IEDA Preprints, 16 July 2021
https://www.ieda.info/article1822vd
Author version

Out of our minds: The new boundaries of Rationality

Authors: Matthew Harris Dennis Venter

Abstract

Decades have passed since Behavioral Economics used cognitive psychology to address the shortcomings of perfect rationality. However, it is concerning that in this time the shortcomings of cognitivism have had seemingly little discussion among economists and debates between psychological schools have not carried over much. Meanwhile, the early contributions of sociology to the theory of rationality have all but been forgotten. The aim of this paper is to provide economics with a more complete view of rationality, one where we are bounded by a mind, which is in turn bounded by the rationality afforded to it by the environment in its present form. Utilizing these alternative approaches, we no longer merely ask how rational agents are but instead ask how much rationality the environment affords. We propose that rationality is developed in the environment as a response to increasing complexities and challenges. We explore a brief history of various measurement devices and the dynamic process whereby our capacity for rationalisation develops as well as the implications for economic growth.

Keywords: Rationality, behaviour, cognitivism, interdisciplinary economics, complexity.

1. Introduction

Neoclassical Economics has been criticized for being ahistorical[1], static, and far too abstract. Since the 2008 crisis, it has had no shortage of critics (and surprisingly, no shortage of power over the field either), also spawning an “Anti-Textbook” (Hill & Myatt 2010). Heterodox economists have frequently criticized neoclassical theory for its unrealistic assumptions. This criticism has largely been dismissed since Milton Friedman wrote his 1953 *Essays in Positive Economics*. Since all assumptions are inherently unrealistic, the point, according to Friedman, is to generate a predictive model. Orthodox and heterodox economists have largely talked passed each other, accusing one another of misunderstanding.

Let's review Friedman’s essay in brief. If you surveyed expert billiard players they likely wouldn’t be able to answer any advanced physics formulas that go into predicting the trajectory of the ball, but the players still make accurate shots. In this way, Friedman argues that we shouldn’t test a model by the accuracy of its assumptions but the accuracy of its predictions. If we assume

[1] Not just ahistorical though, sometimes just plain historically incorrect especially when it comes to the important things like money, see David Graeber’s 2011 book entitled Debt: The first 5,000 years.

players know the physics then they should be able to make the shots. This example is a classic in economics and wrong in two ways. The first is that it rightfully admits it is wrong to compare sports professionals to computers, but the second is that the conclusion is circle logic and there is evidence to contradict it (Blackford 2016). A mentally adept physicist is not going to become a sports professional overnight because the rest of his body doesn't know how to perform the movements. Additionally, instead of predicting the outcome of who will win a tournament based on some technique, Neoclassicals find the winner and assume it is because of some idealized version of the winner's technique. If there are many different techniques then any given ideal model can justify a given practical outcome. Even marginal productivity theory of income distribution and revealed preference theory both do this as post hoc explanations for why CEOs get paid hundreds of times more than the average employee or why one product is chosen over another. Find your winner, and then fabricate some idealized explanation for why they won and will likely continue to win.

Friedman invokes physics again when he analyses the law of falling bodies. Vacuum is not a common or "realistic" condition and yet it still helps make accurate predictions even in non-vacuum conditions. It is certainly better than no model at all for physics, but should we compare this to the workings of social science though? Psychology spent many decades analysing people in what can be described as a cultural vacuum. Most of its test subjects were from the same small demographic and the universality of its claims were called into question (Henrich, et al 2010). While we can certainly describe the behavior of a body in a vacuum, is it possible to have a person in a social vacuum?[2] Is this a meaningful exercise at all? If economics is not concerned with human beings at all and merely wants to model an economy where robots barter things then perhaps, but I don't think that is what we are paying them for. A study of humans without history or culture might be about as meaningful as a study of physics without time and space.

In Edwin Mansfield's *Applied Economics* he writes "it is important to add another point that is frequently misunderstood: If one is interested in predicting the outcome of a particular event, one will be forced to use the model that predicts best, even if the model does not predict very well. The choice is not between a model and no model; it is between one type of model and another." This is fine and agreeable among natural science, but in social science prediction frequently means control over people. If you provide such a large incentive such that the agent only has the options to comply or die, then you have a fairly predictive model at the cost of human freedom and generosity. As we shall see later, history has examples where predicting people's behavior requires immense control over their lives. If a model is used to generate such instances, then perhaps it is the model and not the critics that must be dismissed.[3]

---

[2] This has been an issue since the foundations of Liberalism and social contract theory. Hobbes wrote "Let us return again to the state of nature, and consider men as if but even now sprung out of the earth, and suddenly, like mushrooms, come to full maturity without all kind of engagement to each other...where every man is Enemy to every man" Instead of seeing human nature is to be a social animal, the asocial man supposedly demonstrates that we are naturally selfish and violent.

