Network Capital: Value of Currency Protocols
Bitcoin & SolarCoin cases in context

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Note: this document is an early working paper.
It is a subset of a larger paper, Network Capital, to be published at a later date

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Disclosure:
Both of this papers authors have active roles with the SolarCoin project. Paul Johnson is a board member of the SolarCoin Foundation PBC and Nick Gogerty is co-founder of SolarCoin and CEO of the SolarCoin Foundation PBC.
A Network Capital theory of value for currency protocols

Progress in economics and finance is based on new understandings of value and risk. The development of theories and tools for measuring value and risk lets us manage economic development for the collective benefit of society. Unfortunately, current economic theories associated with understanding the value and function of currency are limited.

Financial theories of value associated with debt and equity are fairly robust, well examined and falsifiable. These theories generally value capital assets as a claim on future cash flows denominated in a currency unit discounted for the time value of money, inflation expectations, and uncertainty.

Theories associated with currency generally ignore fundamental questions such as why currency has value and fail to examine what function currency provides in an economy. Instead, economists generally explain currency as having three roles, namely (1):

1. Unit of account
2. Medium of exchange
3. Store of value

We believe the logic underlying these categorizations is flawed. We argue that the explanation is misleading and does a poor job of explaining why currencies exist and importantly, which currencies prevail. Most economists misinterpret the process by which currency emerges and currency’s primary economic function. This misunderstanding can lead to errors of understanding, particularly when these theories are used to explain credit and the broader money supply, which depend on currency as a base referent.

To explain currency’s value most economist believe in the quantity theory of money and its reliance on the velocity of currency. Unfortunately, these theories have a poor track record when compared with empirical data and provide limited insight when currency is analyzed as part of an actual financial system. Even when focusing on currency alone versus. money, these theories are limited.

The theories fail on first principles, even to the casual observer. Finally, these claims are too vague to be challenged systematically, and thus cannot be falsified, which might be part of the reason they continue as part of current economic theory.

Money is not currency

When economists discuss money they usually refer to money in aggregate or to a monetary system, one that includes currency (usually notes, bills and electronic equivalents in circulation) and credit such as government obligations (t-bills and bonds), commercial paper and other forms of financial obligations, all denominated in the same currency.

Credit is created (issued) by and between the private and public sector actors. For purposes of this paper, we will focus on currency (narrow money) to show currency as a shared informational protocol for enabling and accelerating value flows across potential economic networks.

Capital Networks are fields of possible transactions

Transactomes: Economic Networks are potentials defined by the agents accepted protocols

Networks are often displayed using the objective *a postor* display of past transactions between links and nodes. Economic networks are better understood as the subjective expected potentials of links that are influenced by past transaction information held by individual actors. Transactions are links occurring in finite time reflecting the accumulated intersubjective information collapsed into a prices. Depictions of fully linked nodes etc. are *post priori* representations of past states.

Capital network transactomes are the expected set of opportunities with which an agent may transact. Until an interaction occurs, the network exists only as a set of expectations or a field of uncertainties held in the agent’s mind. As a transaction/exchange closes; a link occurs collapsing the capital function for a finite moment.

For simplicity we treat economic agents as standardized with similar utility functions. The reality is that agents have differing utilities for things in terms of value perception, intention, transaction expectations and holding period.

Networks can be shown intersubjectively as potential links and nodes. These potential structures can be defined as a transactome field, which is the set of agents expected to accept a good or service for some price. The U.S. Dollar (USD) transactome for example is the group of agents expected to accept the USD currency protocol expressed in a medium–note, coin, card or electronic entry, etc. This transactome could be defined by geographic or other probabilistic boundary definitions.

**Accepted protocols define transactome boundaries**

The boundaries of a transactome are defined by expected participants willing to accept an economic protocol. A protocol is an expected information state which may be based on any form of capital. A protocol could be a gallon of milk, a fish, a basket of strawberries, or USD(unit of information). Protocols have different specifications features, and conventions.

