and choice."[68] It is for this reason that neuroeconomists argue that economic models should not neglect to include the new variables coming from neuroscience, in a way that recalls Behavioural Economists' argument in favour of the inclusion of psychological variables.

The boundaries between neuroeconomics and behavioural economics are indeed blurred and undefined: although neuroeconomics is commonly regarded as a branch of Behavioural Economics, it would be reductionist to consider neuroeconomics and neurofinance as nothing but a technologically sophisticated laboratory for behavioural theories. The difference between behavioural finance and neurofinance has been captured by Tseng as follows: "the former investigates how people act and interact in the process of making financial decisions and interpret these actions based on established psychological concepts and theories, whereas the latter examines why and how these behaviors occur based on the observations on people's brain and hormonal activities". While this is the main source of diversity between the two fields, a quick review of the aims and methods of neuroeconomics will help us clarify that neuroeconomics and neurofinance have their own specific scientific identity and distinctiveness.

[65] Bossaerts, Peter. "What Decision Neuroscience Teaches Us About Financial Decision Making." *Annual Review of Financial Economics* 1.1 (2009): 383-404. Web.
[66] Schultz W, Dayan P, Montague PR (1997) A neural substrate of prediction and reward. Science 275: 1593-1599.
[67] Yoshida W, Ishii S (2006) Resolution of uncertainty in prefrontal cortex. Neuron 50: 781-789.
[68] Camerer, Colin, George Loewenstein, and Drazen Prelec. "Neuroeconomics: How Neuroscience Can Inform Economics." *Journal of Economic Literature* 43.1 (2005): 9-64.

3.2 Aims and methods of Neuroeconomics

As we have seen, in the short run, the primary aim of neuroeconomics is to examine the neural mechanisms which underlie particular behavioural patterns of economic interest, such as evaluation of reward, time discounting [69], self-control [70], as well as social mechanisms like trust and reciprocity [71]. But the ultimate purpose of neuroeconomics goes beyond mapping the neural pathways that elicit our behaviours.

In a long-term perspective, the ambition of neuroeconomics and neurofinance is to create a single theoretical framework that may combine different academic disciplines "into a single, unified discipline with the ultimate aim of providing a single, general theory of human behaviour"[72]. As Rustichini puts it, the aspiration is to "complete the research program that early classics (in particular Hume and Smith) set out in the first place: to provide a unified theory of human behaviour".[73]

But what are the main directions that neuroeconomics pursues and aims to pursue? According to Camerer [74], the potential of neuroeconomics is three-fold. The first possible application of neuroeconomics is to construct "evidence for utility maximisation in simple choice" by for example simulating tasks in which subjects evaluate simple alternatives by comparing them and choosing the one to which they attribute higher value[75]. Secondly, neuroeconomics can provide insights on the variables and parameters studied by behavioural economics, by identifying the biological bases of heuristics and biases, for example in the domain of time and risk perception. And thirdly, neuroeconomics can observe the neural mechanisms with which mental states, such as pain, fear, fatigue and anger, condition our decisions and constrain our actions. We will have the chance to further discuss this point in chapter 4, by looking at the financial impact of feelings like fear and greed.

[69] McClure, S. M., Ericson, K. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2007). Time discounting for primary rewards. Journal of Neuroscience, 27, 5796–5804.

[70] Benhabib, J., & Bisin, A. (2005). Modeling internal commitment mechanisms and self-control: A neuroeconomics approach to consumption-saving decisions. Games and Economic Behavior, 52, 460–492.

[71] Zak, P.J., Kurzban, R. and Matzner, W.T. 2004 The neurobiology of trust. Annuals of the New York Academy of Science, 1032, p.224-227.

[72] Glimcher, P.W. and Rustichini, A. 2004. Neuroeconomics: The Consilience of Brain and Decision. Science, 306(5695): 447–52.

[73] Rustichini, A. 2005. Neuroeconomics: Present and Future. Games and Economic Behavior, 52: 201-212.

[74] Camerer, Colin F. "Goals, Methods, and Progress in Neuroeconomics." *Annual Review of Economics* 5.1 (2013): 425-55.

[75] Platt ML, Glimcher PW. 1999. Neural correlates of decision variables in parietal cortex. Nature 400:233–38; Rangel A, Hare TA. 2010. Neural computations associated with goal-directed choice. Curr. Opin. Neurobiol. 20:1–9

What kind of instruments do neuroeconomics and neurofinance use in order to achieve these aims? How can one identify the specific neural correlates of economic and financial choice? There are several techniques available to neuroscience to understand which regions of the brain are activated when an individual is involved in different tasks.

The most commonly employed tool is BOLD fMRI (blood-oxygenation-level-dependent functional magnetic resonance), which uses magnetic resonance (MR) technology to detect variations in levels of blood oxygenation during functional behaviour.[76] The reason why fMRI works is that magnetic exposure produces more evident effects on haemoglobin molecules without oxygen than on haemoglobin molecules with oxygen. And since we can confidently assume that neurons in more active regions of the brain consume more oxygen than neurons in inactive regions, we can consider the rate of deoxygenated haemoglobin as a reasonable proxy for neural input[77]. In other words, the more active a brain region is, the higher its level of deoxygenated haemoglobin molecules (i.e. the higher the level of molecules that will react strongly to magnetic resonance). The figure below is drawn from a study of Kuhnen and Knutson (2005) and shows a typical image resulting from a fMRI measurement. In particular, this one illustrates which areas are more active when we evaluate gains versus losses and relative market value.

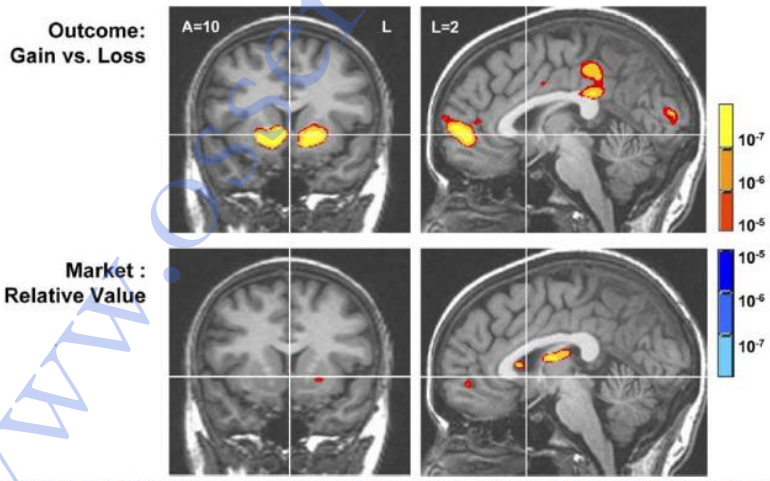


Figure 1: Effect of actual and Relative outcomes on neural activation Adapted from Kuhnen and Knutson (2005). The top panels depict the contrast of large gains versus significant losses during the Outcome period following stock choice. The bottom panels depict the contrast of chosen versus unchosen outcomes during the Market period following stock choice. n = 19.

[76] Logothetis, Nikos K. "The Neural Basis of the Blood-Oxygen-Level-Dependent Functional Magnetic Resonance Imaging Signal." *Philosophical Transactions of the Royal Society B: Biological Sciences* 357.1424 (2002): 1003–1037. *PMC*. Web. 9 June 2017.

[77] Lo AW. 2013. Fear, greed, and financial crises: a cognitive neurosciences perspective. In Handbook on Systemic Risk, ed. JP Fouque, J Langsam. Cambridge, UK: Cambridge Univ. Press. In press

Positron emission tomography (PET) is another common brain-imaging technique, in which the subject is injected a small quantity of a radioactive solution. This enables us to measure blood flow in the brain and tells us whether a region is more or less neurally active (the higher the amount of blood entering a neural region, the higher the activation of that region).

fMRI and PET, together with the more traditional electroencephalography (EEG) measurement of neural activity, are useful tools for identifying which brain regions are mostly involved in specific behaviours. And successively, as Camerer suggests: "Once candidate circuits are established, it is useful to ask whether behavior is changed when parts of the circuit are broken or disrupted."[78]

This is a 'primitive' but really effective way to investigate the human brain. The so-called lesion studies indeed usually provide very strong evidence of neural causation. If a subject is unable to perform task X when his brain region Y is damaged (or deactivated with TMS, transcranial magnetic stimulation) then this means that brain region Y is responsible for task X or is implicated in the neural circuit that handles task X. Scientists have therefore long relied on the study of psychopathologies and brain damage (examples include research by Damasio[79], Freeman and Watts[80]) as well as on the simple analysis of psychophysiological indicators such as blood pressure, sweating and pupil dilation.

