A Stochastic Economy
DRAFT VERSION 0.5

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I. INTRODUCTION

There is a set of laws that everyone, every living thing, and all matter on this planet follows, because they have no choice in the issue. These are the Laws of Thermodynamics. (See AppendixA.) However, the bare form in which physics text books present these laws might not suffice when it comes to discussing the living creatures that inhabit this world. For each creature is the result of billions of years of evolution, and therefore the result of billions of years of energy absorbed from the sun. So it might be incorrect to assume that the true thermodynamic cost of, say, a fish consists only of the amount of energy absorbed by a single growing fish during its lifetime. The true thermodynamic cost has to make reference to the real amount of energy required to recreate (starting from a soup of chemical elements) an organism with all the properties of a contemporary fish of some species. But even this might not be enough, because those billions of years of evolution have brought with them a property of ecological harmony. By necessity (thermodynamic and ecological) a fish species is in harmony with (or at the mercy of) the environment in which it exists, and that environment contains all the other species that the fish interacts with directly or indirectly. The true thermodynamic cost (TTC) of a fish must therefore also take into account the cost of recreating an organism which slots neatly into an environment with a rich ecology without results that would be disastrous for the overall flourishing of the organisms in that environment, including, of course, humans.

At present, biological scientists are able to take a soup of chemicals and design and create simple lifeforms such as primitive viruses. They cannot yet create more complex organisms like bacteria, amoeba, or crop plants from scratch, though new species can be created by altering the DNA of existing organisms. However, the potential impacts that these species are likely to have on the environment into which they will be placed are not well understood. To some extent biological science is presently much better at creating viruses than it is at finding cures. This is because the environments these designed organisms are released into are vastly more complex than those organisms. A robust way to determine the environmental harmony cost *a priori* of a designed organism does not yet exist. Likewise, the amount of energy consumed in the process of humanity learning how to undertake these tasks of creation and comprehensive risk assessment has not yet been properly taken into account.

At the time of writing, this Earth is under threat from human actions. It is not just a matter of a burgeoning world population, but more a result of human actions upon the environment, upon the Earth, being too crude. The crudity is not just technological. It is not simply that agricultural or fishing practices use technologies that are environmentally damaging or disruptive. Nor is it simply that industry produces too much pollution. It is that contemporary systems of value exchange are too simple-minded. Present monetary systems have many flaws, but their interaction with the natural environment is now their gravest weakness. (More will be said about this later.) It might be thought that finding ways to price aspects of the natural environment according to the system of valuation that comes with present monetary systems is a step forward. But such a system would retain an anthropocentric bias at its core. Trees might become hugely more expensive (in monetary price terms) to cut down, but that might not prevent monetary inflation being exploited so that the prices could be met. If that happens, human economies will continue to amass digits in electronic bank accounts while the true thermodynamic cost of their devastating activities is wilfully overlooked. There is no human power on this Earth able to recreate a square mile of tropical rainforest from a dust bowl. At present, it doesn't matter how many electronic monetary digits are thrown at the problem. Only Nature is capable.

It will be a wilful overlooking if these problems are not addressed soon. However, merely developing accounting systems for the true thermodynamic cost of aspects of nature might also fail to suffice for reasons similar to those noted above. There is an extra energy cost associated with developing and tracking the complex true thermodynamic cost of natural flora and fauna. Moreover, it is possible that *any* price-based system will not suffice to prevent overexploitation of natural resources. (See Appendix B.) This is partly because, where natural resources are concerned, people are strongly motivated by their grumbling stomachs and the need to eat. But it is also because any monetary pricing system implicitly reinforces a view of human action as something competitive performed by small localised groups with no unifying drivers or controls.

In short, pricing systems abhor controls and thus retain an anthropocentric bias at their core. The existence of this imbalance of power is likely to fail to prevent overexploitation of natural resources. It therefore becomes pertinent to ask about ways around this problem. It might be asked whether the absence of a pricing system naturally gives rise to adequate capacity to control. So an initial inquiry might look into whether human societies can exist without pricing systems at all. In section §II a simple economic model called the Stochastic (or Lottery) Economy will be introduced. This model is powerful, having many desirable features and lacking a pricing system, but it is possibly too abstract to be pragmatic. Investigating what might be required to turn it into a real functioning economy will provide insight into how our present economic problems might be overcome.

Before moving on, something also needs to be said about the issue of controls. It has been noted that human actions are

largely performed by small localised groups. It is also true that additional complexity adds an energy cost. As a result it is also true that large baroque centralised systems of control are more likely to be locally undermined or circumvented than locally arising self-control that is an emergent function of the way things get done. It is therefore desirable to seek economic system designs that promote such emergent self-control. Of course, the idea is not that everyone should be equally oppressed by their nasty neighbours, but rather the opposite. A healthy economic system should require only minimal self-control to emerge, and ideally this should be less than the levels of control currently prevalent in contemporary capitalist societies.