[3] For more examples of this you can read Naomi Klein's "The Shock Doctrine" where Friedman's own Chicago Boys are also shown to be culpable in the deaths of thousands under Pinochet's leadership.

At times, the Nobel Prize has been less dismissive of critics, having given a prize to psychologist Daniel Kahneman for his theory of bounded rationality and contributions to Behavioral Economics. We certainly see this as a great step in the right direction and do not want to downplay this progress. However, while Behavioral Economics explores and adjusts the assumption of economics, it takes with it some debatable assumptions from cognitive psychology that haven't been discussed as much by economists. Alternatives to cognitivism in psychology, such as Gibson's ecological approach (Gibson 1979) , have had almost no mention in economics at all. Given that there is some debate about cognitivism in the very diverse field of psychology, it behooves us to bring that perspective into economics as well.

Cognitivism and Economics both tend to focus on the individual and describe agents as calculating computers. The main difference between the two is that economics describes optimal calculated decisions and cognitivism frequently demonstrates how people consistently make poor decisions, usually due to some form of "cognitive bias". This is "bounded rationality", we are rational and can make calculated acts but with certain limitations because the brain is just a computer made of meat and electricity.

Perhaps the brain isn't a bad computer though, maybe computers are a bad metaphor for the brain instead. If such is the case, the hundreds of "biases" supposedly found in Behavioral Economics may require re-examination as each one serves as a growing disproof of the underlying assumption of the computational brain instead of mounting developments in a new field (Collins 2016). While the benefits of the Cognitive Revolution have been immense, it is worth exploring other approaches that note it's limitations. Some have even come to say that behaviorist psychology, cognitivism, and affectivism compliment each other and build on one another instead of contradict. (Dukes et al. 2021)

Lets review Gibson's Theory of Affordances with a simple example: a chair. This object is probably no more than a meter high and half a meter wide. To a person it affords sitting. To an elephant, it is a strangely shaped object. To a mouse, it is a monumental tower or a plastic landscape. A chair is something to sit in, not because of your brain, but because of what your brain is in: a body. The job of the brain is not to classify, represent and compute the world (copy and pasting the entire world would require a far better organ), but to link the body and environment through perception and action. This is the ecological/embodied approach to perception in psychology. An animal perceives or senses what it can use and "affordances" are what the environment offers the animal.

If we were to take Friedman's sports example and compare different strategies, then the data unambiguously support the ecological strategies over the computational one. Outfielders in baseball never run to a predicted landing location (like how a physicist might program a robot), outfielders run at varied speeds and with curved paths (Wilson 2017).

Economist and cognitive scientist Herbert Simon explains that complex behavior may not be the result of a complex mechanism, but simple responses to a complex environment instead.

Watching an ant navigate various paths may tempt us to describe the ant as following complex internal rules, but it just reflects the complexity of the environment (Simon 1969). An ant is no physicist either. Forcing complexity into the head places huge burdens on the cognitive process and it's simpler to assume the complexity lies out in the environment. Humans frequently alter their environment to make it more livable and simpler. While most have thought of rationality as a complex internal process, we would like to emphasize that much of it is outside the agent.

The only other author we are aware of that has combined the work of Gibson with economics is German psychologist Gerd Gigerenzer who has coined the term "ecological rationality" and critiques the common Behavioral Economic preoccupation with cognitive biases (Todd & Gigerenzer 2012). He notes that the common approach to rationality is to have consistent, fixed rules which can work under conditions of risk, but ignoring information and using a rule-of-thumb works better under conditions of uncertainty. More importantly, "ecological rationality" is contextual and based on adapting to a changing environment rather than logical precision and consistency, though those can certainly also aid people.

While we are aware of Gigerenzer's work and applaud his contribution, we would like to go in a slightly different semantic direction. Perhaps due to our background in economics, we have a different interpretation of what rationality is. There is another field of social science that has an "environmental" way of looking at rationality which is the sociology of Max Weber. Instead of focusing on the individual's adaptive choices and the measurable benefits of those strategies, we can look at the calculation an environment affords us. This places the burden out of the brain and onto the environment. Utilizing sociology and ecological psychology, we no longer ask how rational agents are but instead ask how rational the environment is.