The strength of neuroeconomics thus comes from being able not only to employ modern and sophisticated technologies such as fMRI, but also to match "older technologies with new tasks"[81] and corroborate data by combining different complementary brain-imaging and brain-stimulation tools. Will this technological resources be enough for neuroeconomics to spark a revolution in the economic field?

3.3 Discussing the case for mindless economics

The evolution of scientific knowledge has always been an issue of great epistemological interest. In 1676, Newton stated: 'If I have seen further, it is by standing on the shoulders of giants', embracing the traditional view of science as a linear and cumulative process by which new discoveries are

[78] Camerer, Colin F. "Neuroeconomics: Using Neuroscience to Make Economic Predictions." *The Philosophy of Economics* (n.d.): 356-77.
[79] Damasio, A.R. 1994. Descartes' Error: Emotion Reason, and the Human Brain. NY: G. P. Putnam.
[80] Freeman, W.J. and Watts, J.W. 1942. Psychosurgery in the Treatment of Mental Disorders and Intractable Pain. Springfield: Thomas.
[81] Camerer, Colin F. "Neuroeconomics: Using Neuroscience to Make Economic Predictions." *The Philosophy of Economics* (n.d.): 356-77.

made by building on previous ones. In 1962, Thomas Kuhn influentially refuted this conception in 'Structure of Scientific Revolutions'[82].

For him, inventions and discoveries are not added to the previous body of knowledge in the way one brick is placed on top of another in the construction of a building, but rather, there exist scientific revolutions which shake the 'normal' progression of science and lead to radical paradigm shifts. When these revolutionary moments occur, continuity with the past is broken and there is a reorientation of science away from old, unsatisfactory assumptions.

In economics, Kuhn's paradigms and scientific revolutions are of great relevance. Existing paradigms represent the lenses through which economists do research and whoever tries to subvert them will encounter great resistance (see Akerlof's difficulty in publishing his 'Market for Lemons' article). Is a 'scientific revolution' occurring right now, as Behavioural Economics and Neuroeconomics gain increasing consensus?

Neuroeconomics is undoubtedly introducing progressive scientific theories and observing phenomena that were previously unobserved and unexpected. Yet, many critics deny the scientific raison d'être of neuroeconomics and criticise its ambitions as misplaced and utopian.

Detractors of neuroeconomics argue that there will never be a common language between economics and psychology, since the two incompatible disciplines have different ends and legitimately use different means to achieve them. They maintain that there cannot exist a single 'all-purpose' account of human behaviou. As Gul and Pesendorfer write: "Economics and psychology differ in the question they ask. Therefore, abstractions that are useful for one discipline will typically be not very useful for the other. The concepts of a preference, a choice function, demand function, GDP, utility, etc. have proven to be useful abstraction in economics. The fact that they are less useful for the analysis of the brain does not mean that they are bad abstractions in economics."[83]

[82] **Kuhn, Thomas S.** (1962). *Structure of Scientific Revolutions* (50th anniversary edition) Chicago, IL: University of Chicago Press. Introductory essay by Ian Hacking

[83] Gul F, Pesendorfer W. 2008. The case for mindless economics. In The Foundations of Positive and Normative Economics: A Handbook, ed. A Caplin, A Shotter, pp. 3–42. New York: Oxford Univ. Press

For centuries, economics has flourished independently of brain science and some economists argue that standard economics still does not need neuroeconomics[84], that the economic discipline can and should remain "mindless"[85]. Some say that neuroeconomics addresses inessential questions, while others are skeptical of the interpretational challenges posed by sophisticated brain-imaging techniques[86]. Others still, lament that neuroeconomics too easily jumps to conclusions, relying on scanty data and using a vague and generic rhetoric. According to scholars like Rubinstein and Harrison[87], neuroeconomics "sweeps lack of knowledge and uncertainty under the rug" and "suffers from a lack of self-criticism and a reluctance to discuss details"[88].

From a philosophical point of view, neuroeconomics challenges the mind-body problem and risks to transform decision-makers into "machines with no soul"[89]. So why should economics care about the mechanical "micro-micro factors"[90] that govern our brains? The relevance of neuroeconomics is not self-evident. Even if many neuroeconomists take for granted that studying the neural substrates of our behaviour will be "ipso facto informative to economists"[91], the simple evidence that decision-making happens in the brain does not inherently imply that neuroscience has direct bearing on economics.

Finally, some economists attack neuroeconomics for being superfluous, arguing that behavioural studies are more than sufficient to supply economics lack of psychological depth: "Even if nothing were known about the neural mechanism of emotion, choice or their interaction, purely behavioural data would be sufficient for many economic questions. The small size of neuroscience experiments complicates analyses of individual differences and even well-conducted, adequately powered experiments may lead to equivocal conclusions."[92]

[84] Harrison GW (2008) Neuroeconomics: A critical reconsideration. Econ Philos. In press. ; Bernheim BD (2008) Neuroeconomics:A sober (but hopeful) appraisal. National Bureau of Economics Research Working Paper. Available: http://www.nber.org/

[85] Gul F, Pesendorfer W. 2008. The case for mindless economics. In The Foundations of Positive and Normative Economics: A Handbook, ed. A Caplin, A Shotter, pp. 3–42. New York: Oxford Univ. Press

[86] Logothetis NK (2008) What we can do and what we cannot do with fMRI. Nature 453: 869-878.

[87] Harrison, G. W. 2008. Neuroeconomics: a critical reconsideration. *Economics and Philosophy* 24.

[88] Rubinstein, Ariel; (2008) "Comments on Neuroeconomics" *Economics and Philosophy*, **24** 485–494 Copyright Cambridge University Press doi:10.1017/S0266267108002101

[89] Rubinstein, Ariel; (2008) "Comments on Neuroeconomics" *Economics and Philosophy*, **24** 485–494 Copyright Cambridge University Press doi:10.1017/S0266267108002101

[90] Bernheim, B.D. 2009. On the Potential of Neuroeconomics: A Critical (but Hopeful) Appraisal. American Economic Journal: Microeconomics, 1(2), p.1-41.

[91] Fumagalli, Roberto (2011) Philosophical foundations of neuroeconomics: economics and the revolutionary challenge from neuroscience. PhD thesis, The London School of Economics and Political Science (LSE).

[92] Clithero, John A., Dharol Tankersley, and Scott A. Huettel. "Foundations of Neuroeconomics: From Philosophy to Practice." *PLoS Biology* 6.11 (2008): n. pag. Web.

While these considerations on the potential limitations of neuroeconomics are not to be lightheartedly dismissed and superseded, we need to recognise that neuroeconomics still is a very recent branch of knowledge and it may be too soon to draw conclusions about its relevance and validity. As Smith notes, the future prospects of neuroeconomics and neurofinance will only be uncovered in the next few years of further research[93].

So far, neuroeconomics looks far from being a scientific dead end. Scholars like Glimcher, Dorris and Bayer respond to the mindless economics critique by stating that neuroeconomics "can be much more than efforts to locate a brain region associated with some hypothetical faculty" and "will reveal the nature of the economic computations brains perform".[94] Conversely, Camerer replies to the mindless critique by suggesting that venerable economists from the past like Edgeworth, Fisher and Ramsey would applaud the possibility to directly measure utility as neuroeconomics now does[95].

In the context of our paper, rather than reacting to the critiques to neuroeconomics with abstract and speculative arguments, we will focus on specific contexts on which neuroeconomics and neurofinance can shed light. To demonstrate that neuroeconomics contains a powerful, yet unexplored, potential, we will first discuss the contribution of neuroscience to the study of game theory and then look more in depth at how neurofinance could be useful to the study of financial crises.