II. THE STOCHASTIC ECONOMY TOY MODEL

It is important to stress that the model introduced in this section is an abstract toy model[8], used only for expository purposes. Crucially it lacks consideration of time and space, so there is no accounting for how goods get transported. (In later sections there will be an attempt to address these points.)

Assume that the present money system has become unnecessary, or has failed, yet the Internet remains active. Then imagine that there is a way to assess when particular goods are sufficiently abundant that everyone can have enough, and their reproduction is sustainable. Such goods would be considered *sufficiently reproducibly abundant* (SRA). Fossil fuels would not meet this condition: Even if they were considered to be abundant on a short time scale, they are not reproducibly abundant. Products from sustainably managed forests such that all reasonable demand could be met reproducibly into the future would be SRA goods. But care has to be taken over the concept of management. It is probably not, for example, 'management' to replace a rainforest with a palm oil plantation with a huge cost to biodiversity. For now though, tackling these complications will be postponed so that the characteristics of the toy model can be seen for the first time. Also the question of whether SRA goods actually exist on this planet will be temporarily postponed.

In this toy model then, the first break from classical economic orthodoxy is that SRA goods get given away. For example, adequate food, clothing, shelter and heating energy production systems are all feasible in the real world for a global population of approximately 9 billion people.[9]

In contrast, *scarce goods* could be defined by their being insufficient in immediate quantity, and/or insufficient in quantity into the foreseeable future. That is, there is no possibility of them matching all of the demand over time, and doing so reproducibly. As such, a lottery could be used to regulate the rate of use in accordance with any wider moral imperatives. In the toy model, scarce goods get allotted according to a lottery system. There exists an online system where consumers can enter the lottery system. There could be a website handling ticket requests, random draws, and new product ideas/requests. Everyone who wants the scarce commodity in question requests a ticket. Uniform random draw winners get the goods.

There remain complications about which types of scarce goods could be effectively submitted to the lottery system, but again it is fitting to delay these temporarily while some key advantages are considered.

A. Key Properties of the Toy Model

A crucial property is that this model allows for supply to be managed according to what is realistic given the reproductive rate of Nature, as demand does not skew interest in good management of natural resources toward bad practices. This is because the pattern of incentives in this model is completely different from one based on a monetary system. There is (at first sight) no possibility of excessive gain at the expense of one's neighbours. Folks produce because they want to produce things that other folks request and because the division of labour makes sense. Folks receive because they expressed a desire and they had a lucky ticket. Everyone has equal opportunity.

Can this process be applied to communal goods, like building, for example, concert halls or stadiums? The rationale for building something like that could be whether enough people expressed a desire to use it. The question is whether the builders would build it because they liked building things for other folks. Firstly, they might use these facilities themselves, and secondly they might rely on other goods in their daily lives that others had made. So they would be in the same relationship to everyone else as others would be to their acts of building.

It could be asked whether the absence of global warming would be a good product? Or whether ensuring sufficient biodiversity would be a good product? In which case, products that are SRA whose use endangers these more important aspects of the bio-sphere require regulation. In the stochastic economy it would make no sense to manufacture more of a product than was requested. But failure to legislate regulation in favour of the wider moral imperative of bio-sphere preservation would also not make sense. Once again, this is because the incentive structure is not skewed in favour of behaviours that surreptitiously impoverish one's neighbours. (Cf. [1].)

In an economy where SRA goods are given away, and no select group profits from making potentially harmful products that create wider losses in use, what would be the incentive to produce such harmful goods in the first place? There might be a conspiracy to poison half the population so as to raise the odds of gaining scarce goods in the lotteries, but such a conspiracy would have to guarantee that producers of such goods would not be poisoned. Hopefully, such a plot would be too difficult to realise.

It cannot be stressed enough that the ability to separate supply control from demand is the only way towards adequate natural resource management for scarce goods, and this model is offered as one possible way to tackle the issue. It limits consumption in a way that satisfies the immediate constraints of the Laws of Thermodynamics while avoiding the complicated issues surrounding developing a model of true thermodynamic costs of things like ecologically embedded organisms. But

this model is currently a fiction that requires many questions to be answered in order for it to become a suitable transition model away from a broken monetary system.

B. Toward a Functional System

For emphasis, it is fitting to state again that the pattern of incentives in this model is completely different from one based on a monetary system. Indeed, the pattern of incentives is so radically different that a mind versed in orthodox patterns of money and price will struggle to envisage anything at all. So as a first step, imagine that human society could start again, with its current level of technological sophistication, but with a blank slate upon which to write the rules of society. If everyone had their basic needs for food, clothing, shelter and warmth satisfied automatically, and an internet connection, how would they then choose to organise their societies?