Frequently left out of the debate on rationality is the field of sociology. Sociology has criticized the economic assumption of human self-interest since inception (Marx and Engels), and this is one way to alter economic rationality but not the purpose here. Instead, we should take a look at Max Weber (1987), one of the founders of sociology who was concerned with modernity and the large social changes that happened around the time of the industrial revolution.

Weber argued that what separated modernity from the past was its high degree of "rationalization" which incrementally replaced traditional and emotional motives. The feudal system whereby offices were gained through lineage or favor was dismantled and replaced with a bureaucracy that was meritocratic, objective, and impersonal (at least in outward appearance). Methods of precise calculation and organization come to increasingly dominate the social world as factories adopt "scientific management" and various measurement devices. The factory worker doesn't wake, start work, or go home whenever they feel like it. They have to follow what their employer's schedule and clock has organized.

The study of rationalization is still very relevant even today with newer sociologists such as Jürgen Habermas and George Ritzer both building on Weberian sociology and being quite well known. Habermas (2018) contrasts Weber's bureaucratic, impersonal "instrumental rationality"

with the much more democratic and inter-personal “communicative reason”. Ritzer (1993) identifies four main aspects of rationalization: efficiency, calculability, predictability and control.

Scholars of Weber may note that a two paragraph summary is a gross simplification or an uncritical take of his work, and perhaps this is true. All or most of the qualitative aspects of “rationality” have been debated at some time (just compare Gigerenzer to the rest of Behavioral Economics), but calculability appears to be the least debated feature. Calculation also has the most in common with economics as a quantitative science and will be our main focus for this paper. Our purpose isn’t merely self-serving though, many of the debates around the term come from conglomerating too much under its umbrella. Simplifying rationality to the capacity for calculation makes it quantitative and separates it from the many qualitative debates as well as equivocations with other common synonyms like reason or logic. Without getting too much into the history of the word “rationality”, we would like our readers to grant us this distinction.

We propose that rationality, as in our capacity for calculation, is both “bounded” and developed. It is not something we are merely born with or even fully internal since much of human rationality comes from access to tools entirely outside the brain. Rationality is bounded not just by biases, but also by how “rationalized” our context is, which refers to the amount of calculation our environment affords us.

In a chapter on bounded rationality Herbert Simon (1990) writes “Human rational behavior (and the rational behavior of all physical symbol systems) is shaped by a scissors whose two blades are the structure of task environments and the computational capabilities of the actor.” The important part to note is that a frequent common thread between economics, sociology and psychology is the capacity for calculation. This is an agreed upon feature of rationality that is cross-disciplinary, but to make it a truly interdisciplinary definition then we must be able to move beyond the brain and look at the environment as well.

2. Beyond the brain

As Cantilon (2012) shows, animals[4] can learn to count when instructed, but why don’t they naturally? Pigeons can count and monkeys can even learn to use Arabic numerals. While they have a sense of numbers there are no known cases of animals performing arithmetic in the wild. Why and how did we humans develop these abilities? What is the difference? Are animals subject to some form of “cognitive bias”?

First it is worth noting that evolution does not work to produce rational behavior, merely behavior that survives in a particular environment. When large flaws do appear, it’s likely due to being outside of that niche or that niche disappearing, for example a deer in headlights or a mouse going for the cheese in a trap. Our ability to do math isn’t due to some teleological end where evolution strives to make the perfect utility maximizer where deviations from this ideal form are

[4] In fact, many experiments have supported that primates’ capacity for numbers is comparable to human children.

“biases”. As fragile bipedal beings, intelligence is a tool we use to survive and make claws or fur where we have none.

Various animals from insects to fish and human toddlers are shown to be able to recognize quantities up to four and have an “approximate number system” for numbers larger than 4 and the “approximate number system” can identify differences between two large quantities if the ratios are large enough. An example would be distinguishing 10 objects from 40 objects, but not 40 from 41 similar to how you identify how loud something is by the rest of the surrounding sounds or you can only tell if one thing is brighter than another if it is significantly brighter.[5]

The simplest method of information processing relies on an innate *ability for discriminating quantities*, it allows us to immediately identify the quantity of a few objects without counting them (Nunez 2017). In a basic environment this method leads to the best outcome. However, as output and trade increased, individuals had to find new methods to rationalize.

Primates like ourselves are skilled with ordinality. We can recognize sequential symbols and quantities, we can recognize the specific order of numbers in a set and this is different from determining if a value is greater or less than another because ordinal values only increase one by one. So when discussing our ability to count we are primarily interested in ordinality. When did this begin for us?