3.4 Neuroeconomics and Game Theory

One area of economics that neuroscientific data can help exploring is Game Theory, i.e. "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers."[96] In particular, neuroeconomics has examined the case of the so-called Ultimatum Game, a typical experiment used by behavioural game theory to show the limitations of traditional economic assumptions. The rules of the Ultimatum Game are fairly simple: player A (the "proposer") proposes to player B (the "responder") to split a given sum of money (say $10). Facing player A's

[93] Smith, V.L. 2007. Rationality in Economics: Constructivist and Ecological Forms (New York: Cambridge University Press.
[94] Glimcher, P.W., Dorris, M.C. and Bayer, H.M. 2005. Physiological utility theory and the neuroeconomics of choice. Games and Economic Behavior, 52: 213–256.
[95] Camerer, Colin F. "Neuroeconomics: Using Neuroscience to Make Economic Predictions." *The Philosophy of Economics* (n.d.): 356-77.
[96] Myerson, Roger B. (1991). *Game Theory: Analysis of Conflict,* Harvard University Press, p. 1. Chapter-preview links, pp. vii–xi

proposal, player B can either agree to split the money accordingly or refuse the offer altogether (in which case both players earn zero). In both events, the game is then over (i.e. there is no possibility for either A or B to propose a different division of the sum).

According to standard theoretical economic predictions, and thus according to the belief that agents will strive to maximise their self-interest, the solution to the Ultimatum Game is that the proposer will try to earn as much as possible and propose to give to player B the minimum sum he can (say he will give B 1$ and keep 9$ for himself). As for the responder, he or she should accept any offer above zero, regardless of its value, "on the reasonable grounds that any monetary award is preferably to none".[97]

However this rarely happens in experimental studies: in fact, extensive research[98] has observed "an intriguing discrepancy between experimental results and game-theoretic predictions"[99]. No matter what the total monetary amount is, proposers will typically offer to split it evenly (the modal offer made by proposers being around 40-50%). On the other hand, in most samples, about ½ of the responders will reject offers where they would receive less than 20% of the whole sum. This apparently makes no economic sense. As it was noted by an Israeli student whose low offer in a 10$ ultimatum game was not accepted: "I did not earn any money because all the other players are stupid! How can you reject a positive amount of money and prefer to get zero? They just did not understand the game! You should have stopped the experiment and explained it to them…"[100]

In contrast with what the Israeli student thought, it is highly improbable that participants did not understand the game, given its extremely simple outline. More likely, players objected unfair proposals which they perceived as offensive so as to affirm their social standing - they probably preferred forgoing some monetary reward to being humiliated by accepting a derisory sum. Of course, one could argue that those who rejected the offer somehow acted "rationally" by rejecting an offer that they deemed unfair - but this is not the kind of rationality which is sustained in

[97] Sanfey AG, Rilling JK, Aronson JA, Nystrom LE, Cohen JD. 2003. The neural basis of economic decision- making in the ultimatum game. Science 300:1755–58

[98] Thaler, Richard H. (1988). "The Ultimatum Game." Journal of Economic Perspectives 2(4), 195-206. ;

Roth, Alvin E. (1995). "Bargaining Experiments." In John Kagel and Alvin E. Roth (eds): Handbook of Experimental Economics. Princeton University Press.

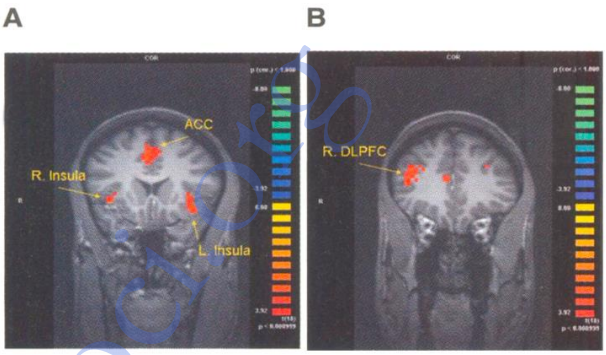
Camerer, Colin, and Richard H. Thaler (1995). "Anomalies - Ultimatums, Dictators and Manners." Journal of Economic Perspectives 9(2), 209-219.

[99] Zamir,Shmuel. 2000. "Rationality and Emotions in Ultimatum Bargaining," Discussion Paper #222.

[100] Zamir, S. (2001). Rationality and Emotions in Ultimatum Bargaining. *Annales D'Économie Et De Statistique*, (61), 1-31. doi:10.2307/20076266

economic textbooks. Indeed, classical game theory rigorously claims that "a rational person prefers receiving any positive amount of money to nothing" and does not take into consideration the possibility that a person's rationality may be torn between "cognitive ("accept") and emotional ("reject") motives"[101].

Neuroscience has shed light on why we may deviate from expectations of rational behaviour during the Ultimatum Game. Sanfey et al. (2003) have indeed monitored - through fMRI - what goes on in the brains of subjects who take part in the game. If you look at the image on the right, you will see, coloured in orange, the brain regions which were most active in subjects who received unfair offers ($1.00-$2.00 out of a total sum of 10.00$).



Low offers mainly activated 3 areas: the Dorsolateral prefrontal cortex (DLPFC), the anterior cingulate (ACC) and the insula cortex. These regions were activated to a greater degree when unfair offers were proposed by other humans as opposed to when they were generated by a computer, suggesting that we react more strongly when some sort of social component (/interaction) is involved. An interesting finding was that the anterior insula (an area normally associated with disgust and anger) was sensitive to the degree of unfairness of the offer, being significantly more active when the offer was lower (see figure on the right). The activation of the insula was thus found to be the "neural locus of the distaste for inequality or unfair treatment posited by models of social utility"[102], reflecting the intuition that some kind of negative feeling is associated with unfair offers.

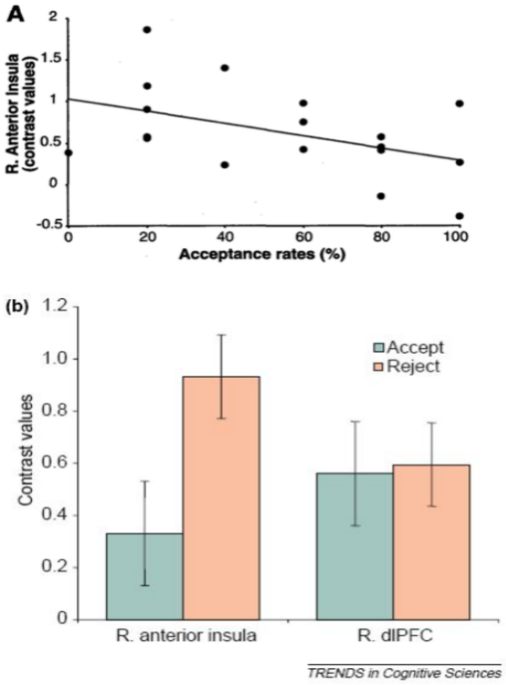


Fig. A: acceptance rates of unfair offers plotted against right anterior insula activation for each participant. Fig. B: Right anterior insult and right DLPFC activation for all unfair offer trials, categorised by subsequent acceptance or rejection. Sanfey et al., 2003.

So can we infer whether a player will reject a low offer by the level of his insula activity? It seems so, as in Sanfey's

[101] Ibidem
[102] Camerer, Colin, George Loewenstein, and Drazen Prelec. "Neuroeconomics: How Neuroscience Can Inform Economics." *Journal of Economic Literature* 43.1 (2005): 9-64. Web.

experiment "participants with stronger anterior insula activation to unfair offers rejected a higher proportion of these offers" with a correlation coefficient r of 0.45.

Activation in DLPFC and in ACC was justified as these two areas are respectively associated with planning (in this case conceiving the planned reward value) and conflict-resolution among brain areas (the ACC is presumably activated to mediate between the insula instinct to reject the monetary offer and the DLPFC desire to accept it).

This study is particularly fascinating in that it shows what happens in our brains when we behave more like Humans and less like Econs. We will now turn to a real-life scenario in which Humans reveal their flesh-and-blood nature: speculative bubbles and financial crises.

4. Neurofinance and financial crises

When the 2008 Global Financial Crisis broke out, it took everyone by surprise. Most economists and policymakers had not foreseen the crash of the housing bubble and its domino effect, and worse, a majority of them was convinced that no such thing could possibly occur. "How did economists get it so wrong?"[103] famously wrote Paul Krugman. What were the factors behind the biggest crisis since the Great Depression?

