



01 June 2022

POPULAR DELUSIONS

"The world is at all times the dupe of some bubble or other."

- Col William Rafter

| SPECIAL EDITION – Market Mind Hypothesis

Welcome to a special edition of 'Popular Delusions' by Calderwood Capital in which we share a recent talk given by Dylan Grice. Cognitive scientists, computer scientists, psychologists, philosophers, economists, and investors were asked, by Patrick Schotanus of Herriot Watt University, to explore whether 'the market' is an emergent phenomenon driven by trader activity in the same way 'the mind' is an emergent phenomenon driven by neuronal activity? Could the market, in some physical sense therefore, be a mind? Does it have moods? Is it conscious? How would we know?

Introduced by George Soros, the speaker line-up included Kiril Sokoloff, Gerd Gigerenzer, Emanuel Derman and Duncan Pritchard. Dylan was invited to speak too and closed the session with Oaktree's Howard Marks.

| Calderwood Capital

Calderwood Capital has two businesses. One that allocates to niche fund managers in a wide variety of strategies from US mortgage-backed derivatives, catastrophe bonds, litigation finance to capital structure arbitrage. It's our belief, that such a diversified portfolio earns better risk-adjusted returns than a typical 60-40 bond/equity portfolio.

The other business is research. Twice a month, we publish *Popular Delusions*. This is a publication for high net worth or institutional investors that are looking for deeply researched investment ideas and perspectives. In 2022 we have covered Japanese Regional banks, US Cannabis, SPACS, what Tether might be hiding, the dispersion in US Biotech, Canadian REITS and Nuclear to name but a few.

| About the authors

Dylan Grice: Dylan was one of the highest profile strategists on the Street before leaving in 2013 to help run one of Europe's largest Family Offices. In 2019 he co-founded Calderwood Capital with Rob Crenian, former CEO of Renaissance Technologies.

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You can subscribe to Popular Delusions [here](#) and learn more about us from Dylan on the Meb Faber show [here](#). We hope you enjoy this special piece from Dylan.

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MARKET MIND HYPOTHESIS

| What is the Market Mind Hypothesis?

Cognitive economics studies the underlying brain activity which drives the well-known 'biases' documented by behavioural economics in recent decades. Thus, a behavioural economist might observe that individuals exhibit loss aversion (eg preferring a sure \$80 to a 90% probable \$100) whereas a cognitive economist will try to understand the neuroscience which explains why.

The Market Mind Hypothesis takes this cognitive approach further still. It says that the neural processes which drive cognition also drive something else: consciousness. Famously, consciousness has been called the "hard problem" of science. How does well defined and tangible matter give rise to the mysterious emergence of intangible phenomena like subjective experience, conceptual thought, and self-awareness?

Patrick Schotanus, of Herriot Watt University in Edinburgh has suggested that financial markets present economics' with its own version of this "hard problem." The competitive actions among individuals transacting in financial instruments gives rise to the mysterious emergence of the intangible phenomenon we know as "the market", created by the simple actions of market participants yet fundamentally separate from them, exhibiting a personality, mood and even knowledge which is distinct. This is the Market Mind Hypothesis (MMH).

At a symposium held in Edinburgh earlier this month, Patrick brought together neuroscientists, computer scientists, psychologists, and philosophers from all over the world to discuss the implications of the idea. He also invited some practitioners, and I was flattered to be one of them. The title of the talk Patrick wanted me to give to the gathering was "What if the Market Mind Hypothesis is correct?" and what follows is based on the talk I gave.

One of the underlying motivations for MMH, and the reason it is proving so provocative is that there is a widespread frustration with mainstream economics as it is commonly practiced, both from within the profession, among practitioners, in finance, and across the public at large. Unfortunately, frustration bordering on the exasperation and a generally held perception that "something isn't right" doesn't achieve much on its own. The great strength of modern economics is that it provides a unified analytical framework capable of answering a great variety of questions. It's easy to criticise that framework for being imperfect. It's harder to suggest an alternative which is even more comprehensive (ie capable of answering even more questions within that single framework). I'm going to argue that embracing the MMH presents a wider opportunity to embrace an entirely new single paradigm which is more comprehensive than the current one it should replace.