Perhaps shocking to many readers is that hundreds of languages that exist even today have an upper limit of three or four. Any amount above that and speakers will use a quantifier like “some” or “a lot” to communicate. There is nothing intellectually lacking about these communities either, it is simply that their hunter-gatherer environment has less need for large ordinal numbers in order to survive. Karenleigh Overman (2013) surveyed contemporary hunter-gatherers and found that those with larger number systems commonly use numbers systems with 5, base 10 or base 20. This suggests that our first counting tool is our fingers.

While finger-counting may be unsurprising, Overmann discovers something else which may be very interesting to the economist. Her research found that those with an upper counting limit of four generally had few material possessions (tools, weapons, jewelry) whereas those with a much higher limit than four always had many more possessions. The evidence suggested that developments beyond finger counting were due to a society’s need for numbers in order to count objects, and later resources and people. Having a large amount of possessions poses an issue that requires new mathematical tools. Once those exist, we can move beyond our hands as record-keeping devices and this sets the groundwork for the rest of economic development. With the emergence of cities, tokens were used to represent different quantities. Combining different tokens together made complex numbers and allowed counting up to thousands. As our environment becomes more complex we develop new ways to rationalise where our previous ones were rendered less effective.

[5] This is also known as Weber’s Law, unrelated to the sociologist Max Weber.

The earliest artifact used for counting found so far is the 20,000 year old Ishango bone. Claudia Zaslavsky (1992) interprets the 29 markings on the bone to be the first recorded instance of a menstrual calendar and perhaps a tool one woman used to aid in family planning and birth control. Such a tool provides women with control over their bodies as well as population size within the tribe.

Here we see two instances where the body is very important to understanding the mind. This is called embodied cognition, part of the extended mind hypothesis (Malafouris 2013), which ecological cognition is also part of. The importance of the body is understated in economic accounts of subjectivity. Homo-economicus doesn't know what hunger is, they only experience "disutility" and the physiology of the digestive system never enters the picture. The typology of satisfaction doesn't get much deeper than utility and disutility for economics. Whether its consumables, sleep or sex, its all treated under the same umberella. Maslow's hierarchy is one of many instances in psychology that attempts to understand motivation with a more in-depth approach.

Precise units of time are also taken for granted by economists who use them in formulas every day. For most of history though, work and time were both "task-oriented" (Tompson 1967). Plantation slaves worked to the rhythm of song, Seafarers sailed when the winds allowed, Mediterranean farmers break when the sun is high and hot, and time can be measured by "a rice-cooking" (roughly 30 minutes) in Madagascar. Clear work-life boundaries are not present and work happens whenever necessary. Domestic chores and daily habits dictate the units of time rather than the reverse. Anthropologist Evans-Pritchard (1940) is worth quoting at length on the topic:

"The Nuer have no expression equivalent to "time" in our language, and they cannot, therefore, as we can, speak of time as though it were something actual, which passes, can be wasted, can be saved, and so forth. I do not think that they ever experience the same feeling of fighting against time or of having to co-ordinate activities with an abstract passage of time because their points of reference are mainly the activities themselves, which are generally of a leisurely character. Events follow a logical order, but they are not controlled by an abstract system, there being no autonomous points of reference to which activities have to conform with precision. Nuer are fortunate."

The development is slow, but important. Lewis Mumford (1934) claimed in *Technics and Civilization* that the clock "is a piece of power-machinery whose 'product' is seconds and minutes" and marks the beginning of the industrial revolution. The earliest mechanical clocks come from 13th century Italian monks. The church bell was how labor was organized throughout the town. For many if not most though, the routine of daily chores on the farm was unaffected by the sundials, hour-glasses, candles, and clanging of clergymen. When the rooster crows, it's time to get to work.

The workday had frequent pauses in between periods of intense work. Even today we see these patterns among the self-employed: writers, artists, entrepreneurs. Most students also do this

and tend to think of themselves as disorganized compared to the industrial 9-5. Parents will know that care for newborns doesn't follow any precise schedule either and you take breaks whenever you can get them.

The need for clocks and other time-keeping devices at work largely depends on the need to synchronize multiple workers. A factory assembly line needs all its workers to start and stop at roughly the same time as the unfinished product passes from one worker to another until completion. However, production confined to the household requires very little synchronization as it is usually completed through individual tasks.

Early into the industrial revolution, workers responded more to the presence of the supervising factory warden than the clock itself. "Time discipline" took generations to adapt to. In 1770, William Tell pushed for children as young as four to be sent to work as well as given two hours of school per day. Once within the school gates, the child entered the new universe of disciplined time. E. P. Thompson notes how incremental these changes were in the following paragraph:

"The first generation of factory workers were taught by their masters the importance of time; the second generation formed their short-time committees in the ten-hour movement; the third generation struck for overtime or time-and-a-half. They had accepted the categories of their employers and learned to fight back within them. They had learned their lesson, that time is money, only too well."