Almost 10 years later, the causes of the crisis remain unclear and are still a central topic of the economic debate. Who is to blame for the disastrous housing bubble which took place in the US at the beginning of the 21st century and led to the 2008-2009 financial crisis and Great Recession? Who is responsible for what has been defined as the "mother of all asset bubbles"? While some economists blame the permissive mortgage finance system and its widespread (and risky) practice of subprime lending, others point at the Federal Reserve, which is accountable for inducing historically low interest rates and applying a policy of regulatory inaction and deregulation. But who was the real responsible? Was it Alan Greenspan? Was it the explosive growth of swap derivatives as instruments of speculation? Probably a combination of all the above-mentioned factors, together with a diffused 'speculative fever' and the collective belief that 'home prices could go in only one direction: up'.

What is certain is that psychological factors were among the main triggers of the crisis. Can neuroscience explain the mechanisms behind these psychological factors? **Can neurosciences**

[103] *How Did Economists Get It So Wrong?* P. **Krugman,** 2008 Nobel laureate in Economics and Professor at Princeton.

explain financial crises? These are the questions that we will now address. But first, it seems well to digress and overview how financial crises work, and how they have traditionally been tackled.

4.1 What causes financial crises?

There is an ancient Greek ethical concept that is of great relevance to modern economics and finance: the concept of human *hubris*. Hubris is the tendency to adopt overconfident and overoptimistic views about one's own capabilities. In ancient Greek tragedy and literature, whoever committed the sin of hubris was doomed to be punished by the gods and bound to forever bear the heavy consequences of his or her arrogance. Consequences, it was thought, would not only strike the individual hubris sinners, but also their family and progeny.

It is not difficult to see how well the ancient concept of hubris parallels the "irrational exuberance"[104] which underlies modern financial crises. As Reinhart and Rogoff[105] influentially explained, in the dawn of every financial crisis, economic actors tend to suffer from the arrogance of the so-called "this time is different" syndrome. Actors affected by this syndrome fail to notice (or to properly evaluate) the warning signs of a crisis and are incapable of connecting the dots and foreseeing the disruptive consequences that will punish their euphoria.

The psychological roots of financial crises can never be overstated, although it must be recognised that they are not the only points of similarities between the different financial crisis episodes that have occurred over the centuries. Other common traits of financial crisis are for example speculative demand (demand aimed at capital gains rather than at consumption), lax regulatory supervision and the so-called Fear of Missing Out, which leads people to rush in what are perceived as profitable markets.

We will now try to identify the general causes of financial meltdowns and to investigate whether the causes of different financial crises followed similar patterns. To this end, we will organise our reasoning as follows: First, we will provide a quick historical excursus of the major financial crises of modern times; secondly, we will look specifically at the case of the recent Global Financial Crisis, with the aim of assessing whether it is possible to foresee and prevent financial crises in general. Finally, having looked at the drivers of several major financial crises, we will highlight the

[104] **Shiller, Robert**. "Definition of Irrational Exuberance". Princeton University Press. 2005.
[105] **Reinhart & Rogoff**, This Time is Different: A Panoramic View of Eight Centuries of Fi- nancial Crises. National Bureau of Economic Research Working Paper No. 13882. March 2008

neural basis of these similar patterns. Thanks to this thorough historical analysis we will conclude that the main causes of financial crises are factors such as speculative fevers, fear, irrational exuberance and the illusion that asset bubbles can last forever. The overall message that we can learn from this research is that the bank panics that we have gone through in the past few years are "nothing new"[106] and are in fact generated by old, well-known, biologically deep causes.

Financial crises have been an endemic feature of the capitalist economy over the last four centuries[107] and it would be impossible to identify their drivers without referring to actual historical episodes of financial meltdowns. Refusing to engage in a purely abstract speculation of the causes of financial crises, we then provide a brief overview of the major financial crises in modern economies. This overview will be instrumental to later examine the common psychological and non-psychological aspects that crises from very different times and locations share. Let us begin with two classic episodes of early financial crises: the Dutch tulip mania and the South Sea Bubble that took place in the 17th and 18th centuries.

The Dutch 'Tulipmania' was created by an incredible rise in the price of tulip bulbs in 1634/1637, a period of unprecedented prosperity for the Dutch, who had established monopoly on the tulip market and discovered new flower varieties. The popularity of exotic tulips had increased hugely in those years and so did their prices. Many Dutch then entered the market to take advantage of rising prices: they bought tulip bulbs and resold them for a profit, initiating an unsafe speculation that degenerated into an absurd form of gambling[108]. While the 1630s bubonic plague certainly contributed to the creation of a culture of 'fatalistic risk-taking', one of the major factors behind the 'Tulipmania' is linked to pure biology: bulbs are in the ground for most of the year and, therefore, to make trade possible all year round, sale had to take the form of contracts for future payment, shifting the object of trade from bulbs to forward bulb-purchase contracts. The artificiality of this market is precisely what created- and eventually destroyed- the tulip bubble.

The South Sea bubble later added some new, more sophisticated ingredients to those already present in the Dutch financial crisis: for example the role of government and the international circulation of securities. Let us better illustrate these elements by making reference to the historical episode. The South Sea Bubble occurred in 1720, and its major cause was the overvaluation of the South Sea Company's shares on the London stock market. In exchange for the monopoly to trade to

[106] **Sacerdote,** The causes of financial crises, TED talk, 2010.
[107] **Bilginsoy C.,** A History of Financial Crises; Dreams and follies of expectations, Routledge, 2015.
[108] Goldgar A., Tulipmania; Money, Honor and Knowledge in the Dutch Golden Age, The University of Chicago Press, 2007

South America, the company had purchased a large share of the English debt from the public, through a simple debt-conversion proposal: £100 of national debt were to be exchanged for £100 of the company stock[109]. As people were increasingly willing to exchange the dubious credit of the State for the prospect of large profits from the South Sea Trade, the value of the company's shares rose incredibly and disproportionately to their intrinsic value, since the company was not as profitable as the shareholders believed it to be. This misforecast about the value of the South Sea Company's shares generated a speculative bubble which involved much more than the company that names it and which ruinously collapsed in September 1720.

What this two early crises highlight is the role that **speculative euphoria** plays in creating risky asset bubbles. By looking at these two examples, it could be claimed that the major determinant of financial crises is people's optimism and their ever-increasing desire to make profits out of capital gains opportunities. But the analysis of the major financial crisis in the US may highlight the extreme importance of other factors, such as the crucial role of the Fed and the risks related to a system of easy credit.

Before turning to the determinants of the Global Financial Crisis and its implications, let us briefly examine the causes which drew the US economy from the prosperity of the Roaring Twenties to the misery of the Great Depression. In the decade preceding the Wall Street Crash, the US had experienced a period of unbounded optimism and wealth accumulation, when output, productivity and employment were high and rising and income inequality was sharpening. In this period of high production, high consumption, over-confidence and easy credit, stock market prices grew rapidly. The urban upper-middle class entered the market in large numbers, increasingly channeling savings to stocks- which they optimistically regarded as 'lucrative, long-term investment vehicles'[110]. Speculators, who longed for large capital gains, also bought stocks, financing their purchases through 'margin loans'.

So far, the causes of the 1929 bubble closely resemble those of the early classic financial crises. But let us now explore the ways in which of the Fed turned the bubble into a recession. In early 1928, the daily Down Jones Industrial Average grew by 33 percent over the year and the Fed became apprehensive about this stock market boom. While the technological advances and the profitability of businesses of that time could partially justify high stock prices, the exponential growth of the

[109] **Viscount Erleigh,** The South Sea Bubble, Greenwood Press, 1889
[110] **Hall T. and Ferguson D.**, The Great Depression; An International Disaster of Perverse Economic *Policies*, The University of Michigan Press, 1998

stock market was disproportionate and clearly represented excessive speculation which, as such, had to be stopped. The Federal Reserve thus started a contractionary monetary policy in an effort to stem the stock market in advance. But the policy proved to be a failure and on Oct 29, 1929 the NYSE market crashed tragically.

While the causal relationship between the 1929 crash and the subsequent Great Depression must not be taken for granted, many economists, such as Friedman and Schwartz[111], agree that the restrictive monetary policy initiated by the Fed in response to the Wall Street bubble was the main cause of the initial economic slowdown that eventually turned into the Great Depression. While the money stock of the nation shrank dramatically, the Fed did nothing to assist the banking failures which destroyed one third of the deposit money.

Fed regulatory inaction therefore played a huge role in exacerbating the 1929 financial crisis, and we will see that that was also a contributing cause to the 2007-2008 Global Financial Crisis.