A collection of transactome participants often overlap across protocols as agents have multiple wants. Multiple transactomes form an economy, which can be defined by geographic, political or the dominant transactome boundaries. The barley, dollar or gold economy for example are collections of transactomes with a dominant reference protocol transactome.

**The medium is not the protocol**

A protocol may be expressed in many mediums. For example, gold may be expressed as a 1 oz. coin, a case in which the medium and protocol of gold are approximately the same. An ETF or claim on 1 oz. of gold is the gold protocol in an electronic medium. It is estimated 90% of gold traded today is electronic, not physical.

A given protocol has different features depending on the medium. For instance, spending (transacting) a USD in paper form is different from spending a USD used on a credit card that may have airmiles or some other traits associated with it. The protocol often defines the transactome boundary constraints.

Much currency history involves protocols expressed in mediums evolving better traits or dimensions of use for individual users across transactomes. This concept will be explored in depth in the fuller Network Capital paper.
Network capital value, currency and uncertainty
In this paper we focus on currency. We define capital as the human projection of value onto any thing or expectation. As such capital is subjective and uncertain in nature. Capital is objectively measured after a transaction creates a price ratio. Capital can be anything a person assigns value or utility to. We will focus on currency as a protocol for value transactions.

Broadly speaking any form of capital has 3 subjective utilities that create its expected value or transacted price. For the sake of simplicity in this model we will treat price and uncertain value as equivalents.

In its most generalized case the proposed network capital pricing formula is:

\[ P = \text{Max} \ [R, N+S] \]

this equation can also be viewed as

Objective outcome | Subjective expectations

The formula above applies to any type of capital in the most generalized sense but requires further enumeration for specific capital types beyond currency. P is the expectation of a maximum function prior to a transaction.

\[ \begin{align*}
P &= \text{Price} \\
R &= \text{Redemption utility} \\
N &= \text{Network utility} \\
S &= \text{Speculative utility}
\end{align*} \]

**P=Price**
The price of capital is only known after a transaction is complete. The formula allows for uncertainty and can be read as a conditional one *a priori* to a transaction in terms of estimated value. This perspective inverts the typical objective focus on price and certainty is fixed or defined things.

**R=Redemption utility**
Redemption is the most highly certain outcome capital can have. In the past the R for a currency could have come in the form of redeeming a currency unit for gold at a central bank. In the case of a fish as a form of capital asset; the R could be the transactive act of “redeeming” and eating the fish.

**N=Network utility**
Network utility is the expected utility or value that one receives from trading with a potential set of economic agents in a network of willing acceptors of that form of capital. All agents expected to accept a fish in a transaction represent a transactome network. The fish transactome is any expected willing acceptor of fish. Transactomes exist in the intersubjective.

A network is not a set of linked nodes reflecting objective historical activity, rather it is a set of the potential or expected links and aggregate expected value as viewed by the capital owner. Currency protocols tend to have a standard range of uncertainty values per expected user.

**S=Speculative utility**
Speculative utility is the set of expectations found among participants in a transactome of the future increased or decreased supply or demand factor within the transactome. Speculation can push the Price above or below the network utility value.
Currency protocol transactome networks emerge to resolve resource and information coordination pressures (gradients)

Subjective Value in Utils: economy #1
Economic networks have actors who value things in util (utility units)

I like apples. You don’t. I value an apple at 3 utils, you value it at 1. I value a fish at 1 util and you value it at 3. We trade to resolve this util value gradient (difference). This exchange increases the total subjective utility value in our 2 person network economy through trade.