It is worthwhile to consider the fundamental requirements of any modern society, and then to ask whether these are incompatible with the Stochastic Economy approach to scarce goods. A modern society needs energy, and in the 21st century there is an additional requirement that it comes from non-polluting sources. This energy needs to be available 24 hours a day. There is already sufficient evidence that it is possible to provide clean energy for the entire globe[2]. So it is plausible to suggest that energy could be a SRA good. This energy is necessary to maintain (as a minimum) production and sufficient distribution of enough perishable goods (food and medical supplies) to support the population. With a sufficiently widespread and robust clean energy infrastructure there is little to prevent the distribution of goods, or the provision of healthcare, from also being SRA goods. Clean energy will also support sewage treatment and waste water recycling processes in a similar way. Sufficient clean energy will also go a long way toward ensuring that freshwater supplies can be maintained, by powering desalination processes[2].

Assuming clean energy supply and infrastructure can be installed then, issues like competition between food production and biodiversity can be considered appropriately. A by-product of sufficient clean energy and water supplies is the ability to irrigate soils in regions not previously capable of supporting agriculture. With what is known about permaculture approaches to food production there is also less reason to maintain the current destructive course of agri-business monoculture in regions that would be better left as pristine natural (rain)forests.

Through use of similar energy generation mechanisms (solar collectors, wave snakes) it also becomes possible to make shipping goods largely a matter of ensuring that freight ships (or perhaps schools of 'microships') are well maintained and safe. International shipping would perhaps not therefore be hostage to costs that could drive international dispute in respect of shipping certain scarce goods.

In this light, it becomes possible to see that adequate clean energy supplies can radically change the economic terrain. In addition, when many aspects of the economy are no longer driven according to the rate at which goods and people must move around, it becomes possible for people to commute in personal vehicles at speeds which would match current solar powered vehicles. The secret is clean energy production, and once that is in place there are seemingly no obvious barriers to the use of a stochastic economy approach to balance supply and demand of scarce goods to ensure protection of natural resources.

1. *Ensuring an Absence of Distortion*

The hub of the Stochastic Economy idea is the uniform (flat) probability distribution on the interval $I = (0,1]$. For any particular scarce good, available within some time period T, some system akin to an internet website will accept tickets from those who wish to have a chance of receiving the product in question. Let there be N participants that submit tickets in the time interval $t \in (0,T]$ with the draw being made at the first time when $t > T$. The interval I will then be divided into N segments, $(i_1, i_2, ..., i_N)$, each of length I/N. A high quality random number generator will then generate without bias a random number $x \in I$. If there is then a particular subinterval $i_n = (a,b]$, such that $a < x \leq b$, then the person holding the ticket for segment i_n will win the product.

It is suggested that this process can be used to uncouple demand for a good from rate of supply; because it is hoped that there are, in theory, no incentives for supplying scarce goods to the (lottery) market at a rate faster than the rate which reproducibly and persistently maximises the amount available. The incentive is to provide good things for other people and ourselves and to manage supply to maximise the amount of good things that can be supplied. The key to ensuring that the system is not distorted, preventing any group from gaining more than their fair share, turns upon ensuring the lack of bias in the lottery draws.

Technical ways in which the possibility of bias might be avoided could include:

- If the program code for the random number generator (RNG) was made open source;
- If the RNG in use was regularly updated from this source code;
- If the sampling from the RNG was tracked to ensure that the probability distribution remained uniform;
- If the subintervals i_n were checked to ensure that they were always equal to I/N in length in any draw;
- Ensuring the availability of the system.

Non-technical measures are those which try to minimise the actions of people that might skew or circumvent such systems for undeserved personal gain. A good opening question is, which goods are people likely to attempt to hoard for personal gain, given the presence of the lottery system? Earlier it was asked: If everyone had their basic needs for food, clothing, shelter and warmth already satisfied, and an internet connection, how would they then choose to organise their societies? The question about hoarding is really just a variant on this

theme. If some goods beyond these basic needs were scarce goods, is it also likely that people would want to hoard them? It was noted at the end of §I that global or national systems are typically subverted in local ways. One way in which the Stochastic Economy idea might be locally undermined is if an external submarket for some good develops in a local region.

Under the idyllic conditions where everyone's basic needs are met, it is hard to think of a product that might be both scarce and worth hoarding. Consider instead a tougher situation where the supply of these basic needs could come under threat. As a possible example consider natural rubber, needed for vehicle tyres, gaskets, contraceptives and much more besides. Its availability might assume international strategic importance as oil resources dwindle. It is reasonable to assume that any surplus production above that which meets local needs could be submitted to a more global stochastic economy system. However, local demand could be sufficiently high, and production geographically constrained (for example, because of a suitable growing climate for rubber trees), such that the product is considered to be locally scarce. How can equitable distribution of such a good be ensured?