4.2 The Global Financial Crisis

The Global Financial Crisis of 2007-2008 was indeed caused by a variety of coexisting and reinforcing factors that eventually lead the US and the world economy to face the worst financial crisis since the Great Depression. The magnitude of the crisis became fully evident in 2007, however it had started years earlier with a boom in the US subprime housing market. The bursting of the housing bubble, which peaked in 2004-2005, is commonly regarded as the immediate cause of the GFC, although the roots and predictability of the bubble still remain controversial.

Indeed, there exists a huge academic debate with regard to whether the 2005 real-estate bubble- and thus the Global Financial Crisis- could have been foreseen and prevented. On the one hand, as we have seen in the Introduction, most economists underestimated the severity of the problem. On the other hand, numerous warning signals led a minority of economists, such as Robert Shiller and Paul Krugman, to rightly argue that policy makers failed to see the obvious and that the US housing market was experiencing 'the biggest bubble in history' (*The Economist*, 2005). One clear hint was the precipitous rise of housing prices, together with low interest rates and spreading speculation. By 2002, the growth of house prices had already outraced the general level of inflation by 30%. As R. Leeson put it, in 2005: 'The unsustainable increase in house prices could only be explained by the

[111] **Friedman and Schwartz**, *A Monetary History of the United States, 1867-1960*. Princeton: Princeton University Press (for the National Bureau of Economic Research), 1963. xxiv + 860 pp.

existence of a speculative bubble'. According to this school of thought, the GFC is the result of human action and inaction and as such, it was a crisis which could have been prevented and avoided, as there was proof of the bubble happening already in the early 2000s.

The strongest evidence that home prices were not only incredibly high but also over-valued with respect to their intrinsic value, i.e. the strongest evidence of the bubble, was the diverging relationship between house prices and rents: in 2005, while rental income stagnated, house prices increased to dizzying heights, due to factors that encouraged home buyers to borrow more money more easily, such easy and available credit, low interest rates and widespread subprime lending.

The bubble grew, and it seemed a win-win situation for everyone at first. But as the prices rose to increasingly dizzying heights, the bubble burst, with catastrophic implications. The consequences of the collapse of the bubble were far-reaching and prolonged, as it led to the 2008-2009 financial crisis and the Great Recession. The downfall of the financial system took 2 years: from 2006 to 2008. It started with a decline in home prices and subprime-mortgage-originator bankruptcies, caused by failures in the repayment of subprime mortgage loans.

A crisis of liquidity and trust among banks occurred, which spread to the government-sponsored enterprises (GSEs) and which engulfed private investors, hedge fund insurers and big companies, as well as the large investment and commercial banks themselves, such as Lehman Brothers, Bear Stearns and Merrill Lynch. As in a cascade, one bank after another fell, and not only in the US. Indeed, the crisis highlighted the international linkages between financial markets of the US and the EU and the fatal interdependence of financial institutions.
The financial crises affected the whole world, led to a global recession and hit heavily the Eurozone. It is important to notice that in Europe, additional factors and causes which contributed to the financial crisis (especially in the PIIGS countries) are mismanagement and excessive government spending.

From the Behavioural Economics point of view, it is interesting to explore the cognitive biases that led investors to underestimate the risk of a crisis. Indeed, Coval, Jurek, and Stafford[112] show that investors systematically underestimated the likelihood of mortgage defaults when pricing mortgage

[112] **Coval, Joshua, Jakub Jurek, and Erik Stafford**.Symposium: Early Stages of the Credit Crunch: *The Economics of Structured Finance.* Journal of Economic Perspectives 23 (1): 3–25. 2009.

backed securities. Similarly, Foote, Gerardi, and Willen[113] suggest that investors did not even contemplate the magnitude of home price declines that actually occurred . Risks were not only considered unlikely, or at best far-off in the future, but they were also entirely neglected by most. If we want to avoid future crises, we therefore need new insights, possibly from behavioural sciences, to be consistent with sharp underestimates of the odds of a crisis. Understanding behavioural incentives may indeed help us prevent errors of assessment and thus future financial crises.

4.3 The neural mechanisms behind Keynes's animal spirits

Our panoramic view of the history of financial crises has highlighted that both the very early financial crises and the most recent ones shared some important psychological underpinnings: the overconfidence and overoptimism of economic actors, their fear, their *hubris*, During periods of booms and bubbles, euphoria spreads among the general public of savers, giving vent to what Keynes would define as 'the animal spirits'. As Keynes pointed out, these "irrational" factors may often be the real drivers of financial crises. Examples of irrational behaviours include sudden runs on banks, contagion and spill overs among financial markets, credit crunches, and all other aspects related to financial uncertainty.

Can we explain these phenomena through the lenses of neuroscience? How can our knowledge of the brain help us understand financial behaviour in critical situations?

An interesting response comes from a pioneer study of neurofinance published in 2011 by Andrew Lo on the topic of Fear, Greed and Financial Crises[114]. Lo shares the view that emotions play a huge role in influencing economic behaviour and maintains that fear and greed are the common historical determinant of all financial crises. In his view, there exist a clear causal relationship between these feelings and financial boom/bust patterns: "Periods of unchecked greed eventually lead to excessive leverage and unsustainable asset-price levels, and the inevitable collapse results in unbridled fear, which must subside before any recovery is possible". If, as he believes, fear and greed really are the fundamental causes of financial crises, then, studying how these mental states are produced and processed in the brain can surely help us improve our financial models and policies.

[113] **Foote, Christopher L., Kristopher S. Gerardi, and Paul S. Willen**. Why Did So Many People Make So Many Ex Post Bad Decisions? The Causes of the Foreclosure Crisis. Federal Reserve Bank of Boston Public Policy Discussion Paper 12-2. 2012.

[114] Lo AW. 2013. Fear, greed, and financial crises: a cognitive neurosciences perspective. In Handbook on Systemic Risk, ed. JP Fouque, J Langsam. Cambridge, UK: Cambridge Univ. Press.

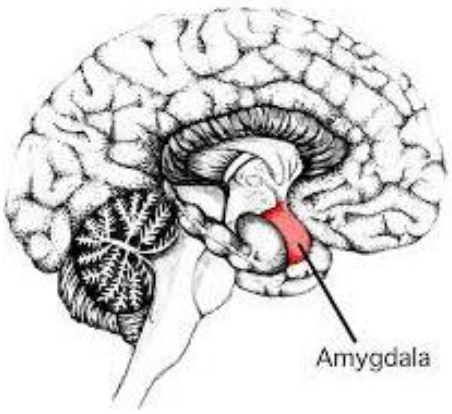
For example, cognitive neurosciences may illustrate the neural components involved in the build-up of speculative bubbles, that is, the neurophysiological mechanisms that stimulate our pleasure and greed. Neuroscientists have indeed shown that inside our brains, we have a neurological reward system that processes all kinds of reward experiences. Interestingly, we use the same reward system regardless of what the reward is, whether money, food, music, or love: "The pathways of this system all transmit the same chemical signal: dopamine"[115].

It thus comes as no surprise that the biological response to the anticipation and experience of monetary gains parallels the biological response to taking cocaine - in either event, our body releases the same neurotransmitter (dopamine) in the nucleus accumbens. The phenomenon was studied in a fMRI research project by Breiter, Kahneman et al., which confirmed that monetary gain and euphoria-inducing drugs such as cocaine produce the activation of the same neural circuitry: the more money we gain (or the more cocaine we take), the more our nucleus accumbens, sublenticular extended amygdala, hypothalamus and ventral tegmental area are activated.[116] The activation of this areas reinforce the behaviours that activated them in the first place and this is what creates addictive component of gambling and drug-taking.

What this means is that "an imbalance in an individual's dopamine system can easily lead to greater risk-taking, and if risk-taking activities are, on average, associated with financial gain, a potentially destructive positive-feedback loop can easily emerge from a period of lucky draws."[117] These neural mechanisms thus clearly explain the origins of our addictive behaviours and fevers. It is easy to see that these findings are greatly relevant to the study of speculative bubbles and financial manias and provide insight into situations in which greed abounds and our reward system craves more and more money.