<table>
<thead>
<tr>
<th>Economic State of UnME</th>
<th>Original Objective value</th>
<th>Inter-subjective value</th>
<th>Economic Subjective value T0</th>
<th>Total economic value T0</th>
<th>Post Trade value T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economy #1</td>
<td>1 apple &amp; 1 Fish</td>
<td>0</td>
<td>4 Utils</td>
<td>4 utils</td>
<td>6 utils</td>
</tr>
<tr>
<td>Economy #2</td>
<td>1 apple &amp; 1 honey</td>
<td>3 utils</td>
<td>4 Utils</td>
<td>6 utils</td>
<td>6 utils</td>
</tr>
</tbody>
</table>

Trade doesn’t scale without information placeholders. (economy #2)
Trade is information intense. Trade requires discovery, optimization and clearing information. Barter (co-incidence of needs) doesn’t scale across time, space or large numbers of goods and actor potentials. The information costs associated with barter derived IOU type credit scale exponentially; potentially N^2 as function of the number of trade partners and goods as shown in the diagram to the upper right.

I have fish, but want apples. There are no apples in the market today. I need a placeholder good because my fish will spoil over time. Timing and transaction mis-matches require intermediate goods. I trade my fish in another transactome for honey (1 util to me) as an intermediate good to reduce my rotten fish portfolio risk.

I have information expectations believing you value honey at 3 utils. I treat honey as a currency with the expectation you will value it and trade apples for it in the future. I have created honey as my currency protocol and medium. Honey is for me an informational placeholder. I possess it expecting to trade into an N network of 1 rather than R redemption consumption value. The smallest unit of capital and currency is that perceived by a single user. Currency is firstly a subjective phenomenon emerging into the intersubjective causing objective effects at scale.

Which Intermediate goods emerge as currency
Individuals converge on the intermediate goods having the best properties of durability, divisibility, fungibility (recognition) etc. so as to minimize expected transactive value risk. Any intermediate good expected to perform as a currency by an individual in terms of expected transactome acceptance is a currency. Any form of capital held has an uncertainty of becoming an R or N type transaction.
Protocols such as a currency emerge from the intersubjective to enable better interactions and faster network flows

Protocols are expected behavior/communication standards or responses. Protocols exist as the intersubjective. Protocols are chosen by individuals for that users expected utility function. Protocols are not objective forces, but their existence in the intersubjective accelerates objectively measurable flows across networks.

Generally protocols become widely recognized winner take most outcomes. Some internationally recognize protocols are shown below. Protocols are positive economic externalities in which more utilization among more participants increases their aggregate value contributions.

<table>
<thead>
<tr>
<th>Technology protocols</th>
<th>Fast</th>
<th>Faster safer communication flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FAX</td>
<td>TCP/IP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Socio/legal protocols</th>
<th>Fast</th>
<th>Faster safer physical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STOP</td>
<td>TRAFFIC LIGHT</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Economic protocols</th>
<th>Faster safer value flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$100 bill</td>
</tr>
</tbody>
</table>

Protocols exist in the intersubjective
Much of traditional macroeconomics offers objective models for outcomes. We posit that macroeconomic phenomenon is collective information emerging from subjective beliefs, behaviors and expectations about other actors.

Nothing forces individuals to stop at a stop sign or to choose a fax or internet protocol. Individual choice is made based on best locally expected outcomes. These choices emerge from an intersubjective group belief held across agents.

Protocols such as currency emerge because they are informational short-cuts for hedging risk, imputing price, calculating relative value and reducing trade friction. This topic is explored using an agent based approach in the fuller Network Capital paper.

Transactome networks function as information processors of individuals using protocols. In stable currency regimes protocol price information propagate over time and space to coordinate far flung value producing economic activity.

This emergence of standardized information value units give rise to greater network flow (economic growth). Currency protocols help economies process value (GDP) faster by accelerating demand information signals and value flow data.

“It is a profoundly erroneous truism, repeated by all copy-books and by eminent people when they are making speeches, that we should cultivate the habit of thinking what we are doing. The precise opposite is the case. Civilization advances by extending the number of important operations which we can perform without thinking about them.” — Alfred North Whitehead
Q: Why is there economic and currency confusion?

A: Currency is a protocol for uncertain expectations occurring in Intersubjective transactomes. Currency is not an objective phenomenon.