The need to synchronize labor was such that by World War 1 wristwatches became standard issue in the military. Moving too early or too late could cause certain death to friendly infantry during an artillery bombardment so the first industrialized war put a timepiece in the hands of every man in the developed world. Not long after the war, they returned to their employers factories fully attuned to the clock upon their arm.

We can also see from more recent examples that time discipline is hard to impose. Those in warmer regions, like the Mediterranean, are frequently stereotyped as being lazy and lacking the "Protestant work ethic" of the anglo-sphere. Henry Ford tried to establish an American colony in the middle of the Amazon thinking he could just port over American food and working customs onto a blank slate. He called this project Fordlandia. Amazon Natives would work in a newly built factory in the middle of the jungle and get to live the American lifestyle. The tradition of the afternoon "siesta" was not part of the mold and workers frequently disobeyed their supervisors by going on breaks during the hottest section of the day. Time and time again, imposing a new environment and local adaptation takes generations. Some locations may never change as the siesta shows.

In developing regions it is best to pay workers based on completed tasks rather than an hourly wage contract. Paying miners for the amount they mine rather than the time significantly improves productivity as they are more familiar with task-orientation. Once again, these people aren't lazy. Changing the framework to something they are more accustomed to makes them

work day and night for their daily bread. They will tend to keep their habitual lack of work-life separation though such that a clear split based on a schedule won't be very effective. Whether you measure distance in metric or imperial units shouldn't matter for measuring the speed of an object, but in this case the kind of measure workers use does matter for efficiency.

Aside from time, another important measurement in economics is money. Textbooks will usually hypothesize that money originated in barter and that it helped smooth trade by providing a common unit which eliminated the so-called 'double coincidence of wants'. If I want oranges but I only have pumpkins and you want meat, then we cannot trade unless I find someone that wants pumpkins for meat first. To solve this issue, the most commonly accepted commodity becomes the currency. Money ends up as a medium of exchange in this scenario and reduces transaction costs.

This story is perfectly compatible with externalized rationality, but we the authors do not feel comfortable repeating convenient falsehoods. The last decade has seen a lot of work done on the subject of money and much interest in its hypothetical origins. Many authors consider the barter hypothesis a "myth" either due to evidence from cultural anthropology (Graeber 2011) or focussing on money as a "means of payment" instead of a "medium of exchange".

As thousands of pages can be written on the history of money, we will attempt to be brief. The 'double coincidence of wants' is fundamentally a non-issue. Not only do small tribes share like a family rather than trade as strangers, but the situation of trading various fruits and vegetables is simply impossible on the spot due to different harvest seasons. Late spring may be the time for oranges while autumn is best for pumpkins, the two farmers would simply never have the time to do an exchange. An easier solution for small groups is simply to share like family and another alternative that solves the timing issue is "debt" or a promise. As nearly everyone can make promises, there is no need for an object or commodity to be a common denominator. There's no double coincidence of wants for people speaking the same language since they can pass around favors. While it is archeologically impossible to find or date the first promise humans ever made, it is certainly older than the use of gold or any other object as money.

There are a few significant things about this difference from the standard text, one is that promises are not limited to trades and exchanges: promises can be given for arranging marriages, or as part of gaining forgiveness from a court. The main difference though is that it means money does not merely mediate a relation between things and people, or a mediate a relation between heterogeneous things, instead it's a measure of human relations. Families share and don't require much for accurate accounts or formal contracts to maintain obligations. Debt signifies less trust than sharing and trade signifies even less trust. Put another way, certain means of distribution afford social stability with less trust and familiarity between agents.

One historical example that highlights this is the invention of coinage over 2500 years ago. Rulers could have chosen any number of commodities to make tokens out of, such as shells or paper so why did they choose gold? Graeber believes that due to the ongoing wars there was a great need to pay mercenaries and turn them into the first professional armies. Mercenaries are

not a particularly trusted lot since one day they may be defending you and the next they could be pillaging your town. And when they pillage, what did they commonly take? Valuables such as gold jewelry that could be pawned in the next city. Gold coins would be an acceptable form of payment to soldiers and give a financial edge in the war effort. Coins also gave soldiers more freedom to make deals within the realm as it was far less suspicious than someone walking in with a pocket full of rings with different family crests on them. Soldiers no longer needed to pawn or smelt gold items before making other purchases unless they were leaving the state that paid them.