This issue can be split into two separate questions. (A) Is it OK for external submarkets to exist alongside the Stochastic Economy? (B) If external submarkets undermine the Stochastic Economy are there incentive structures to ensure that goods are submitted to the Stochastic Economy system? To be clear about question (A), situations where the Stochastic Economy exists as a set of regional lotteries to which transregional players are permitted to submit 'transregional' tickets are not really a problem. Globally equitable distribution could still ensue in these situations. It is therefore the situation where transregional tickets cannot be submitted (or even created) to access a regional market which could be problematic in some sense. (This situation might not *always* be problematic: The organisers of some regional market might stifle access to some good in their region in order to stimulate the generation of productive capacity elsewhere.) If there is a regional stochastic economy system, then questions of transregional access are likely to hinge on discussions concerning the mutual benefits of transregional access. The real benefits might be more indirect than mere tit-for-tat exchange of materials and products.

As a toy model for thinking about this situation at the large scale, imagine that the world contains only two nations, P and Q, each of which has its own stochastic economy system that is closed to the other nation, and each of which is initially self-sufficient. Imagine then, that nation P runs out of some strategically necessary product R whereas the other nation does not. (If it is not clear how goods could run out under a stochastic economy designed to ensure sustainable production, imagine that the lack arises from a natural disaster.) Nation P needs to access some R in order to sustain viability, but the prior self-sufficiency of both nations suggests that nation Q has no incentives to open its stochastic economy to some quota of transregional tickets from P. What happens next? Would Q have a reason to be greedy? It is possible to imagine that even if Q does not have a surplus of product R, that it would be in the best interests of both nations to collaborate to overcome the shortage of R in nation P. Even though a stochastic economy does not necessarily give rise to latent surpluses of goods that can be stockpiled in case of emergency there is still greater resilience in the overall system than there would be if the economic system was geared more to promoting short-termist, zero-sum games. At the very least, there could be greater room for political magnanimity as a prelude to promoting overall welfare, because there are no real overarching incentives for applying beggar-thy-neighbour strategies. All wars to date have, in essence, been about stealing the *money* profits from the land and productive capacities of another region or population. But what gets stolen when Stochastic Economy systems are pervasive? If monetary systems are absent, then the reasons for wars begin to look even more insane than before.

If the true regional market for some good is outside any regional stochastic economy system, and the reasons for denying transregional access are largely about selfish political advantage, then this situation could be problematic. Such circumstances can give rise to resource wars between regions and tend to be the grounds on which nation states assert the need for militarism. The problem here concerns the submission of goods to the Stochastic Economy system, and the subsequent ability to submit transregional tickets. The core issue concerns the benefits of economic isolation. History has demonstrated that there can exist nation states that have sufficient natural resources for arguments about economic comparative advantage to be weakened. History has also shown that long term isolationism is probably not healthy, but the possibility of this isolationism occurring is still worth considering. But the worst scenario is when the reasons for denying transregional access turn upon preserving the basic needs of a population, the national security, when another population's survival is in jeopardy. This is the situation in which wars are most likely to arise, when attempts at aggressive land grabs *appear to be* profitable, or even necessary, risks to take.

There are no clean and clear solutions under such circumstances. It is much better to avoid their creation altogether. If all the products that contribute to a population's basic needs are termed *necessary goods* there will be a subset of these that (not being robustly SRA) are also potentially scarce goods. The provision for maximal availability of potentially scarce goods has to avoid geographical constraints in order to prevent large-scale political or social contests. It is suggested that the Stochastic Economy minimises the barriers to achieving this aim by allowing regions to worry less about achieving economy of scale of comparative advantage, thus permitting healthier diversification of productive capacities. The absurd imbalances of currency exchange rates and spending power of present monetary systems could be ignored. Possibly, less resources would be wasted on feeding 'foreign' empires and more spent on ensuring local resilience. The word 'foreign' might even start to lose negative connotations.

The remaining issue of the submission of goods to a stochastic economy system at the micro-level could be taken in part to be a matter of incentives to follow local laws. However, in any economy that has sufficient sophistication to support and sustain a healthy population it is likely that the inter-

dependencies between producers will also drive peer-pressure incentives to submit goods to regional lottery systems.

2. *Mitigating the Domination of Lotteries*

Little can be said about the particular behaviours and propensities of specific regional lottery systems without empirical research. Though transregional access to lottery systems would suggest the need for a standard interface for ticket submissions. It is possible, however, to discuss some general aspects. The lottery systems will exist on the Internet, where mechanisms for ensuring the unique identity of participants could be difficult to construct and maintain, and where the ability to circumvent such measures might exist or arise. It is also possible that some people will find ways to automate ticket submissions, thus outstripping the rate at which ordinary people would be able to submit tickets manually. There is also a good case to be made for the system to be decentralised — in the sense that regional lotteries and system redundancy might be considered to be positive features. In a similar vein, it might be beneficial if anyone could initiate a lottery for any scarce good. So it might seem that there arises the classic set of tensions between individual identification, controls, and the maximisation of liberty and flexibility, where the preservation of fairness is desired.