Before I do though, it's important to address a commonly heard complaint concerning the 'use of mathematical models' when 'everyone knows that economics isn't even a real science'. In my opinion, such criticism is wholly misplaced and of all the sticks to beat economics with, this isn't one. Mathematics is the language of nature. The economy is a natural thing. Therefore, use of the correct mathematics will be essential if we are to unlock the many mysteries of economic behaviour. Until now though, economists haven't used mathematics. They've abused mathematics. As we will see, the judicious application of mathematical techniques by neuroscientists and biologists to phenomenon previously thought beyond the scope of scientific enquiry, such as 'consciousness', or notions of 'trust', have yielded deep analytical insight into the underlying structure of those phenomenon. In other words, the problem isn't that economics isn't a science, it's that economists aren't good scientists. MMH offers an opportunity to rectify that.

| The role of metaphor in science and knowledge

Patrick asked me to explore the possibility that MMH was correct, but there's quite a fundamental problem to overcome before we can get started: how would we know? If the hypothesis is that the market is a mind, how do we test it? Some neuroscientists are trying to figure out ways of estimating measures of consciousness. Giulio Tononi, for example, has proposed that mathematically speaking, consciousness can be thought of as a system's integrated information, which is the amount of information generated by a system above and beyond the information generated by its parts. Measuring the brain's integrated information (Φ , 'phi') should allow us to measure its consciousness. Christoph Koch, chief scientist at the Allen Institute for brain science explained it in an [interview](#) with Tam Hunt as follows:

"The bigger Φ , the more the system exists for itself, the more it is irreducible, the more it is conscious. A system with zero integrated information, or zero Φ , does not feel like anything. It is not conscious. It does not exist for itself, as it can be fully reduced to its subcomponents."

In principle, and assuming for the time being that Tononi's idea is correct (there are critics), all we'd have to do to test MMH would be to compute the market's Φ to determine the extent to which it was conscious. In practice though, Φ is not computable. It requires calculating all possible connections between all possible partitions. For the simplest living organism, the c-elegans, which has just 302 neurons, that number 10^{497} (the universe only has 10^{80} atoms). People are trying to make short-cut estimates, but as things stand the quantitative estimation of consciousness is likely some distance in the future.

Let's change tack. Let's call the statement that the market *is* a mind the strong form of MMH. Let's call the statement that the market *is like* a mind the weak form of the MMH. And let's note that in its weak form, MMH isn't a hypothesis at all, it's a metaphor.

Downgrading from hypothesis to metaphor doesn't downplay the importance of the idea. On the contrary, metaphor is essential to the way we understand and communicate concepts, as you'll see if you try to explain something to a child.

"Have you ever eaten a mango?"

"What's a mango?"

"Is it a fruit."

"Is it like an apple?"

"Not really, it's bigger and softer"

"Is it like a banana?"

"No, it's more mushy than a banana, and wetter"

"Is it like a plum?"

And so on.

We don't just try to explain things to kids using analogy. We use them with each other. We might try to explain how a city feels ("Vienna is like a gothic Rome, the outdoor museum of a different empire"), a football team's form ("Everton are sinking like the Titanic") or some music you just heard ("it sounded like George Clinton and Kraftwerk were stuck in an elevator together").

Scientists use them too: "Maxwell's Demon" is deployed to explain entropy, Schroedinger's cat to explain quantum behaviour. Newton believed the universe was like God's clock, while Rutherford in turn suggested the atom was like a mini-solar system.

Science is arguably the process by which our metaphors for reality improve. So rather than asking if the strong form of the MMH is correct, we can ask if the weak form is a) useful, and b) more useful than the metaphor currently employed in economics (ie that the economy is a machine).

| What is a good metaphor?

A good metaphor doesn't have to be a perfect match (if it was, it wouldn't be a metaphor). For example, the orbit of Pluto exhibits chaotic patterns which demonstrate that the solar system's movements aren't regular like clockwork; the atom isn't a mini-solar system (it doesn't even behave remotely like one). An improved metaphor should correspond better to what we observe, allow us to ask new and deeper questions, and imply new areas of research to help answer those questions.

For example, it was once thought that the heart was like a distillery, purifying the body's blood. The upper chamber contained the impure blood, the lower chamber blood which had been cleansed, and illness was caused by the inability of the heart to properly clean the blood. This led to

the belief that by sucking out unclean blood, by strategically placing leeches on the body, any ailment from fever to flatulence could be cured.

Then William Harvey, physician to King James I in the 17th century came along and said that the heart wasn't really a distillery. It was a pump, circulating blood around the body. The notion of blood being pure or impure as a cause of illness died off, as eventually did the practice of leeching.