Economists traditionally treat currency as an objective phenomenon. Network capital theory treats currency as a form of capital emerging from individual beliefs and expectations of others.

The table below illustrates the distinction. Capital held in any form exists in an indeterminate state. The state collapses once a transaction occurs.

<table>
<thead>
<tr>
<th>Temporal State</th>
<th>Past</th>
<th>Present</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Graph</td>
<td><img src="image" alt="Network Graph" /></td>
<td><img src="image" alt="Present" /></td>
<td><img src="image" alt="Future" /></td>
</tr>
<tr>
<td>Network Capital “currency”</td>
<td>Unit of account</td>
<td>Medium of exchange</td>
<td>Store of value (expected)</td>
</tr>
<tr>
<td>Information /data</td>
<td>Objective falsifiable truth (hard science)</td>
<td>Intersubjective “instantaneous moment”</td>
<td>Subjective (expected uncertain / perceived truths)</td>
</tr>
</tbody>
</table>

“The misconception which has haunted philosophic literature throughout the centuries is the notion of ‘independent existence.’ There is no such mode of existence; every entity is to be understood in terms of the way it is interwoven with the rest of the universe.” *Alfred North Whitehead*

Considering capital with a longer time frame or across cultures reveals its intersubjective nature more clearly. Intersubjective socially normative protocols such as culture, language, currency, values, social norms, political boundaries, narratives and religion. They are socially transitive phenomenon existing as emergent but ultimately localized to a people *in situ*.

Social protocols and beliefs exist only as an intersubjective field of minds. These occur across scales in small groups, nation-state and transnational historical epochs. Shared beliefs and behaviors define individuals and societies for brief periods. Protocols aid in the flow of ideas, coordinated actions and expectations to achieve a group’s macro goals.

Only in the last few decades have microeconomists admitted behavioral biases and irrationality into their models. Macroeconomists still use models ignoring the emergent behavior of expectations, imperfect information that drive network flow capacity and outcomes. Network capital acknowledges the role of intersubjective expectations in driving important macroeconomic phenomenon such as currency and credit.

We address currency as the fundamental measuring unit of capital. Currency protocols allow the mapping of subjective utility onto quantitative scale for group use. Currency protocols allow the quantitative subjective and collective symbolic expression for normalizing our individual utility functions of value. As such, currency emerges as a protocol for enabling trade across time and space. Objectively speaking there is no such thing as a store of value.
Currency “acceptance” becomes the dominant feature
Currency protocols have network effects due to the holders value of transactome optionality driven by increased numbers of expected acceptors. Certain protocols dominate due to these effects and derive trade efficiencies. Value stability and acceptance is inversely proportional to the functional R value of consumability. Consumable capital goods have supply/demand volatility. Volatility increases uncertainty limiting the N currency function of expectations across geography and time. A mature currency with a stable network has low volatility. Mature currencies and stable transactomes witness the emergence of yield curves proportional to the expected stability of the future transactome state.

Economies contain subjective, intersubjective and objective things.
The informational role of intersubjective currency becomes clear. Protocols enable larger transactomes measured as economic opportunity to resolve an individual’s value gradient across time and space. Currency value is the expected sum of informational trade optionality.

The protocol is a ticket to a presumed “acceptor network” of others. Barter trade networks are limited to the portfolio of goods a holder owns. A strong currency protocol emerges to traverse an entire economies set of transactomes. Protocol strength is often perceived as price stability relative to other goods over time and expected time. Price stability is a function of stable supply expectations and underlying demand drivers such as transactome network size. A dominant currency protocol becomes subjectively a near universal intermediate good able to be traded across the entire field of economically possible transactions.

Capital from individual to group future expectation
The smallest unit of capital is the subjective value an individual assigns to something. At scale Capital is the collective expectations of potential value of millions or billions of actors spread across time and space such as the global credit market.

Price is not value
Before exploring a source of value one needs to separate the concepts of price and value. Price is an objective metric derived from closed transactions. Price is created by the collected opinions of expected value. The wisdom/stupidity of crowds create prices. Crowds may over or under estimate capital’s value.