There was some discussion in §II B 1 of how an imbalance in the real distribution of production could give rise biases in the availability of goods via the lottery systems. However, an additional incentive pattern for introducing bias can be created simply because some group (or individual) might view relative greed as a positive path to pursue. For such groups, introducing the bias brings greater material rewards and thus an incentive to pursue the pattern of introducing bias repeatedly. Temporary oneupmanship is perhaps no more harmful than the lottery process itself if an overall balance can be maintained in the longer term. But persistent bias, especially given the use of a stochastic economy system, is likely to create unhealthy tensions that threaten a return to more primitive patterns of behaviour. While it makes sense to think about how to avoid the generation of such incentives, there also needs to be thought about how to mitigate the potential power of automated ticket submissions, in case these become possible.

Some scarce goods will only become available in their lotteries at the rate dictated by their rate of supply. For other scarce goods there might be some tension between maximising present productivity versus optimising supply longevity. One way to assess how these two aspects should be balanced might be to think about the schedule according to which substitute goods would become available, or to consider the circumstances by which a scarce good might become a SRA good. To some extent the duration of each lottery, $0 \leq t \leq T$, can be used to slow demand, but even with this approach the system is still vulnerable to automated mass ticket submission skewing the probability of winning.

Solutions that avoid requiring those who wish to participate in the lottery to register with a central authority for a unique identifier are likely to be based on statistics acquired from the lotteries. One possible solution for preventing mass ticket submission could be to keep track of the physical addresses and locations to which winners of each lottery have their goods delivered. Persistent domination by addresses within a relatively small geographical area compared to the overall geographical range of all ticket submitters might provide a good indication of bias being injected into a lottery, through either group or automated mass ticket submission.

The remaining problem would then be the possible collaboration of an appropriately geographically distributed group to obtain goods which were then shipped onwards to some small region. It is unlikely that any group could sustain statistically insignificant geographical distributions for any length of time. But a possible countermeasure against such behaviour would be to monitor discrepancies between the delivery organisations' records and the delivery addresses supplied by lottery winners. Addresses that received many deliveries but which were not lottery winners in some proportionate degree might arouse suspicion. An advantage of such statistical approaches is that there need not be any tracking of the *type* of goods that were shipped, so no infringement of personal privacy in that regard. In addition, such detection methods are also initially based only on address data, and do not involve individuals' identities. Centralisation of such data by organisations for the purposes of bias detection or other researches need not thereby be problematic, and the structure of the Internet is such that no single organisation need hold a monopoly on the possession of such suitably anonymised data sets. This feature might be important for sustaining fairness.

3. *Learning to Leave Some Fish in the Sea*

Earlier, in §II B 2, the relationships between the geographic availability of some good, its sustainable rate of supply, and its entry into the lottery system were briefly mentioned. Attempts were made to explore scenarios where basic needs were fully met, or where key goods were scarce because of some supply failure (as in a natural disaster). As has been stated earlier, it is envisaged that when the stochastic economy system is pervasive then the dominant incentives to increase supply will not arise from localised self-interest of the supplier. It is also hoped that the stochastic economy system will permit wider distribution of production facilities and hence greater overall resilience of human society.

However, localised political pressures to increase supply beyond what is sensible could arise. It was suggested in §II B 2 that the stochastic economy system would permit geographically separated economic regions to operate with a more magnanimous approach to the welfare of other regions. But there remains a question as to whether regional disasters that curtail supply could generate persistent political pressures to override the stochastic economy system. To some extent, this issue of resilience was discussed in §II B 1 where some discussion concerning the existence and persistence of external submarkets was attempted.

It is obvious that in extreme circumstances the stochastic economy system could be vulnerable to political pressure, in just the same way that money-based systems tend to be forcibly overridden when there are dire shortages of supply. It might be argued though, that under circumstances where shortages of supply would normally give rise to rationing, that the stochastic economy system could be more resilient. When the socio-political pressures are great and supplies are short, inequalities in money-based systems are perceived to be enhanced and are perpetuated until supplies are exhausted without respite, with the result that unrest is likely to arise sooner and be more catastrophic. Under a money-based system a local shortage of key supplies can trigger local unrest that triggers more widespread troubles. Whereas under a stochastic economy system the prior equity of the distribution of key supplies could mitigate strongly against the generation of local flashpoints.