The dominant metaphor in economics today is that of a mechanical machine. Most recognizably, this is embodied in the pervasive notion of 'equilibrium', which borrows directly from linear, closed-system physics. For example, if you warm up a beaker of water which has a lid, the water level will initially drop as water evaporates and condenses onto the beaker's cover. Eventually though, the condensation will drip back into the water. When the rate of evaporation equals the rate of condensation, the water level will find a new level and the system will be in a new equilibrium.

The economy is analogized to work in a similar way, with markets in equilibrium at the price where demand and supply are equal. If there is a 'disturbance' in one or the other, prices will change accordingly to restore the system to a new equilibrium. As each market tends towards its equilibrium (savings equal investment, labour demand equals labour supply, government revenue equals government spending, exports equal imports etc) the economy tends towards its 'general equilibrium'.

The economy as a machine isn't a bad metaphor. It allows economists to use the same basic framework within markets and across them. It opens up the possibility of using the algebra of equilibrium analysis to explore and simulate the behaviour of toy economies in different states, and calculus to explore which ones are optimal. Economists could use those models to think about the effects on the economy if one market was exogenously 'shocked' into a disequilibrium (such as a spike in oil prices), or of how changes in government policy might facilitate a return to equilibrium (eg increase government expenditure to compensate for the loss of demand caused by higher energy costs). Importantly, the metaphor allows them to efficiently communicate to themselves and the outside world what they were doing and why.

In finance, the most famous and explicit use of the metaphor can be found in legendary hedge fund investor Ray Dalio, who has cited his understanding of the ["economy as a machine"](#) as being instrumental to the success of him and the firm he helped found, Bridgewater Associates.

| "Big questions" and the limits to the economy-as-a-machine metaphor

It's important to recognize that the metaphor of the economy as a machine has had some important successes, therefore. The problem is that it not only leaves some very fundamental questions unanswered, it is that it doesn't even accommodate their asking. For example, where does prosperity come from? What properties does the distribution of that prosperity have (ie what determines wealth inequality)? Why do we cycle

from boom to bust? What determines the depth of one recession versus another? Is instability a fundamental property of the financial system or can we improve its design? What causes the general price level to rise or fall?

Some non-economist readers in finance who are nevertheless familiar with finance and business may be surprised to see some of those questions listed. Surely, those like the business cycle, inflation, wealth creation and inequality are the 'bread-and-butter' of economics? Well, yes, they are. And yes, lots of economists have lots of opinions of them, each one certain that theirs is correct. But there is no broad consensus on any of them, and more often than not, it seems that they resemble more of a Rorschach test, in which the theory sees his or her preferences in the output (hence the notion of 'left-wing' or 'right-wing' economists). Importantly too, the study of each of these areas typically occurs outside of the general equilibrium framework.

These might be thought of as some of the 'big questions' of economics. Here are some little ones I've stumbled across during my career in finance, which I would like to see studied but which cannot be studied using the tools implied by today's mechanistic paradigm.

| Little question 1: alpha decay as an evolutionary dance

Our primary focus at Calderwood is to build an 'all-weather' portfolio which performs in a roughly predictable way no matter what the overall macro environment. One of the reasons that is so difficult is because the performance of any particular asset class depends on the environment it is exposed to. Compounding the difficulty, when you get inside any particular asset class and look for different strategies to invest in it, you find that the successful strategy is a function of what everyone else investing in that asset class is doing. Thus, *any* strategy can be successful in the right environment (for an extreme example, witness Cathie Wood's performance over a few years, which seemed to be about purchasing the worst run, poorly managed, unprofitable stocks but which had a zeitgeist-leading narrative).

The problem is that when a strategy becomes successful it becomes widely mimicked, and when it becomes widely mimicked it changes the environment, and when it changes the environment, it changes the strategy. Managers lose their edge not because they've changed but because the market has. Thus, there is no "equilibrium" here. Just a never-ending evolutionary dance between the dominant strategy and the environment in which each seems to 'learn' from the other. How does the "economy as machine" metaphor capture this?

| Little question 2: price as information

Most attempts to outperform the market are likely to fail, and even successful attempts are likely to be transient. The reason is that the market seems to price the odds of uncertain outcomes better than any of

its individual participant, creating the feeling that it generally 'knows' more than we do.