The invention of double entry bookkeeping much later helped in preventing errors and fraud. The importance of accounting and accountability was such that it became a popular theme in the art of the Dutch Golden age and in democratic politics which demanded that leaders be “accountable”. 400 years later the effect is still felt on our political landscape though we are far away from measuring our politicians the same way we do our ledgers or credit scores.

What may come as a surprise to many of our readers from the western world is that price tags are around one hundred years old. For most of human history, and perhaps even most market stalls today, haggling is how prices are made. Retail prices did not have a fixed price and customers were expected to negotiate it individually with the clerk who would fetch the item from behind the counter. Quaker Christians had ethical concerns with this price discrimination and invented the price tag to treat everyone equally. Not long after, big stores tested the new device and found that it drastically reduced training time for clerks and improved service speed. The importance to customers can be demonstrated by anyone who has travelled abroad and been ‘over-charged’ for being a tourist.

All of these various instruments are important for economists to do their work but are also taken for granted. Economics often defines itself as the science of scarcity, which prices are supposed to reflect, but as we can see, prices may not reflect a static equilibrium at all and they are often reflective of the personal qualities and relationships of the agents involved. Whether it is a decision to share, borrow, rent or sell, or a negotiation about the price, there is a consideration and measure of trust that is involved that is not highlighted by a “science of scarcity”. We can still speak of what actions a given economy affords agents though. Parts of the field have moved on from scarcity and analysed non-scarce goods, but in doing so it tends to redefine economics as the science of optimal decision making. This raises the issue of whether or not a man stranded on an island is his own economy or whether a band of gorillas in the forest have one and if ecology is a useless term. In future papers, the authors would like to explore the definition of economics further and its connection with money.

3. Developing rationality and economic growth

As can be seen, there were instances where, due to the amount of rationality required, concepts of measurement had to be developed before there could be further increases in production or development.

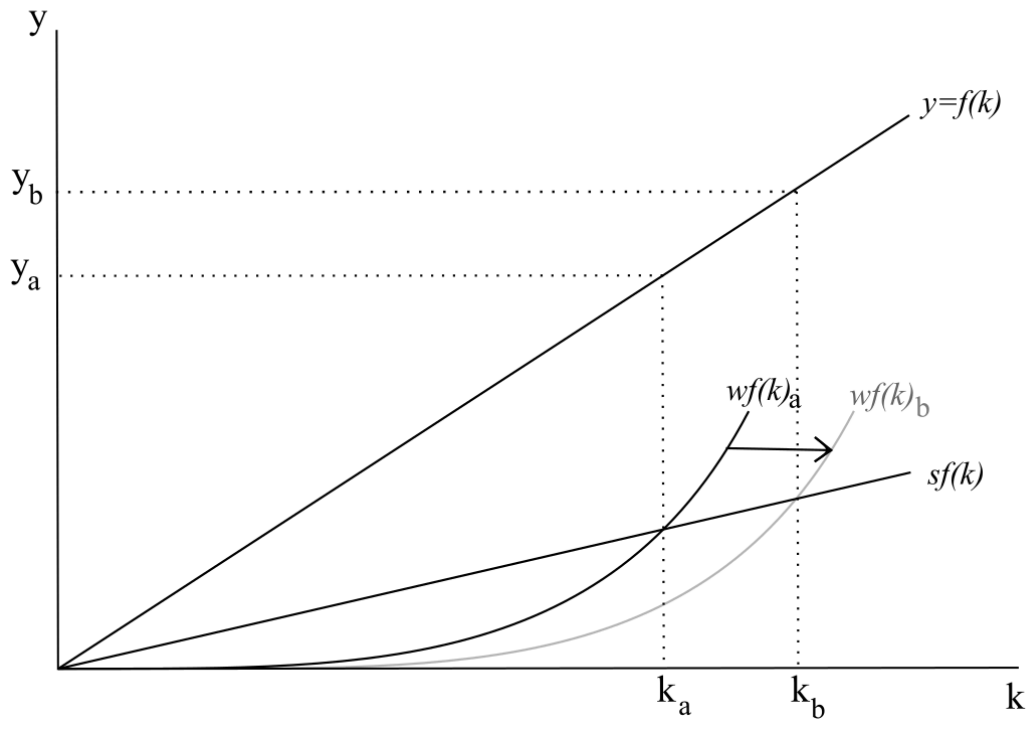
Measurement devices improve production efficiency and have implications for economic growth. To aid in illustrating such implications visually, we will use a simple growth model where k represents the level of effective capital per capita, y represents units of output, and where increases in effective capital comes from investment which is a constant proportion of output saved (sY).