Information counts
Economics emerge from the information subjectively created by economic agents, nothing else. We suggest that Network Capital value is best understood as information asymmetries spread across economic actors.
Currency protocols information value scales with nodes (believers) in the transactome

Currency is a protocol for expected value defined by subjective “accept networks” of people willing to hold them. The chart below shows the narrow money: M0 (notes, bills and electronic equivalents in circulation) or Market cap for the $USD value of 54 of the world’s largest currency protocols used by an estimated 6 billion people and $16 trillion USD in value.

Protocols are intersubjective emergent phenomenon. Each protocol is a shared belief transactome. The aggregate value of a protocol transactome can be measured per participant. Note Gold, Bitcoin and SolarCoin have been added below as currency protocols for illustration.

A key element of the Network Capital thesis for currency value as emergent network phenomenon is that currency protocols emerge as networks resolve individuals’ value gradients. Currency protocols are information tools for a resource coordination problem, namely resolving individual utility gradients. If true, then the value per node (protocol accepting economic agent) should converge to some normative range across economies. The chart below shows the converged value per protocol accepting node normalized by the GDP or economic flow per node.
Convergence of currency protocols values occurs once we normalize the amount of value an economy coordinates in terms of network flow estimated by GDP/capita/year in the protocol transactome.

Poorer economies need less currency protocol value for individual actors to resolve their value gradients. Other factors are at work as indicated by the wide $3,600 variance in normalized outputs vs. $9,200 in variance for M0/Country pop. The M0/Network relationship appears to be robust as shown in the chart below.

By adjusting the M0/Node factor for GDP we see the Log(n) error factors as indicated by lower variance from the USD shows fairly universal convergence.

The USD protocol was chosen as a reference baseline given its global economic dominance, open access, broad utility, and current stability across economic networks and transactormes.

<table>
<thead>
<tr>
<th>Country</th>
<th>Original</th>
<th>GDP normalized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean error</td>
<td>4.82</td>
<td>0.00</td>
</tr>
<tr>
<td>Stdev</td>
<td>23.32</td>
<td>1.40</td>
</tr>
</tbody>
</table>
**Metcalfe's law fails to scale**

Many individuals have posited that a currency network protocol’s value scales exponentially as a function of the agents or nodes expected to accept the protocol. The data indicate this claim is false for currency protocols. We believe this discrepancy is due to the optionality versus actual connectedness of nodes. The value in a currency network is the expectation of utility \( (N) \), not the actual utility enabled post transaction.

One’s expectation of tens of millions of potential acceptors drives intersubjective protocol utility more than the actual objectively realized network connections which is likely orders of magnitude less. No one expects or needs to transact with each individual willing to accept a dollar.

Optionaility has value but only up to a point for each individual. As such we see the M0/Network node value has limited relationship to the scale of the network shown below.

The limit or rejection of the \( N^2 \) and other Metcalfe’s variants is likely due to the useful versus possible links. There is likely a Dunbar equivalent to expected economic transactions for most actors and the types of bounded versus infinite utility they require from a currency protocol.

Most likely there is a small early emergent scaling factor involved in sparse or small networks leading to an asymptote value per node. The emergent value effect appears to be linear after that asymptote is reached rather than exponential at relevant economic scales. Even the small SolarCoin network of an estimated 4,500 nodes falls in normal protocol ranges when measured on a $ per participating node basis.
**Applied: Network Capital Currency Protocol theory**

**Bitcoin**
The Bitcoin protocol value appears to support the Network Capital theory for currency protocols. With an estimated acceptor network of 20-30m users/acceptors and a $110 bn USD market capitalization value. The estimated $/node normalized appears to be $3,666-$5,500, which is well within normal currency protocol range. Bitcoin’s ability to retain network size and value is to be determined. The protocol and medium associated with Bitcoin appears robust over its 10 year life.