The reason for this is that prices aggregate information. But how does it come about? Is one price better than another? Under what circumstances is it true that the 'price is right'? Can we think about ways to measure the information content of any particular price? Can we compare that information content? Does it make sense to talk about some prices being objectively 'better' (in terms of information content) than others? What is the role of those prices in the 'learning' behaviour outlined above? Do better prices lead to better learning, or to a more 'intelligent' system? How does the mechanical equilibrium model penetrate these questions?

| Little question 3: the mood of the market

Anyone experienced at investing in markets will be familiar with the sensation of being 'a part' of the market and somehow emotionally plugged into its movements (relaxed when it's slow, alert when it's fast, apprehensive when it's very volatile). The effect of the market on me is not dissimilar to being in the presence of someone who's in a good or bad mood. It rubs off on you and you physically feel it, without having to say anything, your feeling is proportionate to theirs. Thus, when Lehman Brothers went bankrupt, it didn't feel like a car engine breakdown, it felt like a mental breakdown. And everyone in the market felt it.

This is an interesting phenomenon and gets to the heart of Patrick's MMH. If the market has a mind, it has a mood too. How is that mood created? What effect does that mood have on its participants? Can those participants in turn amplify the mood?

Closed, linear equilibrium systems don't exhibit 'learning' behaviour between different parts of the system. Nor do they somehow seem to take on a life and mood of their own. Yet these are phenomena we know to exist. Again, there is no way to explore them using the current mechanistic framework.

| The right metaphor implies the right tools

Economic activity is social activity and consists of living things exchanging information with one another. It shouldn't be controversial to argue that tools developed to study living things (eg from biology) are likely to provide more insight than tools developed to study non-living things (eg closed-equilibrium systems). The metaphorical framework I believe economists should be using is that of an organism. More precisely, economists should learn to use the analytical tools of biology, more than physics. To see how successful tools have been, consider the following two examples.

The first concerns the nature of 'trust' and related concepts like 'good', 'bad', 'moral' and 'immoral'. While the phenomenon was once thought to be more the subject of religion than science, we now know differently thanks to the work of mathematical biologists like Harvard's Martin Novak, whose work has [helped](#) us answer questions like why people trust each

other, what the evolutionary origins of trust are, and how the willingness to trust waxes and wanes over time.

In a world in which trust in institutions, between nations, and within nations seems to be breaking down, I'd argue that trust would be a good thing to understand, particularly given the importance of its financial market manifestation: interest rates. Can we design systems compatible with greater trust? Maybe, but first we need to understand it. More important for the moment is that a sensible use of mathematics is at least allowing us to explore the question.

Of course, the mind is no ordinary biological organism. It's *the* biological organism, embodying not only the dynamics discussed above - competition, adaptation, emergent-order and evolution through time - but the less tractable 'hard problem' of consciousness. This "ghost in the machine" was also once thought to be beyond the enquiry of science belonging more in the cosmic realm, but as we've already seen, the race is now on in the scientific community to figure out ways to measure it. This isn't just interesting, its important, as there are clear clinical use cases for being able to objectively measure a patient's consciousness.

Such work doesn't answer the problem of what consciousness *is* though. Here, Nobel Prize winner Gerald Edelman's theory of "Neural Darwinism" is important. Fascinatingly, and relevant to the discussion above, it uses a model of *competitive* neural selection to explain how the brain develops its functions, suggesting that cognition, memory, and ultimately consciousness itself are caused by a complex-adaptive process at the neural substrate.

Edelman's theory has its critics and may ultimately be not quite right. What the example demonstrates though, is the potential for the right tools to yield the secrets of phenomena once thought to be "not science". Needless to say, such a framework lends itself to us asking some of the far richer and relevant economic questions we've already posed, like does the market have a mind?

| Questions a biological metaphor allows us to explore

I've argued that a better metaphor is one which can accommodate a richer range of questions. I've also shown that use of the right tools has answered or is in the process of answering questions previously thought out of reach. Here I want to offer some speculations about how the use of the right metaphor and the right tools might answer some of the economic questions currently out of reach. Importantly, I believe these questions can be answered using the same broad organic and informational framework.

Let's start with some of the "big questions" I outlined earlier.

The first is in the notion of prosperity. Former IBM researcher Rolf Landauer linked information to thermodynamic entropy, showing that the permanent deletion of one bit led to the dissipation of heat energy. Landauer thus demonstrated that "information is physical". In his 2007

book, "[The Origins of Wealth](#)" Mark Beinhocker exploited the equivalence: wealth *is* information.