Another important research concerning the neural underpinnings of speculative bubbles and the pitfalls of human group decision-making was published by Smith et al. in 2014. Through the use of the fMRI technology, they observed subjects' neural activity while they took part in an experiment simulating the workings of an asset market where price bubbles were endogenously generated. The aim of the research was to understand how behaviour and neural inputs interact during financial

[115] Lo AW. 2013. Fear, greed, and financial crises: a cognitive neurosciences perspective. In Handbook on Systemic Risk, ed. JP Fouque, J Langsam. Cambridge, UK: Cambridge Univ. Press. In press
[116] Breiter, Hans C., Aharon, I., Kahneman, D., Dale, A., and Shizgal, P., 2001, "Functional imaging of neural responses to expectancy and experience of monetary gains and losses", Neuron 30, 619–639.
[117] Lo AW. 2013. Fear, greed, and financial crises: a cognitive neurosciences perspective. In Handbook on Systemic Risk, ed. JP Fouque, J Langsam. Cambridge, UK: Cambridge Univ. Press. In press



bubbles. From the results of the study, they found that differences in earnings were correlated with differences in neural activity : **"**Traders who buy more aggressively based on Nucleus accumbens signals earn less. High-earning traders have early warning signals in the anterior insular cortex before prices reach a peak, and sell coincidently with that signal, precipitating the crash."[118] They also observed a correlation between the aggregate nucleus accumbens activity of all participants and the prices of risky assets, so that the peak of the aggregate nucleus accumbent activity coincided with the peak of the prices in the speculative bubble. This suggests that higher nucleus accumbens activity leads to higher risk-seeking and provides an interesting neural account of irrational exuberance.

Neurofinance has also explored the role that our fear circuitry plays in generating trading mistakes such as the financial disaster generated by Nick Leeson (see Introduction). Albeit sophisticated, our fear circuitry is primarily meant to respond to physical threats and when taken out of context, it may produce several forms of 'misbehaving'. Our reaction to the risk of financial loss is the same 'fight or flight' reaction that we have when facing a physical danger: our heart beats faster, our blood pressure increases and the levels of adrenaline and cortisol in our blood rise significantly. But "While high blood pressure, dilated blood vessels in our muscles and a rush of adrenaline may protect us from physical threats, they do little to shield us from financial threats". [119] During critical times, our fear impulses may thus push us to take impulsive actions which greatly depart from what would be rational and profitable.

The neural correlates of fear were first discovered by Kluver and Bucy in an experimental study on monkeys[120]. They found that without the temporal lobes of the lateral cerebral cortex (without the amygdala), monkeys enter a condition of 'psychic blindness' in which they are no longer afraid of humans and snakes and lose their sense of fear altogether. The study thus suggested that the amygdala is the neural locus for fear - a finding which was corroborated by subsequent research by

[118] Smith, A., Lohrenz, T., King, J., Montague, P. R., & Camerer, C. F. (2014). Irrational exuberance and neural crash warning signals during endogenous experimental market bubbles. *Proceedings of the National Academy of Sciences*, *111*(29), 10503-10508.
[119] Lo AW. 2013. Fear, greed, and financial crises: a cognitive neurosciences perspective. In Handbook on Systemic Risk, ed. JP Fouque, J Langsam. Cambridge, UK: Cambridge Univ. Press.
[120] Kluver, H. and Bucy, P., 1937, "Psychic blindness" and other symptoms following bilateral temporal lobotomy in rhesus monkeys", American Journal of Physiology 119, 352–353.

Kapp on fear conditioning in rabbits[121] and by LeDoux on the neural path of fear-conditioned stimuli.[122]

The fact that the amygdala is responsible for mediating the human response to fear has remarkable implications for the study of financial crises. The amygdala is directly linked to the brainstem, the control centre which makes our muscles and body move. This neural shortcut from fear to action can prove providential in situations in which we face physical threats and have limited time to react. But in financial trade, strategic decisions, risk governance and economic investments, fear can easily be detrimental: "If we allow our fear instincts to drive our reaction to financial crises, we may eventually regret the policy responses produced by our amygdalas".[123] That is why we need to create a financial system capable of stemming the role of emotions in human actions and an economic theory that may incorporate the precious insights coming from behavioural and neuro economics.

5. Concluding remarks

The key implication of our paper is, in essence, the necessity to rethink the disciplines of economics and finance. The Global Financial Crisis of 2008-2009 has painfully illustrated the fragility of our world vis-à-vis financial shocks and the psychological factors that create them. 'Animal spirits', ranging from the overconfidence of financial traders to the 'this time is different' syndrome, are the common denominator of all financial booms and busts and it is high time that economics fully acknowledged them. As Akerlof and Shiller write: "We will never really understand important economic events unless we confront the fact that their causes are largely mental in nature"[124].

Like earthquakes and other natural phenomena, financial crises are "a force of nature that cannot be legislated away"[125]. But we should nonetheless try to prevent their arousal and minimise their

[121] Kapp, B. S., Frysinger, R. C., Gallagher, M., and Haselton, J. R., 1979, "Amygdala central nucleus lesions: effects on heart rate conditioning in the rabbit", Physiology and Behavior 23, 1109–17.
[122] LeDoux, J. E., 1996 The emotional brain: The mysterious underpinnings of emotional life. New York: Simon & Schuster.
[123] Lo AW. 2013. Fear, greed, and financial crises: a cognitive neurosciences perspective. In Handbook on Systemic Risk, ed. JP Fouque, J Langsam. Cambridge, UK: Cambridge Univ. Press.
[124] Akerlof, G. A., & Shiller, R. J. (2009). Animal spirits: How human psychology drives the economy, and why it matters for global capitalism. Princeton, NJ: Princeton University Press.
[125] Lo AW. 2013. Fear, greed, and financial crises: a cognitive neurosciences perspective. In Handbook on Systemic Risk, ed. JP Fouque, J Langsam. Cambridge, UK: Cambridge Univ. Press.

consequences and behavioural and neuroeconomics hold promising potential to understand how to do so. Indeed, we have overviewed a significant number of ways in which behavioural economics can correct the descriptive failures of the unbounded rationality model and enrich standard economic theory. We have examined the reasons that make the As If approach unsatisfactory and advocated for a 'mindful' study of economics, which should take into account the emerging neuroscientific contributions. Cognitive neurosciences can indeed propose excellent explanations for the feelings and behaviours which generate uncertainty in financial markets and new fascinating research questions are being raised concerning the neural substrates of our choices.

As we have discussed in Chapter 3, the extent to which neuroeconomics and neurofinance will be catalysts of a revolution in economic thought is still uncertain. It remains to be seen whether neuroeconomics will radically subvert economic models or whether its theories will incrementally be added to the traditional ones. What is sure is that behavioural and neuroeconomics are sensibly challenging the human archetype which we see portrayed in economic textbooks. Therefore, the standard economic model will necessarily need to be reconsidered in light of the new insights coming from psychology and neuroscience, because *"You know, and I know, that we do not live in a world of Econs. We live in a world of Humans."*[126]

Bibliography

Akerlof, G. A., & Shiller, R. J. (2009). "Animal spirits: How human psychology drives the economy, and why it matters for global capitalism." Princeton, NJ: Princeton University Press.

Alchian AA. (1950) "Uncertainty, evolution, and economic theory". J Polit Econ 58:211–221

Benhabib, J., & Bisin, A. (2005). "Modeling internal commitment mechanisms and self-control: A neuroeconomics approach to consumption-saving decisions." Games and Economic Behavior, 52, 460–492.

Bilginsoy C., (2015) "A History of Financial Crises; Dreams and follies of expectations," Routledge,.

Bernheim BD (2008) "Neuroeconomics:A sober (but hopeful) appraisal." National Bureau of Economics Research Working Paper.

[126] Thaler, Richard H. "Misbehaving the Making of Behavioural Economics" (2016). London: Penguin, Print.

Bernheim, B.D. (2009) "On the Potential of Neuroeconomics: A Critical (but Hopeful) Appraisal." American Economic Journal: Microeconomics, 1(2), p.1-41.

Blanchard, Olivier J., (August 2008) "The state of the macro", Working Paper 14259 (http://www.nber.org/papers/w14259), National Bureau Of Economic Research

Bogacz R (2007) "Optimal decision-making theories: linking neurobiology with behaviour." Trends Cogn Sci 11: 118-125.

Bossaerts P., (2009) "What Decision Neuroscience Teaches Us About Financial Decision Making" | Annual Review of Financial Economics.2009.