Let ε represent a rate of complexity in the environment which increases as output increases, this reduces the effectiveness of capital while concepts of measurement m adds rationality to the environment.

Since $y=f(k)$ we can represent per capita investment as $sf(y)$ while decreases or weakening in effective capital comes from $wf(y)$ where $w=\varepsilon-m$ so that the following equation describes the change in effective capital:

$$\Delta k = sf(k) - wf(k)$$
$$= sf(k) - (\varepsilon-m)f(k)$$

Figure 1. Developing rationality and economic growth



At the level of effective capital k_a, investment in effective capital will no longer result in increases in production. At this point the time is ripe for the development of new concepts of measurement.

At this point, effects from the complexity in the environment given the current conceptions of measurement offsets effects from investment. In this way concepts of measurement place a limit on expansion.

New concepts of measurement reduce complexity in the environment and result in a downward shift in the w curve as indicated above.

New concepts of measurement affords investment in new types of capital. Effective capital per person would thus grow over a period. Examples of this are the machines that rely on a concept of measuring time or accounting software that rely on money and prices. Output and complexity increases until the new limit of k_b is reached.

4. Rationality as a function of mind and environment

Rationality is our capacity for calculation which is both cognitively and environmentally bounded. We are able to summarise it in the following function:

$$R = f\left[(\alpha \sum_{i=0}^{m} \beta_i)\ (P_{m\text{-}\varepsilon})\right]$$

R represents our growing capacity to rationalize, it is a function of cognition and our environment:

Our environment in its present form is represented with P along with subscript m-ε. Here m represents the measurement devices we have at our disposal while ε represents the complexity of the choice or task environment.

Cognition, as Daniel Khaneman (2011, pp. 19-23) explains, consists of two systems. Here we represent the first system with α, it is the part of our mind that gives simple solutions autonomously, among other things it has the innate capacity for quantity discriminaiton, such as the Approximate Number System mentioned previously. However, for more complex problem solving this first system will call on the second system (represented here with β) which includes intentional processes like arithmetic. Here our past experience and education play a role, and we also acknowledge that concepts of measurement can be internalised so that we think of our day for example as consisting out of 24 hours, thus we subscribe β with i representing internalising experiences from 0 up to the latest concept of measurement represented as m.

5. CONCLUSION

As the 2008 crisis showed both academic and laymen alike, it seems like the neoclassical approach has neither made realistic assumptions or predictions. Indeed, some have argued that

the neoclassical models at times suffer from circle logic that can explain any outcome at all post-hoc while being unable to make meaningful predictions.

When Cognitivism was added to Economics we received a new sub-discipline and a new view on the limits of rationality. If we start with Gibson's psychology instead, we also find limitations to cognitivism as well. These can be resolved by looking "out of our minds" and into the external world, which sociology has already done by creating the study of "rationalization".

Bringing these various perspectives into rationality provides a more complete picture of the concept and it becomes clear that rationality is bounded not just by biases, but also by how 'rationalized' our context is, which refers to the amount of calculation our environment affords us. We also saw how rationality is developed as a response to a need to process an ever increasing amount of quantitative information in our environment. We have briefly illustrated how and when these impact production and have provided a functional, interdisciplinary definition of rationality.

Future research could look at how measurement devices reduce uncertainty in the environment and how quantitative and qualitative information are considered in choice, or better incorporate behavioral theories of bounded rationality with sociological theory. This paper also only discusses the rise of new measurements and does not investigate the issues or costs that arise from changing measurement systems (say imperial to metric), or the potential effects of mixing them in production or exchange. Such case studies could prove useful for highlighting the importance these devices have for our decision making models. The mental confusion that can occur over exchange rates while travelling between many countries would be a similar topic. Indeed, any of the devices mentioned previously in this paper are worthy of more detailed and dedicated modelling. Lastly, further research could explore the history of the theory of "rationality" which was intentionally omitted from this paper, but very much inspired it.

REFERENCES

Barras, C (2021) 'How did Neanderthals and other ancient humans learn to count', *Nature*, 2 June 2021, viewed 2 July, 2021, <https://www.nature.com/articles/d41586-021-01429-6?fbclid=IwAR3V9HD6vrucKE4NUkr79y91shypNyyKWyA6JQDeQx4EqTCIigKp4yGtq0o#ref-CR2>

Blackford, G 2016, '*On the pseudo-science nature of Friedman's 'as if' methodology',* Real-World Economics, weblog post 1 November 2017, viewed 4 August 2021, <https://www.rweconomics.com/BPA.htm>

Cantlon, J 2012 'Math, monkeys, and the developing brain', *Proceedings of the National Academy of Sciences*. 109 (Supplement_1): 10725–10732 https://doi.org/10.1073/pnas.1201893109

Collins, J (2016) Please, not another bias! The problem with behavioural economics. [Blog] *Evonomics.* 25 September.