Since the stochastic economy system is intended to encourage production management to provide abundance and long term resilience of supply, it would hopefully be less likely to give rise to sudden global losses of supply. Nevertheless, population pressures (similar to those mentioned in Appendix B) could eventually grow to the point where they become problematic even for this system. Under such circumstances it is not that the stochastic economy system fails, but that the global population as a whole will be facing potentially catastrophic circumstances. The stochastic economy system is potentially considerably robust right up until this point. As such it appears preferable to money-based systems as a way of collectively riding through periods of hardship.

III. FURTHER WORK

It isn't possible for one person to predict all the aspects and possibilities of an idea concerning large scale complex human social interaction. The purpose of this paper has been to introduce the idea of the Stochastic Economy to the world and to outline its potential, but also to open it up for further researches, critiques and improvements by others. Two crucial areas for further research are highlighted below, but they by no means exhaust the possibilities.

A. Taming Capitalism's Excesses

In §II B 1 there was some discussion of the resilience of a pervasive Stochastic Economy model in the face of real pressures towards bias and the presence of markets external to the lottery system. However, it is also possible to think about the case where Capitalism is pervasive and specific stochastic economy systems are minor insertions into the overall system of commodity distribution. Around the time of writing, China began experimenting with the use of a lottery system to throttle down the rate of registration of road licences for new cars[10]. However, this system is, in principle, under strict government control. It is perhaps more interesting to consider ways to gradually insert lottery mechanisms into capitalist market systems to provide a means for controlled transitions.

This subject will be more fully explored in a forthcoming companion paper, where a prototype approach is investigated.

B. Critical Acceleration of Innovation

It was assumed in §II B that everyone had their basic needs for food, clothing, shelter, warmth and long distance communication satisfied already. While sufficient clean energy supplies can guarantee the processes that create shelters, heating and means of communication, the processes of food and clothing production are presently heavily dependent on Nature's capacities. Even if the Stochastic Economy encourages a maximally productive flourishing of supply, it is still likely that novel food production and material technologies will play an important role in the future. Technologies such as the use of biopolymers in clothing, multi-layer permaculture, and protein farming are already likely to play a strong role in the future. While the introduction of such technologies into our present money-based economies may well aid the transition to more enlightened forms of economy, it is possible that there will be considerable differences between the way innovations currently diffuse and the way in which they could diffuse within the Stochastic Economy. Further investigation of systemic propensities will be required.

IV. PATHS TO BRIGHTER FUTURES

To be determined by everyone...

Appendix A: THE IMPORTANCE OF THERMODYNAMICS

In each 24 hour period, the Earth receives a finite amount of energy from the Sun's rays. A portion of this energy is absorbed by various processes to give rise to wind, rain, and the growth of living organisms. This energy is the basis of our lives upon this planet. All of the processes upon which our economies depend, also depend in turn on the fundamental processes of energy absorption and conversion which are physically possible on a planet such as this one. It is therefore quite remarkable how few economists have ever paid proper attention to these matters. It is hard, even now, to find an economist who can sensibly discuss the issue of energy budgets with reference to the true thermodynamic cost. When human actions create and destroy, economists are typically not talking about these actions in terms of Watts per hour per square metre and the true energy costs of natural resources. This oversight is why the theories of most economists are not worth the paper they are written upon. (See below in AppendixB.) When economics pays proper attention to the true thermodynamic cost of goods, only then will the discipline deserve to be called a science.

New research in this area is beginning to tackle the problems. See for examples the non-equilibrium thermodynamics work in [3], [4], and [5]. In the field of ecological economics: See also a range of works by Herman E. Daly and collaborators, and [6]. Properly uniting global thermodynamics with ecological economics ought to be a contemporary priority.

Appendix B: STRIPPING NATURE BARE

Typically, in theories of economy the fundamental concept of value is based on the average, socially necessary, *human* labour–time to produce some commodity. Nature's reproduction is not valued in any of these systems. This is the flaw in our economic systems that has led us to the point where we are literally killing off the living systems we depend on.

To see the mechanism, try the following sketch. In conventional/classical economics, the major premise is about scarcity: the distribution of a limited quantity of product X in society. The fact of limited supply gives rise to market price, etc. What is never said here is how scarcity truly relates to quantity of labour (working population and productive capacity). What happens is that products enter the market at a price determined by labour cost plus some markup, but the labour cost is determined according to:

1. A valuation of labour time that is divorced from any capacity to value the reproductive capacity of Nature.

2. An assumption that this labour time reflects true (natural) scarcity. (The opposite of (1), basically.)

The flaw is that labour cost and hence market entry price can become radically disengaged from natural scarcity.