Breiter, Hans C., Aharon, I., Kahneman, D., Dale, A., and Shizgal, P., (2001), "Functional imaging of neural responses to expectancy and experience of monetary gains and losses", Neuron 30, 619–639.

Brown, Stephen J. and Steenbeek, Onno W., (2000) "Doubling: Nick Leeson's Trading Strategy". NYU Working Paper No. FIN-00-058. Available at SSRN: https://ssrn.com/abstract=1300736

Caldu X, Dreher JC (2007) "Hormonal and genetic influences on processing reward and social information." ANYAS 1118: 43-73

Camerer, Colin and Loewenstein, George and Prelec, Drazen, (2004) "Neuroeconomics: Why Economics Needs Brains." Scandinavian Journal of Economics, Vol. 106, No. 3, pp. 555-579.

Camerer, Colin; Lowenstein, George and Prelec, Drazen. (2005) "Neuroeconomics: How Neuroscience can inform economics" Journal of Economic Literature Vol. XLIII, pp. 9–64.

Camerer, Colin F. (2013) "Goals, Methods, and Progress in Neuroeconomics."*Annual Review of Economics* 5.1 : 425-55.

Camerer, C.F. (2003) "Behavioral Game Theory – Experiments in Strategic Interaction", Princeton University Press

Camerer, Colin, and Richard H. Thaler (1995). "Anomalies - Ultimatums, Dictators and Manners." Journal of Economic Perspectives 9(2), 209-219.

Canessa N. ,Motterlini M., et al., (2009) *Understanding Others' Regret: a fMRI study*, in «PLoS One», 4, 10, p. 7402;

Canessa N. ,Motterlini M., et al., (2011) *Learning from other people's experience: a neuroimaging study of decisional interactive-learning*, in «Neuroimage», 55, pp. 353-362.

Conlisk, John, (1996) "Why Bounded Rationality?" Journal of Economic Literature. Vol. 34 (2). p 669-700.

Clithero, John A., Dharol Tankersley, and Scott A. Huettel. (2008) "Foundations of Neuroeconomics: From Philosophy to Practice." *PLoS Biology* 6.11

Cooper G. 2008, "The origin of Financial Crisis," Harriman House.

Coval, Joshua, Jakub Jurek, and Erik Stafford.(2009). "Symposium: Early Stages of the Credit Crunch: The Economics of Structured Finance." Journal of Economic Perspectives 23 (1): 3–25..

Damasio, A.R. (1994). Descartes' Error: Emotion Reason, and the Human Brain. NY: G. P. Putnam.

Davis, B., (2013) *"What's a Global Recession?"*. The Walstreet Journal.

Dedu Vasile & Turcan Ciprian Sebastian & Turcan Radu. (1970) *"A Behavioral Approach To The Global Financial Crisis."* Annals of Faculty of Economics. University of Oradea, Faculty of Economics.

De Luca G., (2015) *Le crisi finanziarie dalla Tulipanomania alla bolla del 1987: lezioni dalla storia.* Italiano LinguaDue, n. 2.

Drezner, Daniel W. (2017) "The Ideas Industry" New York, NY: Oxford UP.

Egidi, M. (2014) "The Economics of Wishful Thinking and the Adventures of Rationality." *Mind & Society* 13.1: 9-27.

Egidi, M. (2011) "Behavioral finance and cognitive psychology: where do we stand?". Prepared for the seminar "Finanza, comportamenti, regole, istituzioni", Luiss University

Farlow A., (2013) "Crashes and Beyond: causes and consequences of the GFC", Oxford University Press,

Fehr, E. and Fischbacher, U. (2003) "The nature of human altruism". Nature 425, 785–791

Fehr, Ernst, and Colin F. Camerer. (2007) "Social Neuroeconomics: The Neural Circuitry of Social Preferences." *Trends in Cognitive Sciences* 11.10. 419-27.

Fleming, Stephen; C. Thomas; R. Dolan (February 2010). "Overcoming Status Quo Bias in the Human Brain". *Proceedings of the National Academy of Sciences of the United States of America*. **107** (13): 6005–6009. doi:10.1073/pnas.0910380107. PMC 2851882 . PMID 20231462.

Foote, Christopher L., Kristopher S. Gerardi, and Paul S. Willen. (2012) "Why Did So Many People Make So Many Ex Post Bad Decisions? The Causes of the Foreclosure Crisis". Federal Reserve Bank of Boston Public Policy Discus- sion Paper 12-2.

Freeman, W.J. and Watts, J.W. (1942). "Psychosurgery in the Treatment of Mental Disorders and Intractable Pain." Springfield: Thomas.

Friedman and Schwartz, (1963) "A Monetary History of the United States, 1867-1960." Princeton: Princeton University Press (for the National Bureau of Economic Research). xxiv + 860 pp.

Friedman M, Savage LJ (1948) "The utility analysis of choices involving risk." J Polit Econ 56(4):279–304

Fumagalli, Roberto (2011) "Philosophical foundations of neuroeconomics: economics and the revolutionary challenge from neuroscience." PhD thesis, The London School of Economics and Political Science (LSE).

Fumagalli, Roberto. (2015) "Five Theses on Neuroeconomics." *Journal of Economic Methodology* 23.1: 77-96.

Gallagher, BJ. (2009) "Why Don't I Do the Things I Know are Good for Me?", Berkley.

Garber P., (2000) "Famous First Bubbles; The Fundamentals of Early Manias," the MIT Press.

Giddens, Anthony. (1999) "Risk and responsibility". *The modern law review* 62.1 : 1-10.

Gifford, R., Scannell, L., Kormos, C., Smolova, L., Biel, A., Boncu, S., & Uzzell, D. (2009) "Temporal pessimism and spatial optimism in environmental assessments: An 18-nation study". Journal of Environmental Psychology, 29, 1–12.

Gifford R. (2011)**"**The Dragons of Inaction: Psychological Barriers That Limit Climate Change Mitigation and Adaptation." American Psychological Association Vol. 66, No. 4, 290–302.

Gigerenzer, Gerd. (2015) "Risk Savvy: How to Make Good Decisions." London: Penguin. Print.

Glimcher, P.W. and Rustichini, A. (2004). "Neuroeconomics: The Consilience of Brain and Decision. Science", 306(5695): 447–52.

Glimcher, P.W., Dorris, M.C. and Bayer, H.M. (2005). Physiological utility theory and the neuroeconomics of choice. Games and Economic Behavior, 52: 213–256.

Goldgar A., (2007) "Tulipmania; Money, Honor and Knowledge in the Dutch Golden Age," The University of Chicago Press,

Grosse, Robert E. (2010) *"The Global Financial Crisis> A Behavioral View*."SSRN Electronic Journal. Available at SSRN: https://ssrn.com/abstract=1537744

Gul F, Pesendorfer W. (2008). The case for mindless economics. In The Foundations of Positive and Normative Economics: A Handbook, ed. A Caplin, A Shotter, pp. 3–42. New York: Oxford Univ. Press

Hall T. and Ferguson D., (1998) *The Great Depression; An International Disaster of Perverse Economic Policies*, The University of Michigan Press.

Harrison, G. W. (2008). Neuroeconomics: a critical reconsideration. *Economics and Philosophy* 24.

Hausman, D.M., (2008) "The philosophy of economics: an anthology" New York: Cambridge University Press.

Jevons, William S. (1871). The Theory of Political Economy. London : Macmillan and Co.

Kahneman D. and Tversky A., (1979). "Prospect theory: an analysis of decision under risk", in «Econometrica», 47, pp. 263-2

Kahneman, D., Tversky, A., (1986). "Rational Choice and the Framing of Decisions". Journal of Business 59 (4, pt.2), 251-278.

Kahneman, Daniel, Slovic, Paul and Tversky, Amos, (1982), Judgement under Uncertainty: Heuristics and Biases, Cambridge and New York: Cambridge University Press.

Kapp, B. S., Frysinger, R. C., Gallagher, M., and Haselton, J. R., (1979), "Amygdala central nucleus lesions: effects on heart rate conditioning in the rabbit", Physiology and Behavior 23, 1109–17.

Kindleberger P. and Aliber R., (1978) "Manias, Panics and Crashes", Wiley; 5 edition

Kluver, H. and Bucy, P., (1937), "Psychic blindness" and other symptoms following bilateral temporal lobotomy in rhesus monkeys", American Journal of Physiology 119, 352–353.