**SolarCoin applying a currency protocol to incent positive outcomes**
The goal of SolarCoin is to act as a marginal economic incentive for Solar Energy producers over the life of their facilities production. SolarCoin is a reward currency protocol based on a low-carbon blockchain. SolarCoin builds its network by issuing SolarCoin into circulation freely in exchange for proof of solar energy production.

The cost of solar energy is often calculated using the LOCE (levelized cost of energy) a means of normalizing the upfront capital intensity of renewables versus fuel based energy. The financing of many facilities occurs over a 15-25 year period. As of 2015 according to IRENA (International Renewable Energy Association*), solar energy is cheaper on an LOCE basis than any energy source in 30 countries. Solar energy costs have gone down since then.

SolarCoin is a free economic incentive meant to accelerate capital spending for solar energy. It is believed an additional $10-20 / MWh reward is a useful economic incentive. In parts of the world solar energy is produced at $23-30/MWh. At those price points 40-70% of the Solar energy cost could be offset by SolarCoin’s user network. If $100bn in value can be created by issuing a Bitcoin protocol into circulation for proof of work computation why not issue $100bn of SolarCoin into circulation in exchange for proof of solar energy production.

**SolarCoin today**
A small network estimated at 4,500 users appears to be trading below normal value ranges with a circulating economy of 48.9 million SolarCoin and a $0.05 price equating to a $2.4m market cap and protocol unit/node value of $540/node.

**SolarCoin goal**
As of November 2018 there are an estimated 20m solar facilities with 500GW of nameplate capacity globally. Assuming a 4-year average age and an estimated production, a 100% SolarCoin economy would see 20m producer participants and $2.62 billion SLR in circulation. The price point for SolarCoin based on the model above would range from $7.63 to $38.16 per SolarCoin.

The linear nature of a currency protocol’s network effects means the $7.63 to $38.16 per SolarCoin price range is feasible by engaging 1% or 200,000 of the 20m solar participants. The SolarCoin Foundation is in talks with parties representing 10% of global solar energy production and is targeting 25-35% in the next 2 years.

Bernard McCarty created a concept called the Solarity, the price point at SolarCoin’s price and value exceeds the LOCE, effectively making solar energy free. [https://solaritytracker.org/](https://solaritytracker.org/)

*Disclosure: SolarCoin Foundation is a member of the 170 country member IRENA organization’s Coalition for Action.*
Representativeness and conclusions
We believe our data set to be fairly representative of the intersubjective Network Capital phenomenon of currency protocols. The data represent 6 billion people preferred protocol and over 95% of protocols measured by M0 $ value. Currency $ value has a broad range per participating node as indicated in the histogram below.

The average currency protocol only exists for 27 years. Protocol death usually occurs due to hyperinflation leading to extreme uncertainty, information failure and a shrinking transactome as measured by acceptors. Most often hyperinflation is driven by over-issuance of debt by a government, which forces the purchase of credit by the central bank in an attempt to solve a debt or fiscal crisis.

The optionality of expectations of utility are an important social phenomenon in that they represent a positive economic externality. The more individuals expect a protocol to function the more aggregate value that protocol has as measured by M0 or Market Cap. (a popular term in cryptocurrency referring to the Total value of currency tokens in circulation.)

Summary
Currency is an important social phenomenon. We believe currency like all economic phenomenon is best understood as an intersubjective property of expectations emerging from individual beliefs about potential expected transactions.

Further research into the factors contributing to the variance in currency values and functions is needed. The Network Capital paper under development will address additional aspects of this approach to macroeconomic phenomena including but not limited to:

1. The paradox of currency growth, volatility and utility
2. Credit yield curves as emergent protocol derivatives reflecting future network capital flow expectations
3. Diagrammatic languages for any form of capital
4. Explanation in detail for the “how” and “why” currency emerged from primary goods to gold to electronic symbols
5. The Paradox of zero intrinsic value as an important currency protocol property
6. Protocol store of value impossibility
7. The role of asymmetric information in economic networks