The following is just a thought experiment, but it might approximate the real trajectory. Imagine a stretch of seashore with some fishermen. Local demand is low and prices for fish are OK, so the local economy supports this group of fishermen with their hand-made nets and acceptable pace of life. Then along comes a food merchant who says that he will buy their extra fish (above and beyond local demand) at a higher price than the local one. He does this because he has global connections, knowing that the currency differences between nations will bring him a tidy profit for the fish he sells on. Over time the fishermen optimise to bring in more fish, and since being a fisherman becomes a good way to earn good money many more people start fishing. The burst of comparative wealth and creeping access to global markets means that they can get cheaper nets and tackle, and as competition between the food merchants enters the fray the fishermen have motivation to optimise their fishing for profit. They fish like crazy. At some point the local price for fish will stabilise, but there is still competition for fish. So they carry on fishing hard. Now, given the number of fishermen and the rate at which they can extract fish from the sea, they begin to demolish the capacity of the fish stocks to replenish. Not because they are mean or stupid, but because the price of fish stays fixed, and they fish to meet their living costs. The pressure to increase fishing efficiency even further goes up, and those that can meet the costs do so. They perhaps even get bank loans to help them, increasing their incentive to fish more and more in order to meet the interest payments on the loans. All of these actions can keep the cost of fish at a price where the food merchant can still afford to pay for them. So the food merchant doesn't turn away and stop buying. He has profitable customers, after all. So the cycle continues on, until the fishermen suddenly have no fish to catch or sell, because some aspect of the surrounding ecosystem just gave up. Maybe the fish became to few to sustain breeding; maybe the hungry sharks ate the few that were left; maybe their absence allowed some choking weed to destroy their food supply. Worse still, it might be the case that the species of fish in question was a keystone species, and their loss is causing a vast web of the ecosystem to come unravelled.

This is a similar problem as is occurring with the rainforests. Roads into the rainforests have allowed poor people to migrate out of shanty towns and to acquire land for free, which they then strip and farm, to support themselves relative to a value system based on exchange value based on average human labour time of commodity production. They follow this pattern partly because they are not aware of some of the high value commodities that can be extracted from rainforest at a sustainable rate. But even if they did, how long will it be before they are tampering with the rainforest ecosystem so as to maximise their profits within the current market system?

Current notions of markets take the commodity as a fundamental category. But Nature is difficult to commoditise - tricky to put into a commodity forms to be sold as a commodities - because Nature doesn't use human labour. And commodity transactions in markets rely on a pricing system based on *human* labour-time. Nature in itself is not valued, but only *the rate* at which people can exploit it. This valuation approach and its conversion into a price have almost nothing to do with the true thermodynamic cost of goods.[11]

Appendix C: THE QUESTION OF ECONOMIC GROWTH

Humanity has never had a steady-state economy before. The human population on this planet has always been expanding, and an expanding population entails increasing demand for goods. When politicians talk about economic growth it is important to distinguish between aspects of growth that need to be sustainable for the population as a whole, and the other aspects that are comparatively superficial. For example, the wholesome sustainable production of food to serve the global population is an area where the issue of economic growth can be contentious if all growth is taken to mean is growth in profits. In contrast, *real growth* in the amount of sustainably produced food is not likely to upset anyone. Also, economic growth with vastly reduced or eliminated pollution is not upsetting. So if the production of mobile phones has a supply chain that is pollution-free in its entirety (and also devoid of excessive labour exploitation, etc.) then perhaps this is also not something to be upset about. Likewise, non-polluting mineral extraction relates to the capacity to make tools, rather than the immediate need to eat. It affects whether mobile

phones are possible, but does not directly drain agricultural soil of its capacity to support crops. So when growth is discussed, it matters what the likely negative impacts would be, and whether the discussion is about real goods or electronic money digits. It is important to be clear about what is meant.

Appendix D: MAIN IDEAS BEHIND THE STOCHASTIC ECONOMY

There were two principal thoughts that drove the generation of the Stochastic Economy idea. The first was the concern that there might be no way in the long term to make globalised Capitalism sustainable (even on its own terms, irrespective of environmental pressures) that does not also eventually neutralise the money system. Neutralisation of the money system (with money ceasing to have value) could force civilisations to revert to barter mechanisms. The second thought was that pre-monetary systems based on barter do not remain statically effective. They can generate inequalities just as much as monetary systems can support them. However, they also tend to give rise to monetary systems as a matter of efficiency. Humanity is possibly therefore faced with attempting to march into an increasingly pressured future using flawed and decimating forms of economy that are either broken or obsolete or both. The need to find ways of blocking overexploitation of natural resources is also imperative. Therefore it is time for some new ideas.