Krugman P., (2008) "How Did Economists Get It So Wrong?" The New York Times,

Krugman, P., (2009) "The Return of Depression Economics and the Crisis of 2008." W.W. Norton Company Limited.

Kuhn, Thomas S. (1962). "Structure of Scientific Revolutions" (50th anniversary edition) Chicago, IL: University of Chicago Press. Introductory essay by Ian Hacking

Kuhnen, C. M. and Knutson, B., (2005) "The neural basis of financial risk taking". Neuron 47, 763–770.

Krugman P. (2009) "How Did Economists Get It So Wrong?" The New York Times.

Laurent, Éloi. (2016)"Nos mythologies économiques", Les Liens qui libèrent.

LeDoux, J. E., (1996) "The emotional brain: The mysterious underpinnings of emotional life." New York: Simon & Schuster.

Leeson, Nick, (1996) "Rogue Trader". London: Little, Brown and Co. pp.63-64

Levan Efremidze, George Sarraf, Karen Miotto & Paul J. Zak (2017*) The Neural Inhibition of Learning Increases Asset Market Bubbles: Experimental Evidence*, Journal of Behavioral Finance, 18:1, 114-124, DOI: 10.1080/15427560.2016.1238372

Lo, Andrew W., (2013) "Fear, Greed, and Financial Crises: A Cognitive Neurosciences Perspective", (October 2011), printed in "Handbook of Systemic Risk", edited by J.P. Fouque and J. Langsam, Cambridge University Press.

Logothetis, Nikos K. (2017)"The Neural Basis of the Blood-Oxygen-Level-Dependent Functional Magnetic Resonance Imaging Signal." *Philosophical Transactions of the Royal Society B: Biological Sciences* 357.1424 (2002): 1003–1037. *PMC.*

Logothetis NK (2008) "What we can do and what we cannot do with fMRI." Nature 453: 869-878.

MacDonald R., (2014) "Genesis of the Financial Crisis", Palgrave Mamillan,

McClure, S. M., Ericson, K. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2007). "Time
discounting for primary rewards". Journal of Neuroscience, 27, 5796–5804.

Mishkin, Frederic S., and Stanley G. Eakins. (2012) **"***Financial Markets and Institutions*." New York, NY: Pearson.

Mullainathan, Sendhil and Thaler, Richard H., (September 2000) "Behavioral Economics". MIT Dept. of Economics Working Paper No. 00-27. Available at SSRN: https://ssrn.com/abstract=245828 or http://dx.doi.org/10.2139/ssrn.245828

Myerson, Roger B. (1991). "Game Theory: Analysis of Conflict", Harvard University Press, p. 1. Chapter-preview links, pp. vii–xi

Nicolle, A.; Fleming, S. M.; Bach, D. R.; Driver, J.; Dolan, R. J. (2011). "A Regret-Induced Status Quo Bias". *Journal of Neuroscience*. **31** (9): 3320–3327. doi:10.1523/JNEUROSCI.5615-10.2011. PMC 3059787 . PMID 21368043.

Paul H.J., (2011) "The South Sea Bubble, an economic history of its origins and consequences", Routledge

Peacock, Thomas Love, (1831) "Crochet Castle", London: reprinted by Penguin (1969)

Pesendorfer, Faruk Gul & Wolfgang. (2005) *"The Case for Mindless Economics."* Levine's Working Paper Archive. David K. Levine,

Platt ML, Glimcher PW. (1999). Neural correlates of decision variables in parietal cortex. Nature 400:233–38; Rangel A, Hare TA. 2010. Neural computations associated with goal-directed choice. Curr. Opin. Neurobiol. 20:1–9

Pressman, Steven. (1997) "Rogue Trader: I Brought Down Barings Bank and Shook the Financial World." *Southern Economic Journal* V63.N4, Southern Economic Association. Web.

Reinhart & Rogoff, (2008) *This Time is Different: A Panoramic View of Eight Centuries of Financial Crises.* National Bureau of Economic Research Working Paper No. 13882.

Roth, Alvin E. (1995). "Bargaining Experiments." In John Kagel and Alvin E. Roth (eds): Handbook of Experimental Economics. Princeton University Press.

Roubini, Nouriel. (2009) "Warning: More Doom Ahead", Foreign Policy, January/February, 2009

Rubinstein, Ariel; (2008) "Comments on Neuroeconomics" *Economics and Philosophy*, **24** 485–494 Copyright Cambridge University Press doi:10.1017/S0266267108002101

Rustichini, A. (2005). "Neuroeconomics: Present and Future. Games and Economic Behavior", 52: 201-212.

Sacerdote, "*The causes of financial crises"*, TED talk, 2010.

Samuelson, W.; Zeckhauser, R. (1988) "Status quo bias in decision making". *Journal of Risk and Uncertainty*. **1**: 7–59. doi:10.1007/bf00055564.

Sanfey AG, Rilling JK, Aronson JA, Nystrom LE, Cohen JD. (2003). The neural basis of economic decision- making in the ultimatum game. Science 300:1755–58

Schultz W., (2007) *Behavioral dopamine signals*, in «Trends in Neurosciences», 30, 5, pp. 203-210.

Schultz W, Dayan P, Montague PR (1997) A neural substrate of prediction and reward. Science 275: 1593-1599.

Shapira, Z.B., (1997) "Organizational decision making". Cambridge: Cambridge University Press.

Shiller, Robert. (2005) *"Definition of Irrational Exuberance"*. Princeton University Press.

Shiller, RJ, (2003) "From efficient markets theory to behavioral finance". J Econ Perspect 17(1):83–104

Shiratsuka S., (2003) Asset Price Bubble in Japan in the 1980s: Lessons for Financial and Macroeconomic Stability, in IMES Discussion Paper Series, E-15.

Simon HA (1991) "Models of my life". New York, NY, US, Basic Books xxix

Smith, V.L. (2007). "Rationality in Economics: Constructivist and Ecological Forms", New York: Cambridge University Press.

Smith, A., Lohrenz, T., King, J., Montague, P. R., & Camerer, C. F. (2014). "Irrational exuberance and neural crash warning signals during endogenous experimental market bubbles". *Proceedings of the National Academy of Sciences*, *111*(29), 10503-10508.

Stijn Claessens and M. Ayhan Kose,(2013) "Financial Crises: Explanations, Types, and Implications" pp. 5. IMF. 2013

Thaler, Richard H. (1988). "The Ultimatum Game." Journal of Economic Perspectives 2(4), 195-206.

Thaler, Richard and Benartzi, Shlomo. (2004) "Save More Tomorrow□: Using Behavioral Economics to Increase Employee Saving", Journal of Political Economy, vol. 112, no. 1, pt. 2, University of Chicago.

Thaler, Richard H. (2016) *Misbehaving: The Making of Behavioural Economics*. London: Penguin.

Thaler, Richard H., and Cass R. Sunstein. (2009) "Nudge: Improving Decisions about Health, Wealth, and Happiness". London: Penguin, Print.

Titcomb, James. (23 Feb. 2015) "Barings: The Collapse That Erased 232 Years of History." *The Telegraph*. Telegraph Media Group.

Ulrich, Beck. (1992) "Risk Society: Towards a New Modernity". New Delhi: Sage. (Translated from the German Risikogesellschaft, 1986.)

Uzzell, D. L. (2000) "The psycho-spatial dimensions of global environmental problems". Journal of Environmental Psychology, 20, 307–318..

Viscount Erleigh, (1889) "The South Sea Bubble", Greenwood Press.

World Bank Group. (2015) **"**World Development Report 2015: Mind, Society and Behaviour"

Yoshida W, Ishii S (2006) "Resolution of uncertainty in prefrontal cortex". Neuron 50: 781-789.

Zak, P. J. (2002). "Genetics, family structure, and economic growth". J. Evol. Econ. 12, 343–365

Zak, P. J. and Park, K.-W. (2002) "Population genetics and economic growth". J. Bioecon.4, 1–37.

Zak, P.J., Kurzban, R. and Matzner, W.T. (2004) "The neurobiology of trust". Annuals of the New York Academy of Science, 1032, p.224-227.

Zamir, S. (2001). "Rationality and Emotions in Ultimatum Bargaining". *Annales D'Économie Et De Statistique*, (61), 1-31. doi:10.2307/20076266