<https://evonomics.com/please-not-another-bias-the-problem-with-behavioral-economics/> [Accessed 30/5/2021]

Dukes D, et al 'The rise of affectivism', *Nature*, Vol. pp 826-810, viewed 30 June 2021, <https://www.nature.com/articles/s41562-021-01130-8.epdf?sharing_token=gKUwb02a6OaPLSv34ESlwdRgN0jAjWel9jnR3ZoTv0OdOrEH8DNs7MEAH0juXdIeDg1NNwpETS9AoMyKdSgoVZsHvT5cMiiz12t9pd_j2YOWAito3DGSn9O3SV6FKfqp3ju1VdWrGM1JOXtekenonm5_aC9m2G8UTvWAHseN9zE%3D&fbclid=IwAR1k4fXaUrtCNDUQppFCorION9k8lsmUUE8Uuy0uwB4D6xPZ6_-zSKFUfGU>

Evans-Pitchard E, 1940 *The Nuer: A description of the modes of livelihood and political institutions of a neolithic people*. Oxford university Press, London.

Friedman M, 1953 *Essays in positive economics,* The university of Chicago Press, Chicago.

Gibson, J 1979 'The theory of affordances', in *The Ecological Approach to visual perception,* Houghton Mifflin, Chicago, pp. 127-137

Graeber, D 2011 *Debt: The first 5000 years*, Melville House Publishing, New-York.

Habermas, J 2018 *Philosophical Introductions: Five Approaches to Communicative Reason,* Polity Press, Cambridge.

Hill, R & Myatt, T 2010 *Economics Anti-Textbook,* Zed Books, London.

Iliopoulos, A 2019 'Material Engagement Theory and its philosophical ties to pragmatism', *Phenomenology and the Cognitive Sciences,* vol. 18, pp39-63. https://doi.org/10.1007/s11097-018-9596-5

pages

Kaaronen, R 2017, '*Affording Sustainability:* Adopting a Theory of Affordances as a Guiding Heuristic for Environmental Policy*'*, *Frontiers in Psychology,* Vol. 8, https://doi.org/10.3389/fpsyg.2017.01974

Kahneman, D 2011, *Thinking fast and slow,* Penguin Books, London.

Malafouris, L 2013, *How Things Shape the Mind: A Theory of Material Engagement,* MIT Press.

Mumford L 1934, *Technics and Civilization,* Routledge and Kegan Paul Ltd, London.

Nunez, R 2017, 'Is there really an evolved capacity for number?', *Trends in Cognitive science*, vol. 21, no 6, pp. 409-42

Overman, K 2013 'Material scaffolds in numbers and time' *Cambridge Archaeological Journal,* Vol. 23, no. 1, pp 19-39, *https://doi.org/10.1017/S0959774313000024*

Ritzer, G 1993, *The McDonalization of Society,* Pine Forge Press, Thousand Oaks.

Samuels, R 2004 'Innateness in cognitive science', *Trends in Cognitive Sciences* Vol.8, no 6, pp. 136-141. doi:http://10.1016/j.tics.2004.01.010

Simon H 1969 *The science of the artificial*, The MIT Press, London

Simon, H 1990, 'Invariants of Human Behavior', *Annual Review of Psychology*. no 41, pp. 1-19 https://doi.org/10.1146/annurev.ps.41.020190.000245

Todd, P, Gigerenzer, G 2012, *Ecological Rationality,* Oxford University Press, New-York.

Thompson, E 1967, 'Time, Work-Discipline and Industrial Capitalism', *The past and present society: Oxford Journals,* viewed 5 June 2021, *<http://www.jstor.org/stable/649749>*

Wilson, A 2017, 'The ecological approach explained to an 8 year old', [Blog] Psych science notes, <http://psychsciencenotes.blogspot.com/2017/04/the-ecological-approach-explained-to-8.html> [Viewed 506/2021]

Weber, M 1987, *Rationality and Modernity,* Allen & Unwin, London

Zaslavski, C 1992, 'Women as the first mathematicians', *The Women in mathematics education newsletter*, vol. 7, no. 1, <https://web.nmsu.edu/~pscott/isgem71.htm> [Viewed 56/2021]