The other main idea that suggested the form of a Stochastic Economy arose from considering how inequalities of power arise in our economic systems. It is clear that presently, amassing monetary capital can give rise to amassing power over others, and that this relationship can have a positive feedback. More capital creates more power which can create more capital, and so on. Given a scenario in which everyone starts out with the same amount of land and money, inequalities of power and wealth will arise as a natural result of the ingenuity with which different people are able to make best use of their resources. However, in the present system, once a person has an advantage, it becomes possible to capitalise upon it — to increase that advantage. The differences between those that amass advantage and those that do not can increase dramatically over time. The present system of financial power operates in such a way as to reinforce the intensity at which positive feedbacks survive. But these positive feedback mechanisms can benefit the powerful in a way that, if left unchecked, can greatly impoverish others as a result.

It is hypothesised that *any* money system can give rise to this pattern, whether it includes interest payments on loans or not. This is because a money system is only a slightly more refined version of temporal power over resources. In ancient times, gaining monetary advantage might bring with it the ability to raise an army and extort taxes as protection money. However, this initial monetary advantage probably came from an initial land advantage, or from prior banditry. So it doesn't matter whether the initial advantage arises solely as monetary power, or as an advantage in control over real world resources. It also doesn't matter whether such advantages came about as a matter of defensive expediency — the need to maintain an army to protect a collective. What matters is whether the real world circumstances are such that human nature will exploit an advantage to capitalise upon it at the expense of others. History suggests that there will always be some people who will choose to optimise their own welfare at the expense of others if given an opportunity. History also suggests that once they gain some advantage, then recruiting willing foot soldiers is also not a problem. Therefore, in general, given a sufficiently large population, whether there is a money system or a barter system, a mixture of human nature and the uneven distribution of natural resources is likely to generate inequality under certain circumstances and there will be people that seek to capitalise upon that. However, this might be the case solely because no better system has arisen previously.

It is therefore of interest to ask whether a system with the opposite tendency — one that naturally tends towards equality and gently damps out inequality, or a system that retains neutrality — could arise and be sustained in spite of some aspects of some human natures. Possibly, a good way to start might be an absence of money and an absence of title. (Without title no-one can assert a property right.) In the real world, simply tearing away everyone's property rights is probably not going to win any votes. However, it is possible to ask what happens if everyone starts from their existing property rights, has their food, water, clothing, shelter and energy needs catered for, and then participates in a Stochastic Economy. With the Stochastic Economy there is no way to amass a money profit. Also, when goods are produced, they are effectively given away (whether they are scarce or SRA goods), so there is no point in hoarding any surplus production. Therefore, whether someone is a labourer, or a micro-producer, or a mass producer, there is essentially no way in which a real difference of monetary power can arise.

Which leaves the question of whether someone could benefit extraordinarily from amassing lots of land, or from holding on to an existing large holding. It is better to examine the latter case first, because if there is no benefit to ownership of lots of land under the Stochastic Economy system, then perhaps it does not matter if someone manages to amass a large amount. The issue of land ownership will inevitably be the most sensitive issue for most people because land is the foundation of all survival. The ability to assert property rights against others can be the pivot around which inequalities of power arise. There is a problem where excessive land ownership is concerned if such ownership rights are deliberately used to exclude others from land in such a way that the distress of others enables the landowner to start charging rents. A two-pronged defence against this could be instituted by a society. The first is to outlaw rents of all kinds. The second, if required, is to borrow the idea of a Democratic Wealth Limit from [7] and adapt it to suit the Stochastic Economy. The idea would be to have the public decide via referendum each year, or every few years, the maximum amount of land (the Democratic Land Limit) that an individual may hold. If land was held by a group, then the amount of land would be divided by the number of people in the group in order to assess whether a limit had been reached or not. With such measures the neut-

rality of the Stochastic Economy could be defended.

In the former case, hopefully a lot of luck would be required to amass a lot of land, but in any case, the same countermeasures can be put in place. Though it remains that the issue of fairness in an open lottery system that evolves over time needs more thorough investigation.

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[1] M. Braungart and W. McDonough, *Cradle to Cradle* (Vintage, 2009).

[2] URL `http://www.desertec.org/`.

[3] A. Kleidon, Climatic Change **66**, 271 (2004).

[4] T. Volk, Climatic Change **85**, 251 (2007).

[5] A. Kleidon (2011), URL `http://arxiv.org/abs/1103.2014`.

[6] M. Ruth, *Integrating Economics, Ecology and Thermodynamics* (Springer, 1993), 1st ed., ISBN 978-9048142989.

[7] R. E. George, *Socioeconomic Democracy: An Advanced Socioeconomic System* (Greenwood Press, 2002).

[8] The basic idea of the Stochastic Economy appeared on the concept67.net website as a blog post in December 2009.

[9] See www.desertec.org for an example of a feasible clean energy production system whose overall societal costs are comparatively low. We will assume in the toy model that such an energy system has already been installed.

[10] See `http://uk.reuters.com/article/2011/01/26/china-traffic-beijing-idUKTOE70P02L20110126`

[11] Much of the text of this appendix has appeared previously as a blog post made in 2009.