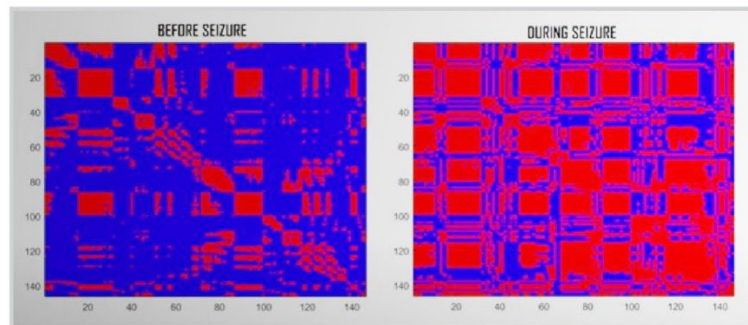
The landing page on the [Society for Neuroscience](#) says that the fundamental questions neuroscience seeks to answer is "how neural systems evolve, integrate, encode and compute information". In what way is this different to what an economy does? If the neuronal structure of the brain in turn effects and is affected by this computation, isn't the same thing true of an economy?

The second is the distribution of that prosperity/information. In brain science, it had always been assumed that neuronal activity and connectivity exhibited properties which could be accurately represented as following a normal distribution. Today though, it is becoming clear that the majority of interactions are [characterized](#) by strongly skewed distributions with heavy tails. This will be familiar to those involved in markets (where price change distributions are fat-tailed) and economies (where wealth distributions follow power laws). Is there a connection here? Or is there something more fundamental about the way in which information is distributed in nature?

The third relates to the information content of prices. Practitioners have long known that prices contain information, and by extension, that markets seem to embed 'knowledge'. Academics should delve further. In what way does this encoding take place? Can we measure the information content of a price, in bits? Is there a measure of how good a price is in terms of its information richness? How do good prices affect the computation referenced above? Are prices signals, information channels, both? What actions weaken price quality; what effect do those actions have on the effectiveness of economic computation? Can the prosperity of a nation be thought of as a maximum entropy problem? What does the imposition of certain constraints imply?

The fourth relates to the boom-bust cycle. Can financial system stability be thought of as network health, economic recession a type of network failure? The following chart (Chart 1) comes from Ramon Guevara Erra of the University of Padua, who has done fascinating work suggesting that consciousness can be modelled as the brain being in a high information entropy state. It shows the cross-correlations between measured brainwave activity at 150 brain sights in a normal conscious brain (left side) compared to one during seizure (right side). Prior to seizure, the subject's brainwaves are firing heterogeneously at their own speeds. During seizure, that heterogeneity disappears. They become correlated. Is this just a spooky coincidental resemblance to the cross-asset correlations one witnesses in financial markets, which are generally low and idiosyncratic, but which rise to unity during panics? Or is there a similar underlying mathematical structure? I suspect the latter.

Cross correlations between measured brain wave activity at 150 brain sights in a normal conscious brain (left side) compared to one during seizure (right side)



Source: Ramon Guevara Erra of the University of Padua

A fifth relates to the possibility of economic plasticity. We know that brain cell connections deepen and atrophy as more or less of a certain activity is performed. We also know they reconnect entirely after suffering injury. We've imposed aggressive sanctions on a number of countries recently – Russia, Venezuela, Iran - without any apparent success, in terms of them yielding to our demands. Frustratingly, for those who've designed the sanctions, those economies seem to have adapted and found other avenues of survival. Are economies plastic in the same way brains are?

Finally, and as already suggested, the mind is not any old biological organism. It is arguably *the* biological organism. When we participate in a market by buying or selling securities, we're a part of that market's creation. But the process creates a structure of prices which none of us fully understand. We can't reconstruct the information content of the price we've all played a part in creating. We feel vulnerable to that price too, because we know that a sharp movement in it might hurt us. What is this thing we've created? How does it behave? Is it mind? Does it have some kind of consciousness? The financial 'mind-body' problem is arguably the most fascinating of all and I would argue the only similarity anywhere in nature is with that of consciousness itself. The tools of mind sciences will surely yield more fruit than those for studying equilibrium water levels in a closed beaker of warmed water.

| Is the universe a mind?

If I haven't convinced you that the mechanical metaphor belongs in the bin, let me leave with one last Hail Mary. It is that machines are found nowhere in nature. They are entirely man made. Why should the universe, let alone the economy, be anything like a machine?

Quantum information pioneer John Wheeler, who coined the term "black hole", supervised Richard Feynman's PhD while at Princeton, and was an integral part of the Manhattan Project. He wondered if the universe wasn't just an organism, but a mind, and one in which we weren't merely observing passengers but active participants: "*Are life and mind irrelevant*

to the structure of the universe, or central to it?" Carl Sagan has famously asked if consciousness is functionally a "way for the universe to know itself."

If it's legitimate for esteemed physicists to wonder if their subject matter is in fact, one giant mind, it's surely legitimate for mere economists.

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